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Comparative Analysis of Ballastless Track System Design Using Analytical And Numerical Tools

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Abstract-Railways is becoming faster, with high speed running vehicles exerting wheel loads on tracks could become critical for track quality and the overall lifecycle. To cope with such high loads, state of the art ballastless track systems could be a long-term solution and to increase its acceptance under limited economic boundary conditions. Finite Element Modeling (FEM) is powerful tool that optimizes the design of the ballastless track. This study examines the reliability and verification of Finite element (FE) Models with analytical tools. Firstly, using analytical tools, the Zimmermann and the Westergaard methods, continuously reinforced concrete pavement (CRCP) slab with various cracking distances are designed followed by numerical design and analysis. Comparative design analysis is then carried out between analytical and numerical tool to evaluate the impact of input parameters on each of the tools. The finite element package SOFiSTiK is used to model ballastless track design. The verification of FE- model is also done based on calibrations, results and boundary conditions to check reliability, behavior and working. Lastly author gives some guidelines for the model verification.

Keywords-Ballastless Track System, Finite Element Modeling, Westergaard and Zimmerman Methods, Continuously Reinforced Concrete Pavement

I. Introduction

Railways have distinct advantages over other transport modes such as it's more efficient in terms of fuel costs and economy over longer distances, safety, reliability and speed, which is achieving new horizons. Railways is becoming faster and due to exponential increase in the number of people using railways, the need to maintain the quality of travel is believed to be more than ever before. The quality can only be improved by constant improvement in the technical design for both vehicles and tracks [i].

Countries around the world are strongly developing rail transportation, especially the development of high-speed rail. There are many forms of high-speedrailway, such as ballasted track, ballastless track, magnetic suspension railway, etc. High speeds and heavy loads of trains are usually accompanied with large vibrations in the train–track–ground system, especially when train speed reaches its critical value, leading to possible train derailment and track damages [ii]. Conventional ballasted railway tracks demand a lot of maintenance works due to uneven settlements of the ballast during operation. Existing experiences show this kind of maintenance work is significantly increased for high-speed lines [iii, iv]. As comfort safety and economy are primarily the most important, state of the art ballastless track constructions offer therefore an alternative solution due to the enormous reduction of maintenance work and the long service life with constant serviceability conditions [v]. The ballastless or slab track is a concrete or asphalt surface, replacing the standard ballasted track. In ballastless track system involving CRCP investment costs are higher and the maintenance costs are lower and the application of CRCP is limited to heavily loaded pavements Concrete is the prevailing material in slab track applications throughout the world. Asphalt has been used less as compared to concrete, as a material for slab track constructions due to its high construction demands. Continuously reinforced concrete pavement (CRCP) is the technology used for ballastless tracks. The absence of the transverse contraction joints and a well-defined pattern of transverse cracks are the major attributes that identify CRCP. [vi].

Taking care of economic boundary conditions and to increase the acceptance of ballastless track systems, Finite Element Models (FEM) is among the best solution to optimize the design of the ballastless track cross-section based on the selected parameters. This optimization can be done by a comparative analysis between analytical (Westergaard and Zimmerman) and numerical (FEM) approaches. Sofistik is Europe's leading software (FEM-based) for analysis, design and detailing of construction projects worldwide. For this paper SOFiSTiK is the main object of utilization and will be used throughout the work.

II. Literature Review

The ballastless or slab track is a concrete or asphalt surface, replacing the standard ballasted track. In Ballastless track rails and sleepers are embedded in concrete and can't be adjusted once laid. Therefore, it must be laid within a tolerance level limit of 0.005 m. As the structure is made of stiff and brittle materials, the required elasticity can be obtained by introducing elastic components below the rail or/and the sleeper [vii]. Typical ballastless track is shown in Fig. 1.

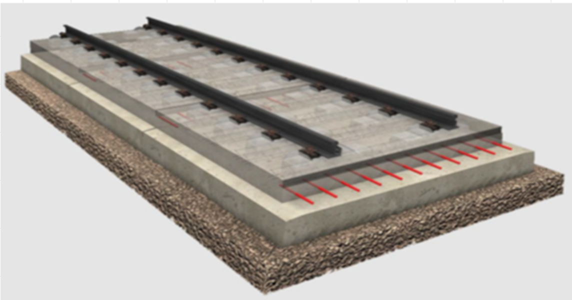

Fig. 1. Typical Ballastless track System

In slab track construction, ballast used in common railway is replaced by a more durable supportive material such as concrete or asphalt. To achieve the required level of track elasticity for wheel/rail systems – normally provided by ballast – slab track construction must use an elastic rail pad for the rail support points. Supportive forces are thus distributed to adjoining support points. The construction principle behind slab tracks is a layered structure with a gradual decrease in stiffness level from top to bottom: Rails with rail fastening to the supportive layer.[viii]. See Fig. 2

- Rails and Rail Fastening system
- Concrete supportive layer (CSL) or asphalt supportive layer (ASL)
- Hydraulically-bonded layer (HBL)
- Frost protection layer (FPL), Subgrade foundation..

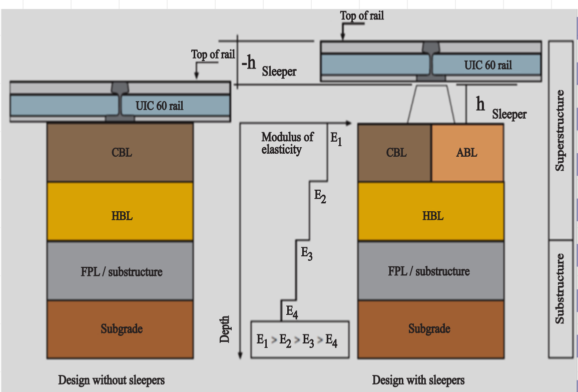

Fig. 2. Usual Construction Profile of Ballastless track system [Darr, 2000]

In practice the application of CRCP is limited to heavily loaded pavements. Continuously reinforced concrete pavements (CRCP) have a small amount of longitudinal reinforcement (around 0.6 to 0.7% by cross-sectional area) for controlling the crack pattern, i.e. the crack width and the crack spacing. The reinforcement is located (about) mid-depth within the concrete layer. A CRCP does not contain any transverse joint as shown in Fig. 3. In general, compared to JPCP, the CRCP investment costs are higher and the maintenance costs are lower. [ix].

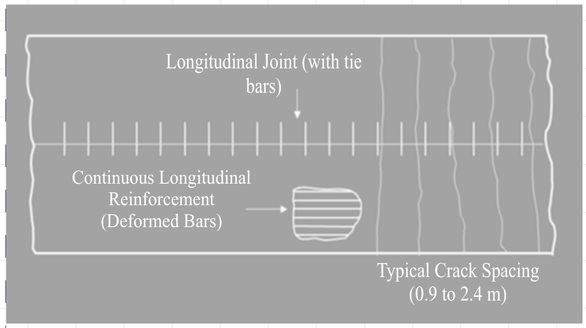

Fig. 3. Design characteristics of CRCP

Some of the main characteristics are:

- Reinforcement does not deal with stresses introduced by traffic loading
- Because of short crack spacing (<<5m) thermal stresses introduced by temperature differences Δt between surface and bottom of the concrete pavement due to heating and cooling (warping and curling) are smaller than for conventional JPCP (slab length 5m). Consequently, slab thickness can be reduced by about 10% to 20% compared with JPCP (Slab length 5m) for same traffic loading [x][]
- Reinforcement controls transverse cracking due to shrinkage and temperature changes in such a way that crack width is not exceeding 0.5mm and crack distribution along the pavement is uniform. Crack distance shall be much shorter than 5m but not shorter than 0,5m

III. Analytical Design of Ballastless Track System

Ballastless track systems with continuously reinforced concrete pavements (CRCP) overlaid by the layer of Cement treated base (CTB) and unbound granular based layer are the case study. Ballastless track without sleepers but direct fixation (discrete rail seats) is considered using UIC (French: Union Internationale des Chemins de fer) 60E1 rail as shown in Fig. 4.

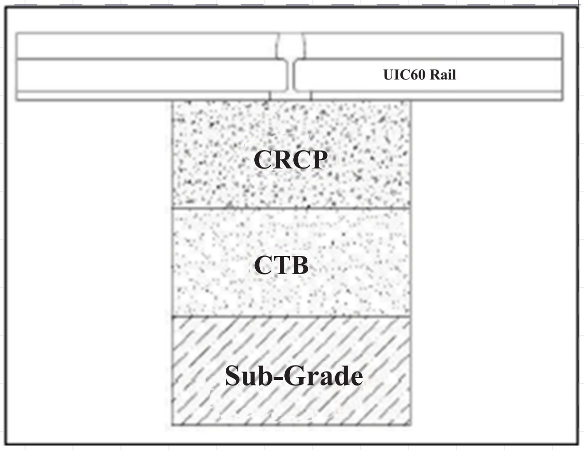

Fig. 4. Ballastless track without sleepers

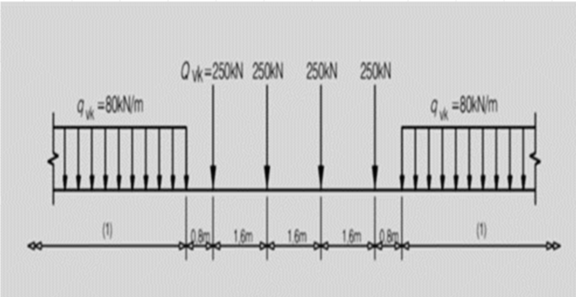

Fig. 5. Model UIC 71

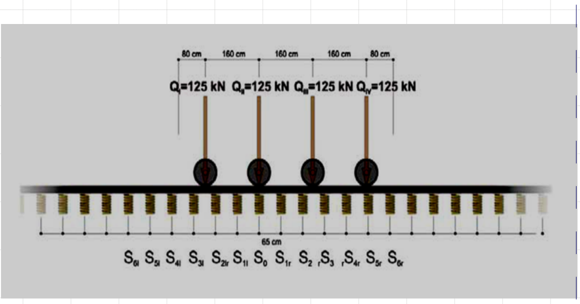

Fig. 6. Pattern of wheel load over the support points [Lehrstuhlfür Verkehrswegebau, 2014a]

For the calculations following parameters had been used:

- Rail 60E1
- Dynamic spring coefficient of Cdyn = 40 kN/mm
- Contact area 150x150mm
- Concrete slab with E1 = 34000 N/mm2
- Cement Treated Base with E2=5000N/mm2
- Unbound layer with Es=Ev= 120 N/mm2
- Spacing between rail pads = 650 mm
- Poisson's ratio of concrete slab µ1=.16
- I = 30550000 mm4 for Rail profile 60E1
- E = 210000 N/mm^2

Rail seat loads are calculated involves dimensioning of ballastless track system. Procedure includes distribution of rail loads into single loads which are further calculated as a rail seat loads.

Rail seat loads are calculated at 11 support points with load acting directly over support point So (Interior of slab)

Using input parameters, the elastic length of rail

$$L = \sqrt{\frac{4.E.I.a}{c}}$$

As seat load S = c.Y and deflection $Y = \frac{Q.a}{2.C.L} \times \eta$. Load, Q is increased by both dynamic and curvature (outside rail) by the factors of 1.5 and 1.2 respectively. While for inner side rails curvature factor of .8 is being used.

Maximum Seat load S_0 under load Q2 considering factors of 1.2 and 1.5 for curves and dynamic loading comes out to be S_0=101000 N using following wheel load pattern over the support points.All the support point forces and deflections due to adjacent loads at outside and inside rail are calculated.

See below Table I & Fig. 7

TABLE I
SUPPORT POINT FORCES AND DEFLECTIONS

Rail Seat Si Support Point on Outside rail	Deflection [mm] Outside rail	Rail Seat Load [kN] Outside rail	Rail Seat Si' Support Point on Inside rail	Deflection [mm] = Reduced by .8/1.2 (Inside rail)	Rail Seat Load [kN] = Reduced by .8/1.2 (Inside rail)
S4l	0.73	29.2	S4l'	0.49	19.6
S3l	1.90	76.0	S3l'	1.27	50.9
S2l	2.40	96.0	S2l'	1.61	64.3
S1l	2.24	89.6	S1l'	1.50	60.0
S0	**2.52**	**101**	**S0'**	**1.69**	**67.5**
S1r	2.16	86.4	S1r'	1.45	57.9
S2r	2.37	94.8	S2r'	1.59	63.5
S3r	2.38	95.2	S3r'	1.59	63.8
S4r	2.25	90.0	S4r'	1.51	60.3
S5r	2.34	93.6	S5r'	1.57	62.7
S6r	1.24	49.6	S6r'	0.83	33.2

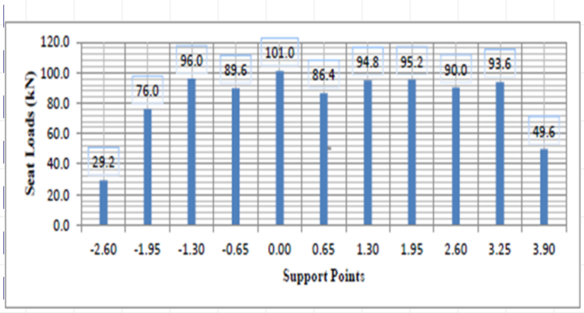

Fig. 7. Support point forces

IV. NUMERICAL DESIGN OF BALLASTLESS TRACK SYSTEM

The aim of this chapter is to understand the procedure to analyze the ballastless track system by developing 2D FE-Model of a slab using SOFISTIK Software.[xi] The model clarifies and verifies the theoretical/analytical analysis as discussed in previous section.

The 2D slab as per required slab length and width of slab track is drawn and the loads/seat loads are placed at their respective support points in Sofiplus as shown below in Fig. 8. After deciding the density of meshing, the model is imported to SSD. The Fig. 9 is showing the slab track model in SSD after getting imported from CAD tool and then linear analysis is taken place.

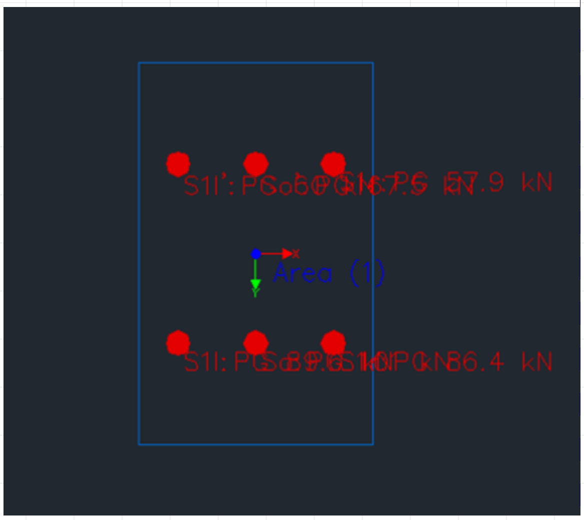

Fig. 8. 2D Slab/Pavement Model in Sofiplus

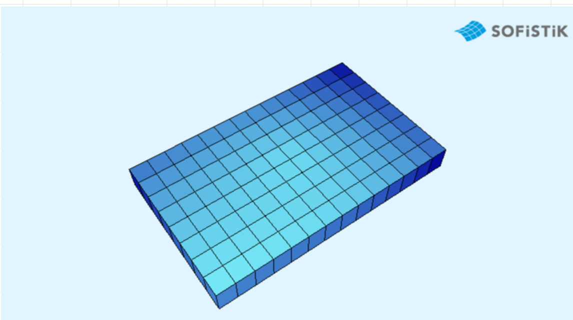

Fig. 9. Slab/Pavement Model in SSD

Different parameters were analyzed individually to see the behavior of model in SOFiSTiK including calibrating the slab model in SOFiSTiK with slab designed analytically. Different software parameters and their effect on the model were also studied. Actual bending tensile stress caused by single wheel acting in the centre of a slab was calculated with the Westergaard theory (Infinite slab size). The SOFiSTiK model was then calibrated by increasingthe slab size with load acting at the centre until it reached the analytical stress value as can be seen in Fig.10 and Fig. 11.

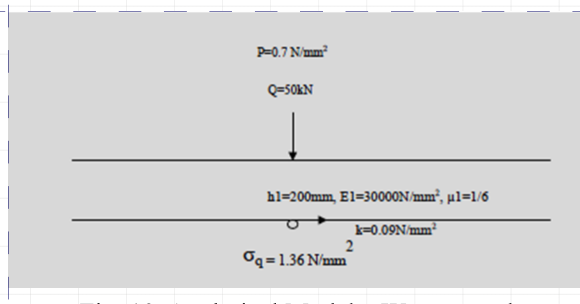

Fig. 10. Analytical Model – Westergaard

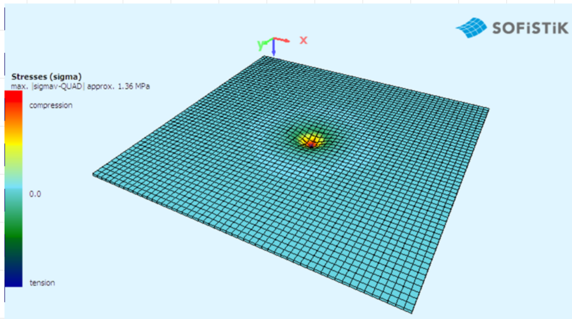

Fig. 11. Calibrated Model in Sofistik

Analysis of point and area loading with same input parameters showed little difference between the output results primarily due to relatively smaller contact area of 150 x 150 mm as shown in Fig. 12.

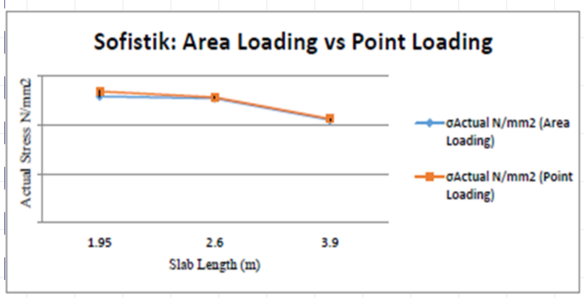

Fig.12. Area vs point load

Different meshing sizes/densities were analyzed to describe the effects on the output results. Analysis showed application of load changes with the change in density thus causes sharp decrease or increase in the output values.

A. Load At Intersection Of Elements

When changes in density of meshing caused load to act at node, a sudden increase in stresses were found thus a consistency of output results must be verified by analyzing meshing behavior. This loading position type was considered throughout in calculations as can be seen in Fig. 13.

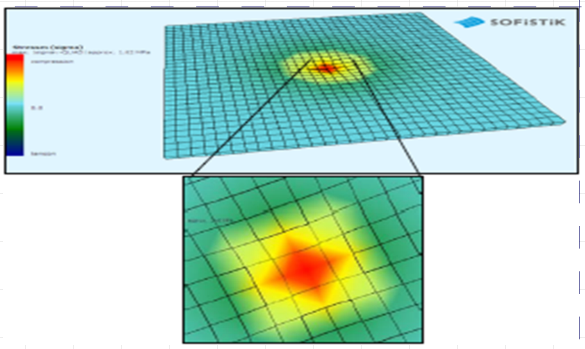

Fig. 13 Load acting at node

B. Load Acting At The Center Of Element

When changes in density of meshing caused load to act at centre of an element, a sudden decrease in stresses were found which can be seen in Fig. 14.

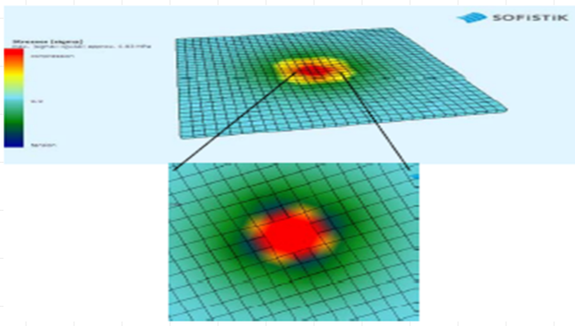

Fig. 14. Load acting at centre of element

Based on the study done in this chapter these are some of the important findings:

- Prior to confirmation results of stresses, suitable meshing density should be decided carefully to avoid sudden changes in the results due to changes in loading patterns. Here in this study load position at intersection of elements – nodes are considered for the calculations.
- Model needs adjustment to be comparable with theory; calibration does the role and shows how Sofistik model can be made compatible with theoretical results.
- Sofistik results shows with 150x150mm rail contact area, any loading type between rectangular and point can be considered for the design.
- Behavioural studies ensure consistent results.

V. Comparative Analysis of Results

Results from analytical and numerical studies are compiled together to understand their relation. Comparative analysis has been performed based on analysis of both analytical and numerical methods and the important conclusions from the study are discussed as follows.

A. Actual And Allowable Transversal/Longitudinal Stresses

Fig.15 and 16 are showing both, analytical and numerical designs are 'ok' and within the limits of allowable stresses for a slab length up till 4550mm thus exhibiting same trend. It is also clear from both figures that longitudinal stress is the decisive stress than the transversal stress. A difference in stress values can be seen between analytical and numerical actual stresses which are due to the fact that analytical design is based on infinite slab size and to make the differences less, calibration is needed.

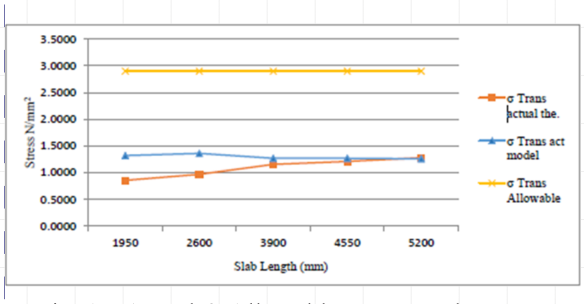

Fig. 15. Actual & Allowable transversal stresses

A. Vertical Stresses

Both actual analytical and numerical vertical stresses are below the allowable vertical stress at optimized thickness thus complimenting each other. The vertical stresses from numerical tool are constant in nature while analytical values increase with the increase in slab length, as shown in Fig. 16.

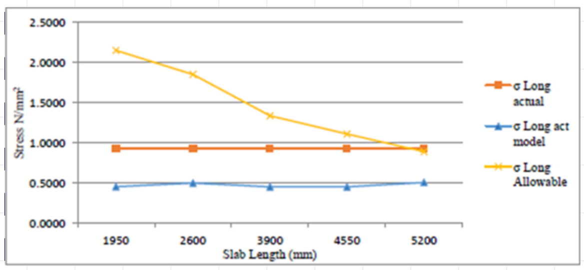

Fig. 16. Actual & Allowable longitudinal stresses

As the length increases the difference between numerical and analytical vertical stresses become lesser because of the UIC 71 loading pattern. Fig. 17 shows, in analytical design, relatively higher deflection trend in smaller lengths which gradually becomes lower with the increase in length because of the lower effect from the neighboring seat loads (as they are smaller in magnitude).

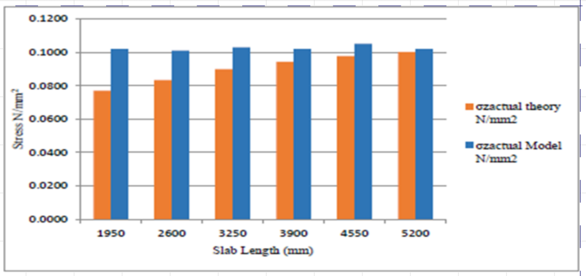

Fig. 17. Actual analytical and numerical vertical stresses

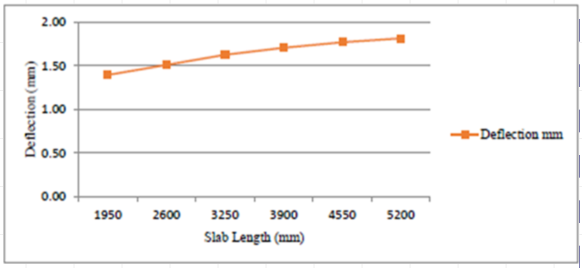

Fig. 18. Deflection-Analytical

VI. Verification of FE-Model

Verification of design based on FE-Models requires respective tools and procedures to ensure that models are properly working. Thus for accepting under study Sofistik model a realistic verification using analytical tools is carried out.

Comparisons between the stress results shows longitudinal stresses determined by FEM model are much lower than the stresses calculated by Westergaard/Zimmermann theories while transversal stresses calculated by numerical approach are higher than the analytical. Significant difference can be seen from Fig. 19 and 20.

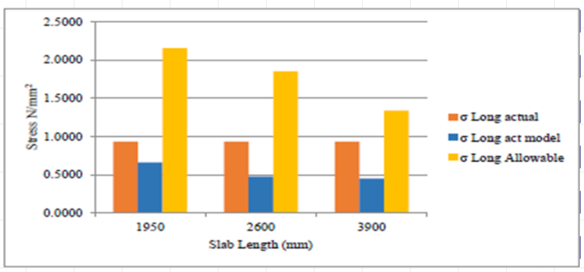

Fig. 19. Actual and Allowable stresses – Longitudinal

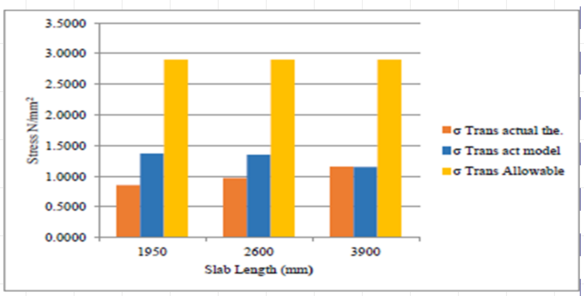

Fig. 20. Actual and Allowable stresses – Transversal

These differences between analytical and numerical could be understood from two theories. First theory refers to the geometry of a slab, Westergaard approach doesn't consider slab size rather size of a slab is considered infinite. Similarly, Zimmerman approach only considers width of slab. Second theory deals with the type of loading as mentioned in chapter 4, there are drastic changes in stress values with the change in load type e.g. load acting at a node.

So to verify the SOFiSTiK model with analytical results, the calibration is done based on both theories and the study being already discussed in chapter 5.

Comparative and closer results are found once model is adjusted and calibrated with analytical values as shown in tables below. As it is previously observed longitudinal stresses coming from models are lower than the theoretical values and transversal stresses have an opposite trend (Fig. 21&22). Lengths are adjusted to get the desired results by considering consistent loading type (meshing) for example in case of slab length 1950mm the adjusted slab lengths comes out to be 2600mm vs. 2750mm with load acting at the intersection of an element. It means longitudinal slab length is stretched by 325mm from each side of a slab and transversal slab length is curtailed by 225mm from each side. Similarly, with hit and trial method following results were found.

TABLE II
Calibrated Actual Transversal Stresses

Slab Length	σ Trans actual the.	σ Trans Call.	σ Trans Allowable
1950	0.8560	0.8880	2.9
2600	0.9690	0.9160	2.9
3900	1.1560	1.1900	2.9

TABLE III
Calibrated Actual Longitudinal Stresses

Slab Length	σ Long actual	σ Long Call.	σ Long Allowable
1950	0.9302	0.8670	2.15
2600	0.9302	0.9140	1.85
3900	0.9302	0.9970	1.34

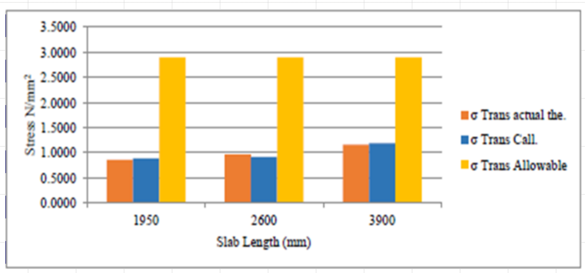

Fig. 21. Calibrated Actual transversal stresses vs. Allowable

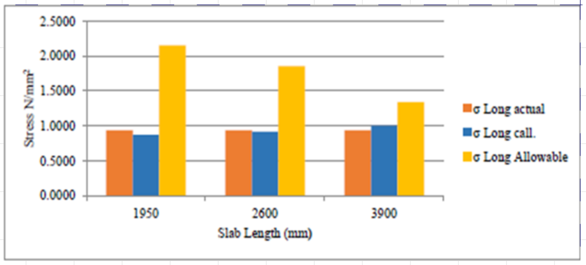

Fig. 22. Calibrated Actual Longitudinal stresses vs. Allowable stresses

Based on all the study being done so far some guidelines are developed showing the steps to be followed for the verification of FE-Models with respect to analytical results/model. Following are the developed guidelines:

- Analytical Design based on certain input parameters
- Numerical Design based on same consistent input parameters.
- Identification of the differences and similarities between numerical model and analytical using comparative analysis.
- Selection of a suitable meshing density/load position type to avoid sudden changes in the results due to changes in loading patterns.
- Calibrate an exemplary simple model with analytical result to get an idea of model behaviour e.g. effect of geometry change on bending stress.
- Calibration of a model process by considering both geometry of a slab in model and loading position types.

VII. Conclusions

There are different ballastless track systems available for coping with high speed running vehicles. This study comprises of a ballastless track system without sleepers but direct fixation (discrete rail seats) with special focus on continuously reinforced concrete pavements (CRCP).

For the design of ballastless track systems with CRCP, Westergaard and Zimmerman approaches are used to calculate stresses and deformations within the entire system. For optimizing design of ballastless track system it is necessary to verify FE model with analytical results. This task is performed by developing a FE model in Sofistik using the same input values as used for analytical.

The main aim of the work involves verification of FE model to ensure that model is working properly with reference to analytical results.

Based on the evaluation of different results and analysis a conclusive summary of whole thesis work can be provided as:

- Smaller rail pad areas can be taken place by point loads in SOFiSTiK without much difference in output results. Thus showing the flexibility of a FE Model as analytical calculations are based on converted circular rail pad area from a rectangular one.
- Geometry plays an important and decisive role in models as change in slab geometry causes considerable changes in bending stresses. Longitudinal length is needed to be stretched and transversal length is to be curtailed to get near the desired analytical bending stress values. However analytical calculations more and less doesn't depend on geometry.
- Load position type is one another vital input parameter to be considered very carefully while modelling in sofistik as nature of load position can change the results drastically. Loading position at intersection of an element – node is considered throughout for the calculations. Loading in analytical calculations are relatively straight forward either acting in the centre or at the corner/edges of a slab.
- Model showed accurate and realistic results under temperature loading; heating of a slab surface causes compression at upper surface and tension at lower surface of slab and vice versa.
- Model in SOFiSTiK was able to calculate actual bending stress using both traffic and temperature loading, however only linear temperature stress could be calculated due to the limitation of 2D FE modelling.
- More than two methods to calculate vertical stresses ensures accuracy in results, is an advantage over long analytical calculation
- Once input parameters are carefully handled, comparable results can be acquired from FE model with reference to analytical results (verification).
- Once the model is verified, the slab model can be analyzed up to different and numerous slab lengths at different thicknesses more conveniently thus ensuring better optimization of the design of ballastless track system.
- Thus verification of a model leads the system towards more economical system.

References

[i] M. Sadri. & M. Steenbergen, "Effects of railway track design on the expected degradation: Parametric study on energy dissipation", Journal of Sound and Vibration, 419, 281-301, 2018.

[ii] M. A. Sayeed, M. A. Shahin,"Three-dimensional numerical modelling of ballasted railway track foundations for high-speed trains with special reference to critical speed", Transportation Geotechnics, Volume 6, Pages 55-65,March 2016,

[iii] S. A. Kollo., A. Puskas, G. Kollo,"Ballasted

Track versus Ballastless Track", *Key Engineering Materials* 660. pp. 219-224,2015.

[iv] S. Freudenstein., K. Geisler., T. Molter., M. Missler., & C. Stolz, "Ballastless Tracks", John Wiley & Sons, 2018.

[v] S. Kaewunruen, J. M. Sussman H. H.Einstein., "Strategic framework to achieve carbon-efficient construction and maintenance of railway infrastructure systems", *Frontiers in environmental science* 3(6), pp. 34-52, 2015.

[vi] L. J. M. Houben , "European Practiceon Design and Construction of Concrete Pavements" ,*Argentine Congress on Road Safety and Traffic*, Mar del Plata, Argentina, 14-18 September, 2015.

[vii] B. Lichtberger, "Track Compendium: Formation, Permanent Way, Maintenance, Economics", Hamburg: Germany, Eurail Press, 192 p, 2010.

[viii] O. Nigel., Q. Franz. "Innovative Track Systems Criteria for their Selection", *Proceedings of the 2010 joint rail conference,* urbana, Illinious, United States, 2001.

[ix] B. Lechner ,"Design and layout of ballastless track systems using unbound base course layers", *8th World Congress on railway research,* Seoul, Korea. 18th-22nd May, 2008.

[x] B. Lechner, "Railway Concrete Pavements", *2nd International Conference on Best Practices for Concrete Pavements*, Florianopolis, Brazil, 2nd-4th November, 2011.

[xi] AG, S. "Tutorial SSD – A Quick Reference" [Online]. Available: http://www.sofistik.com/uploads/tx_sofistik/Tutorial-SSD-SOFiPLUS-2010_1.pdf [Accessed 27.10.2017].

Section B

ELECTRICAL AND ELECTRONICS ENGINEERING

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Video Target Stabilization Based on Motion Vector Compensation

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Abstract-In this paper a solution is proposed for stabilizing the target in un-stabilized shaky videos by using the motion vector compensation technique mainly focusing on template-based approach for locating target in desired frames. Frames are extracted from the input video and are formatted for further processing. Noise filtration is then done to neutralize the affects of inherent noise in the input video. Dimensions and other parameters are extracted from the input frames and the target is then selected. The target is matched in successive frames using cross correlation matching. Center positions are then updated which are later used for motion vector calculation and offset updating. Finally, the effects of un-necessary target and camera movements are removed by linear translations. Modified frames are then sequentially stacked for video reconstruction and display. The proposed algorithm is useful in security applications and in research works like astrological studies and the study of heavenly bodies.

Keywords-Frames Per Second, Motion Vector, Computer Vision Toolbox, Picture Element, Noise To Signal Ratio, Cross Correlation.

I. INTRODUCTION

In todays modern age, security cameras are being widely used in almost every organisation, institute, as well as on moving air and ground vehicles, for the porpose of enhanced security. There arise the problem, with the captured video that the output is of low quality due to slow and undesired motions like zoom, pan and tilt etc. In such scenarios, stabilization of captured results is required which is achieved by estimating and removing the inter frame motion, causing degradation, between the successive frames. Video stabilization is the technique used to remove the unwanted camera motions and hand shaky movements from video.

Video stabilization aims to reduce the high frequency frame to frame jitter that is produced by the camera motion [i]. This problem arises due to presence of camera placed on moving platform. Stabilization is important in fields such as enhancement and restoration, improve contrast and remove blurring, remove scratches from an old movie or image, security and right protection, object or target focusing, information analysis and automatic recognition.

A mechanical stabilization system includes a vibration from the sensors (gyros accelerometer) [ii]. That has been used in early stages of camcorder. Optical image stabilization uses moveable or prism lens assembly that adjusts the path length of light when it travels in camera lens system [iii]. Video stabilization algorithm follows the sequence of interframe motion esimation, motion smoothing or filtering and finally motion compensation as shown in Fig 1.

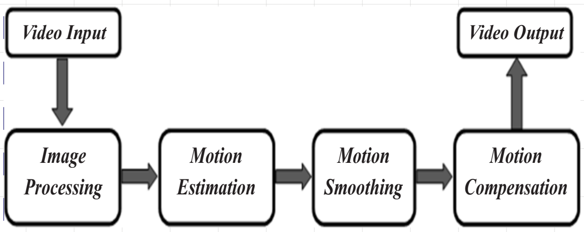

Fig. 1. Video Stabilization Scheme

Motion estimation relies on motion vectors calculation that may be related to part of image or whole image. Pel-recursive approach is one of the most early technique used to calculate approximate motion to establish video coding. Basically, in these methods, displacement is estimated recursively to minimize the Displaced Frame Difference (DFD). Though, the pel-recursive techniques are comparatively easier to put into practice, however their convergence might be time taking, also the motion estimation may not always be of very fine quality. It is particularly observed in the cases where displacement is a vital parameter, or in the cases where there are huge discontinuities in motion that too at the borders of the object. This restraint is typically because of the nature of this algorithm that is recursive, due to the causality constraint.

The output of block matching algorithm contains the motion vectors for each block and have pixels value difference between blocks in current frame and matched block in reference frame [iv]. The main idea behind the matching is to divide current frame into matrix of macro blocks of frame [v]. These blocks are compared with corresponding block and its adjacent neighbors will create a vector that shows movement of macro block from one location to another in previous frame. This movement estimates motion in current and previous frame.

While on the other side, phase correlation method determines the movement between the two fields from their phases and hence estimates relative offset between consecutive frames. Phase correlation method is based on fourier transform and is insensitive to variation of illumination.

Optical flow technique calculates the motion of pixels of an image sequence and gives a point to point correspondence. It provides a vector field that represent the 3D motion of object points across the 2D image, where displacement vector show certain pixels position that points to where that pixels can be established in reference frame. Target template is manually cropped from the first frame. The same template is then matched automatically in successive frames by processing of template matching algorithm. The desired target template is selected in the initiale phase. This template is the target area in the captured video around which the stabilization is required. In the projected proposal, motion vectors are calculated from the extracted parameters [vi].

Motion smoothing helps to smooth out the unwanted camera motions by applying a low pass filter on motion vectors for removing the high frequency components that may cause bluring of sharp edges of image and thus its application is limited to a certain extent. Motion compensation is applied to perform transformation of a reference frame to current frame. As per proposed model, motion compensation is accomplished by inserting a counter effect of the offset on the frames that neutralise the shaky effects of the target.

II. VIDEO STABILIZATION

The whole scheme comprises of three phases; *(i)* initialization phase, *(ii)* processing loop and *(iii)* result display. The working scheme of video target stabilization is as per Fig 2. In the *initialization phase,* the video is fed as input. Video source is either an already stored file in the drive, or it can be a live stream from an integrated camera/capturing device. Video is decomposed into frames at standard frame rate, i.e., 30 frames per second (fps). Standard frame rate of 30 fps has been used throughout in this work. This has been already mentioned in the paper. NTSC (National Television System Committee) video in North America and Japan uses 29.97 fps. Other common frame rates are usually multiples of these. Some high definition cameras can record at 30 fps, as opposed to 29.97 fps. However, before color was added to NTSC video signals, the frame rate was truly 30 fps. Format of all video frames is converted from RGB to Grayscale. De-noising and enhancement filters are implemented where required. Although De noising and enhancement is optional, but without it the resulting video quality will be poor. This info is also added in the paper. Target template is selected by cropping and its basic information/parameters are extracted such as, template's center position, origin, size and dimensions. There is no constraint on the size of cropped area for target selection. *Processing loop,* runs for the number of iterations equal to the number of frames. On every iteration, pre-selected target template is matched and calculations are made for parameters like motion vector, offset, etc. The image linear translation and zero padding is done on the processed frames. Image linear translation is achieved by pixel coordinates shifting. It is implemented by counter balancing the effect of image offset pixel by pixel. Pixels are shifted in the opposite direction as that of the image offset value obtained. Stabilized frames are obtained after the image translation and zero padding. Zero-padding will have a small effect on the quality of final video. However zero-padded areas will appear in black color on almost all four boundaries of the video. After the linear translation of the frame, the stabilized frames are obtained of different sizes. However we want to reconstruct the output video in the end from the stabilized frames. For video reconstruction purpose, all the stabilized frames must be of equal size. Thus zero padding has been done to obtain same sized frames. For the *result display,* all stabilized equal sized frames are run in the display window at standard frame rate.

III. TEMPLATE BASED STABILIZATION

Video target stabilization technique is based on motion vector compensation that makes use of template-based approach for template matching. The selected template corresponds to the desired target in the video that is needed to be stabilized and focused and hence it is the first mile stone to extract useful information like target's origin, size, center, center position and the template search border. Template matching is done to find small parts of an image that match the given or the required template image.

If the template consists of strong features like contours, shape descriptors, textures, invariant moments etc, then a feature based approach is preferable for template matching. Features of an image are specific structures in the image such as points, edges or objects. By strong features of the template we mean the sharp edges which are result of high frequency components. It is computationally efficient when the source images are of larger resolution, as it doesn't require the entirety of the template image. While template-based approach is efficiently useful for the templates lacking strong features, or when the bulk of template image consists of the matching image. Since template-based technique needs sampling of a large number of points to search in order to find the best match location, it is possible to reduce the sampling points by reducing resolution of search and the template images by the same factor and then performing the operation on the downsized images [vii]. This method provides a search window of data points in the search image and has the advantage that the template doesn't need to search all viable data points. The summarization of implementation steps of template-based matching approach is shown as a block diagram in Fig 3.

When the two functions ***f*** and ***t*** are complex valued functions and one of those is being conjugated, it ensures that the aligned peaks or the aligned troughs of the functions will have the imaginary components. Hence these will positively contribute in the integral, while their best match is being sited. The XCORR is an easy and efficient way to find the matching location of the template image in the frame or source image [viii]. XCORR is used for rows and columns of matrices to get 2D results. In the language of signal processing, the cross correlation is actually the measure of similarity of the two waveforms, as a function of time-lag applied to one of the waveform. The other names of cross correlation are sliding dot product or the sliding inner-product. Its purpose is to search a long signal (a frame) for a short, known feature (a template).

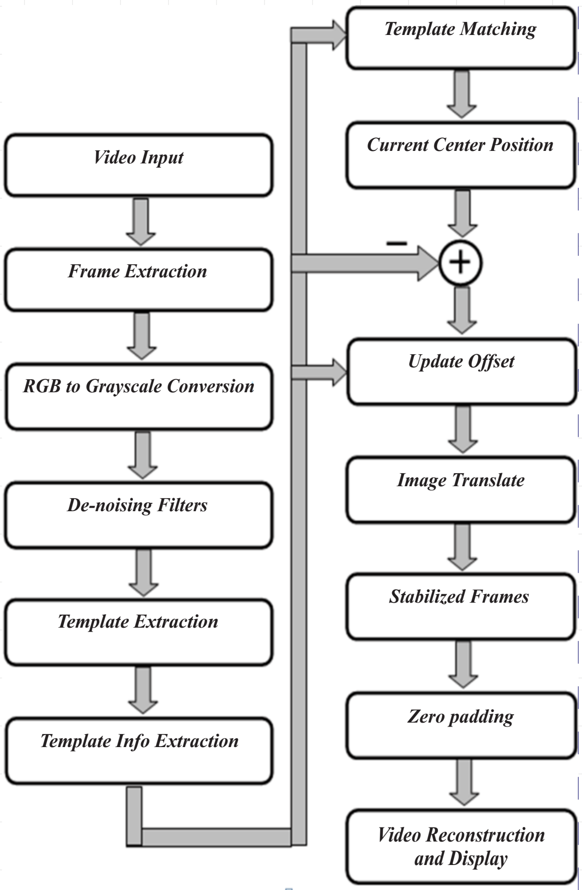

Fig 2: Proposed Stabilization Model

In case of the continuous signals or functions f and g, we can define the cross-correlation by the Eq. 1.

$$(f*g)(t) \overset{def}{=} \int_{-\infty}^{\infty} f^*(\tau) g(t+\tau)\, d\tau \qquad (1)$$

Where in this equation, the satiric sign (*) with the function f indicates the complex conjugate of f.

Similarly in the case of two discrete functions, the mathematical equation of cross-correlation can be written in equation (2)

$$(f*g)[n] \overset{def}{=} \sum_{-\infty}^{\infty} f^*[m] g[n+m] \qquad (2)$$

The nature of cross-correlation is same as that of the convolution of two functions except that convolution requires flipping of one of the functions. In this technique, a convolution mask is used, that contains the specific feature of the anchor frame or the search image, and the result of convolution is maximum at the point where the image structure and the mask structure have the best match, i.e. at the location where the large image values are multiplied with the large mask values [ix]. After each iteration, the maxima and the corresponding subscripts are recorded for motion vector and hence the required offset calculation and updation.

After the template is matched and subscripts are recorded, the templates new origin, center and center position on the anchor frame can be computed by some simple mathematical calculations. As it is previously discussed that the maximum value is at the point where the template's center best matches the frame pixels below. So from that center coordinates, we move to the origin of the template by subtracting half of the template height and width from the rows and columns respectively.

Next parameter is the template center which is simply the half of the template's total size. The template's center position is calculated by making the use of template's origin and center calculated in previous steps. The center position is the sum of the template's origin and the template's cente. While both of these are already calculated. Template tracking is mainly based upon calculation of correlation matrix. Highest correlation index indicates that the template is matched. Further motion vector is then calculated for offset calculations. The template is manually selected only once from the initial frame. All the information is then extracted by algorithm processing. The template and its center position is matched in the successive frames by the processing of template matching algorithm. Template matching algorithm is implemented using cross correlation and same has been illustrated in Fig. 3. Thus no human intervention is involved for tracking the target template center position in successive frames. Zero padding is required to make ensure that all the stabilized frames are of same size. This is essential for video reconstruction from stabilized frames.

IV. Motion Vector and Offset Calculation

The most important element in any process of the motion estimation is the motion vector. By the numerical value of motion vector, the observer can easily tell that whether the motion is performed or not and can also estimate it. Its purpose is to represent a block or a macro block (a small block portion in the whole frame), in an image, depending upon the position of the similar block or the macro block within another frame in the sequence (mostly the previous one), which is often named as reference frame or the reference picture [x].

More precisely and technically, the motion vector of an image can be defined as a 2D vector, which is intended for the inter prediction that gives the offset value from the coordinates in the existing frame of the sequence, to that of the coordinates in reference frame, i.e. the frame previous to the current frame in the sequence.

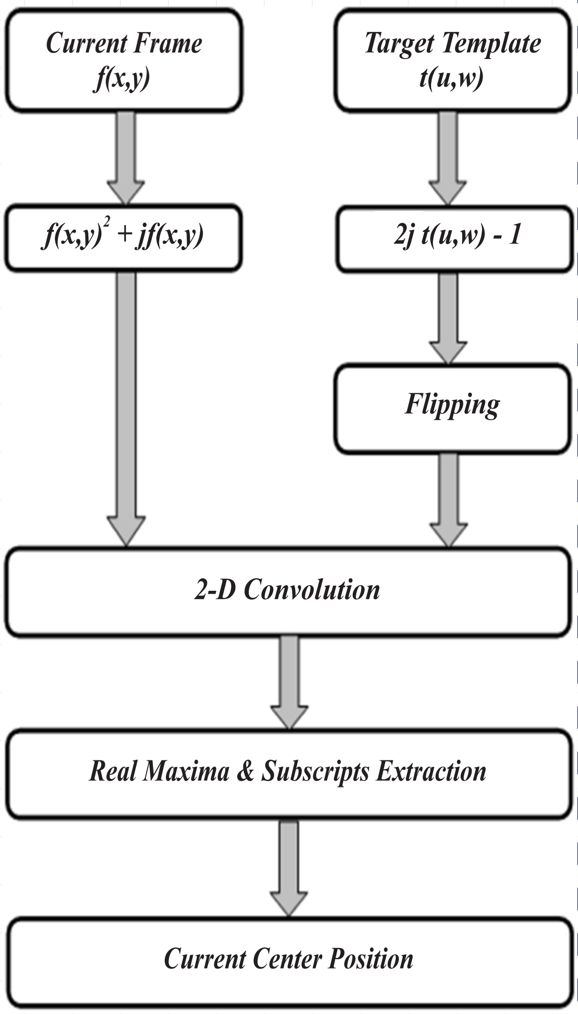

Fig. 3. Template Matching Algorithm

Now by keeping the above definition and discussion in mind, the motion vector can be mathematically explained as the difference of the center pixel location of that block or the macro block which we are considering in the existing frame, and center pixel location of same block or macro block within the preceding frame. However, in our project code, that block is actually the target template, which we have selected manually. This scheme may be described in the form of a block diagram in Fig. 4.

In general, by offset we mean the displacement between two specified points or destinations. In the image processing context, the meaning of the image offset is the displacement of the coordinates of the target or some template from one frame to the next in a video sequence. Such as in present case, we want to find our target's inter-frame offset. Depending upon this target's coordinate offset, the image translation can be performed to stabilize our target in the video. The offset is first initialize to *[0; 0]* for the very first frame and after that it is constantly updated for each frame transition, by the execution of an offset update algorithm [xi].

The implementation of the offset update algorithm is accomplished by some mathematical steps and equations constructed by making the use of some template information, motion vector and the previous offset value. The offset update algorithm can be elaborated by the block diagram shown in Fig. 5.

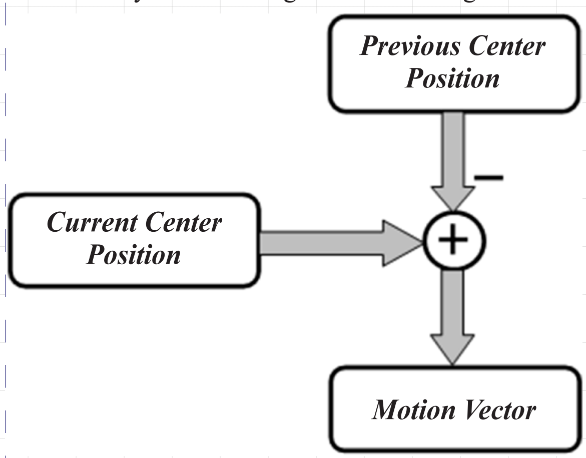

Fig. 4. Motion Vector Calculation

Depending upon the calculated motion vector and offset coordinates, necessary linear translation is performed on each frame and zero padding of all frames is done upto desired level for the purpose of video reconstruction from the stabilized frames. It is required because the linear translation in either direction creates a blank area in the opposite direction. This padding is applicable to all video formats and hence is useful in any applications. Zero padding is the appending of zeros to a signal or an image. It modifies a signal of length N to an extended signal of length M>N. This can be stated in the form of Eq. 3:

$$ZeroPad_{M,M}(x) \overset{\Delta}{=} \begin{cases} x(m), & 0 \le m \le N-1 \\ 0, & N \le m \le M-1 \end{cases} \quad (3)$$

The purpose of zero padding is accomplished by constructing a null matrix of the video size and then over riding the stabilized frame onto it [xii].

V. COMPUTATIONAL RESULTS

Computation of motion vector and the required inter frame offset and translation is done by the basic but most important information extracted out of the template or the target selected. Table 1 illustrates the information extracted and computed from the target template image during the first fifteen processing loop iterations.

The real maxima and its corresponding indices and subscripts computed as a result of template matching algorithm during first fifteen loop iterations are stated in the Table II.

Motion vector calculation is based on the difference of template center position in two consecutive frames which forms the basis of offset computation. Table III states the motion vectors for the first fifteen loop iterations.

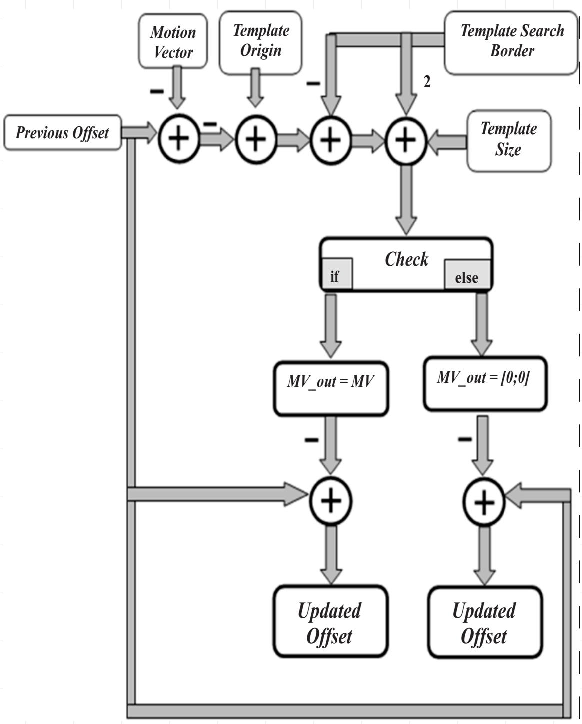

Fig. 5. Offset Update Algorithm

TABLE 1
EXTRACTED TEMPLATE INFORMATION

Iterations	*Origin*	*Center*	*Center Position*
1.	[61 116]	[41 20]	[101 135]
2.	[60 115]	[42 21]	[101 135]
3.	[60 115]	[42 21]	[101 135]
4.	[53 126]	[42 21]	[94 146]
5.	[54 124]	[42 21]	[95 144]
6.	[49 123]	[42 21]	[90 143]
7.	[56 123]	[42 21]	[97 143]
8.	[59 121]	[42 21]	[100 141]
9.	[58 119]	[42 21]	[99 139]
10.	[62 122]	[42 21]	[103 142]
11.	[53 128]	[42 21]	[94 148]
12.	[54 128]	[42 21]	[95 148]
13.	[51 130]	[42 21]	[92 150]
14.	[51 139]	[42 21]	[92 159]
15.	[63 135]	[42 21]	[104 155]

TABLE II
TEMPLATE MATCHING ALGORITHM COMPUTATIONS

Iterations	*Real Maxima*	*Indices*	*Column*	*Row*
1.	54757759	32502	102	136
2.	54757919	32502	102	136
3.	54735453	35135	95	147
4.	54724794	34656	96	145
5.	54730456	34411	91	144
6.	54722462	34418	98	144
7.	54710758	33941	101	142
8.	54705383	33460	100	140
9.	54687955	34184	104	143
10.	54664570	35615	95	149
11.	54664570	35615	95	149
12.	545464722	35616	96	149
13.	54629655	36093	93	151
14.	54622804	38253	93	160
15.	54613216	37205	105	156

TABLE III
MOTION VECTOR CALCULATION

Iterations	*Previous Center Position*	*Current Center Position*	*Motion Vector*
1.	---	[101 135]	[0 0]
2.	[101 135]	[101 135]	[0 0]
3.	[101 135]	[101 135]	[0 0]
4.	[101 135]	[94 146]	[-7 11]
5.	[94 146]	[95 144]	[1 -2]

6.	[95 144]	[90 143]	[-1 -5]
7.	[90 143]	[97 143]	[7 0]
8.	[97 143]	[100 141]	[3 -2]
9.	[100 141]	[99 139]	[-1 -2]
10.	[99 139]	[103 142]	[4 3]
11.	[103 142]	[94 148]	[-9 6]
12.	[94 148]	[95 148]	[1 0]
13.	[95 148]	[92 150]	[-3 2]
14.	[92 150]	[92 159]	[0 9]
15.	[92 159]	[104 155]	[12 -4]

TABLE IV
OFFSET CALCULATION AND UPDATION

Iterations	***Previous Offset***	***Motion Vector***	***Template Origin***	***Updated Offset***
1.	—	[0 0]	[61 116]	[0 0]
2.	[0 0]	[0 0]	[60 115]	[0 0]
3.	[0 0]	[0 0]	[60 115]	[0 0]
4.	[0 0]	[-7 11]	[53 126]	[7 -11]
5.	[7 -11]	[1 -2]	[54 124]	[6 -9]
6.	[6 -9]	[-1 -5]	[49 123]	[11 -8]
7.	[11 -8]	[7 0]	[56 123]	[4 -8]
8.	[4 -8]	[3 -2]	[59 121]	[1 -6]
9.	[1 -6]	[-1 -2]	[58 119]	[2 -4]
10.	[2 -4]	[4 3]	[62 122]	[-2 -7]
11.	[-2 -7]	[-9 6]	[53 128]	[7 -13]
12.	[7 -13]	[1 0]	[54 128]	[6 -13]
13.	[6 -13]	[-3 2]	[51 130]	[9 -15]
14.	[9 -15]	[0 9]	[51 139]	[9 -24]
15.	[9 -24]	[12 -4]	[63 135]	[-3 -20]

Depending upon this target's coordinate offset, the image translation is decided to stabilize desired target in the video. The offset for the very first frame is initialized to *[0; 0]* and is constantly updated for each frame transition afterwards, by the execution of offset update algorithm. The offset calculation and updated results are enlisted in Table IV.

Relying upon the updated offset, each frame is linearly translated by required coordinates to achieve the stabilized frames which in turn reconstruct the stabilized video. This concludes that the offsets are the undesired motions required to be eradicated.

To compare the results, variance and standard deviation of offset arrays of both input and output videos are computed. Standard deviation and variance of input video are as follows;

$$\sigma_1 = 10.5857 \quad 7.5506 \tag{4}$$

$$\sigma_1^2 = 112.0565 \quad 57.0122 \tag{5}$$

While the results of standard deviation and variance of stabilized output video are as follows;

$$\sigma_2 = 0.1443 \quad 0.1015 \tag{6}$$

$$\sigma_2^2 = 0.0208 \quad 0.0103 \tag{7}$$

Above mentioned comparison results clearly show that the standard deviation and variance of the stabilized video are less than the input video. From these values it is concluded that the output video is 98% stabilized compared to the input destabilized video.

VI. CONCLUSION

PRAs are the repetitive refining of the motion estimation, for the individual pixels, by the gradient techniques. The BMAs presume that all of the pixels inside a certain block, has the similar activity of motion. The BMAs estimate the motion, depending upon the rectangular blocks, and thus they create merely one motion vector, per individual block. The PRAs engross more complications of computations and a lesser amount of regularity, therefore these are tricky to be realized in the hardware. Generally, the BMAs are comparatively more appropriate for realizing an uncomplicated hardware, due to their simplicity and regularity.

The proposed technique for video target stabilization is a simple easy-to-implement technique. It has wide spread uses in many security, research and engineering fields. Moreover, it has the flexibility to be extended in implementation at high security and sensitive areas, for giving better and up to the mark results. Right now this technique is best efficient for video streams having the focused target within the boundaries of the frame and where the target must not exceed the moderate size ranges, otherwise manually selected target is stabilized for better perception of important information in the video data such as vehicle number plate reading, suspicious luggage checking on airport and bus stops, stabilization of astrological videos and in endoscopic videos for medical diagnosis etc.

REFERENCES

[i] L. Zhang, and Q. Huang, “A Global Approach to Fast Video Stabilization,” IEEE Transactions on Circuits and Systems for Video Technology, Volume: 27, Issue No 2, Feburary 2017.

[ii] P. Rawat and J. Singhai, “Review of Motion Estimation and Video Stabilization techniques for hand held mobile video,” Signal & Image Processing An International Journal (SIPIJ),

ISSN:1813-1786 (Print) 2313-7770 (Online)

Volume: 2, Issue No. 2, June 2011.

[iii] F. L. Zhang, J. Wang, H. Zhao, R. R. Martin, and S. Hu, "Simultaneous Camera Path Optimization and Distraction Removal for Improving Amateur Video," IEEE Transactions on Image Processing, Vol 24, Issue No. 12, December 2015.

[iv] K. Mayen, C. Espinoza, H. Romero, S. Salazar, M. Lizarraga, and R. Lozano, "Real-time video stabilization algorithm based on efficient block matching for UAVs," Workshop on Research, Education and Development of Unmanned Aerial Systems (RED-UAS), IEEE, 2015.

[v] L. C. Manikandan and R. K. Selvakumar, "A study on Block Matching Algorithms for Motion Estimation in video coding," International journal of Scientific and Engineering Research, Vol. 5, Issue 7, 2014.

[vi] J. T. Philip, B. Samuvel, K. Pradeesh, and N. K. Nimmi, "A comparative study of block matching and optical flow motion estimation algorithms," Annual International Conference on Emerging Research Areas: Magnetics, Machines and Drives (AICERA/iCMMD), IEEE, 2014.

[vii] S. K. Sahani, G. Adhikari and B. K. Das, "A Fast Template Matching Algorithm for Aerial Object Tracking," International Conference on Image Information Processing, 2011.

[viii] J. N. Sarvaiya, S. Patnaik, and S. Bombaywala, "Image Registration by Template Matching using normalized cross-correlation," International Conference on Advances in Computing, Control, and Telecommunication Technologies, 2009.

[ix] F. Essannouni, R. Oulad and D. Aboutajdine, "Simple Noncircular Correlation Method for Exhaustive Sum Square Difference Matching," Optical Engineering, Volume 46, Issue 10, Image Processing, 2007.

[x] P. Liu, H. Wang, and W. Xiaojuan, "Motion Compensation Based Detecting and Tracking Targets in Dynamic Scene," 2010 International Conference on Measuring Technology and Mechatronics Automation.

[xi] A. Hameed, "Video Shot Detection by Motion Estimation and Compensation," International Conference on Emerging Technologies, 2009.

[xii] K. Briechle, U. D. Hanebeck, "Template Matching using Fast Normalized Cross-Correlation," SPIE Proceedings, Volume 4387, Optical Pattern Recognition XII, 95, March 20, 2001.

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Partial Discharge defects recognition using different Neural Network Model at XLPE cable under DC stress

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Abstract-There are many advantages and applications of DC-XLPE cables under DC stress, it is of paramount importance that it is required to have some reliable diagnosis system to check the insulation state of cable insulation in order to avoid the unpredictable service failures of the cable system. Thus, it has been conceived that partial discharge diagnosis is one of the major tools for this purpose. However, very few research works have been reported regarding the PD diagnosis on XLPE cable under the DC stress.

By keeping this fact in mind in the current work, PD detection has been carried out using artificial defects introducible into DC-XLPE cable system and then PD signals have been analyzed by use of Chaotic Analysis of Partial discharge (CAPD). Afterwards, the application of the artificial neural network has been done in order to improve the recognition rate of the PD defects by adding power spectrum data for the first time in this concerned area. In this method, the power spectrum data of the PD signal is combined with CAPD data as the training data for artificial neural networks models. And then different NN techniques have been applied for the recognition of PD defects by using CAPD data and CAPD data combined with power spectrum data. As a result, better recognition rate as well as low mean square loss by using CAPD data combined with Power spectral data, also the MLP techniques has shown best results among all other NN networks.

Keywords-Partial Discharge PD, Chaotic Analysis of Partial Discharge CAPD, Neural Network (NN), XLPE Cable.

I. INTRODUCTION

Most of the service failure in power apparatus is due to the occurrence of Partial discharges from the presence of various natures of defects or irregularities existing at any place in the insulation system. A Partial Discharge (PD) is alocal electrical discharge caused by the excessive local electric filed beyond the breakdown strength of the insulation. And gradually bridging the insulation gap of the insulation system is taken place due to the unexpected propagation of the electrical trees. Fig. 1 below describes schematically that how the PD is occurred in small cavities present in the insulation structure for the power apparatus. Techniques have been proposed for the identification of PD in AC electrical apparatus in ceramic and polymeric insulators [i-v]. For the PD in AC-XLPE cables, several methods have been proposed for the related diagnosis by applying different sensors in the cable insulation as well as cable joints [vi-xi].

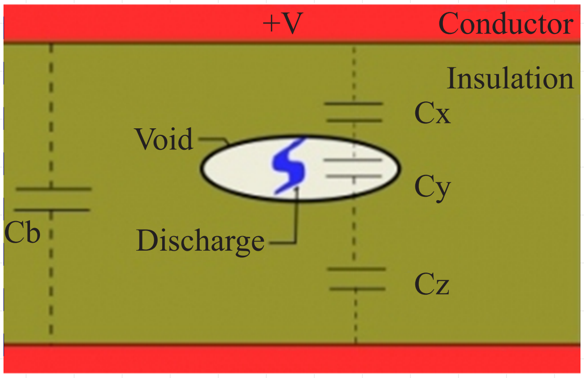

Fig. 1. The small cavity inside the insulating material responsible for PD

In case of power cable insulation system, the process from PD occurrence to breakdown is shown in Fig. 2.

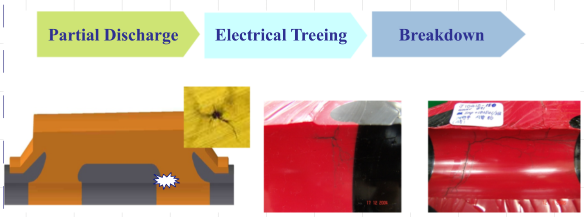

Fig. 2. The breakdown process of insulation due to Partial discharge.

Recently the DC apparatus had been developed with the expectation of less transmission losses. So far, not many techniques have been proposed for diagnosing the reliability of insulation in DC power apparatus instead of its huge applications to the large power grids [xii-xiii]. The Ultra-High Frequency (UHF) Sensors are used to detect the PD under DC stress [xiv]. The diagnosis and evaluation of high power DC apparatus are used to detect PD which is accepted as a plausible diagnostic method for the status of insulation state [xv-xx]. The PD signals are generated from different insulation defects connected to the XLPE cable put under DC stress by using CAPD method and the defects patterns are proposed [xxi].

The Fuzzy Identification System has been proposed in order to identify corona, internal and surface discharge: easy for the corona but hard to distinguish the internal and surface discharges. For that, the characteristics of internal and surface discharge have been expressed as a function of temperature and humidity as well. However, it requires additional facilities such as oven and humidity chamber to investigate the effects of temperature and humidity.

A statistical correlation between consecutive PD events is been proposed to identify PD sources under the DC stress, which is unable to show any specific pattern for the type of defects detected. Moreover investigation parameters of Weibull distribution could not distinguish the PD and noise nor differentiate the type of PD defects.

These parameters obtained from each PD signal are mapped onto two dimensional Time- Frequency plane and then mapped points are clustered respectively in different manner making a region on this plane. In this way, the clustered zone could be separated into "Noise" group from the noses at the site and "PD" group for the PD signals from the defects. The signals in the "PD group" are used for further analysis enabling to make pattern recognition of the defects. [xxii].

From the review on the precedent works, it has been remarked that the main problem to diagnose PD patterns under DC stress is to distinguish the patterns from the different type of defects. For this purpose, it is necessary to develop a more reliable and accurate PD pattern recognition tool and accordingly CAPD method has been selected.

The Pulse Sequential Analysis (PSA) is basically related to the accumulation of local space charges due to change in the local electric field. In PSA there is a strong correlation between consecutive discharge pulses. This means that successive PD pulses cannot be considered to be independent without a correlation with preceding discharge pulses. Because of this in PSA the important parameters like applied voltage or the phase angle do not have the absolute value where the discharges occurs. This is because the local electric field and its effect has to be considered when finding out the values of these parameters.Due to these discrepancies this technique is not used for the current work.

In CAPD Method the absolute value of the magnitude of the PD pulses and time interval between two consecutive PD pulses are the two main parameters taken into the account

II. EXPERIMENTAL TEST SETUP AND PARTIAL DISCHARGE DETECTION

The complete experimental test setup is shown in Fig. 3. It consists of a PD free 100 kV transformer which produce AC signal, AC to DC rectifier circuit, Voltage divider to measure DC voltage, XLPE cable specimen, PD defect to produce PD signal, HFCT sensor to receive PD signals and Lab VIEW system as a data acquisition module.

The voltage source is PD free (HAEFLEY 100 kV, 1A) transformer, located inside the well shielded room as shown in Fig. 4, connected with the XLPE cable specimen including a joint. A converting system from AC to DC (150 kV/50 mA) through rectifier (1.5% ripple without load) is shown in Fig. 5.

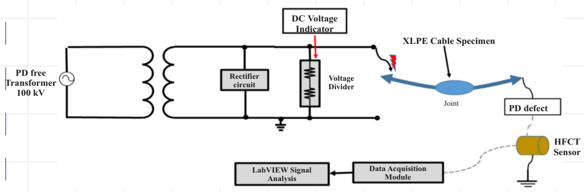

Fig. 3. Experimental Test system diagram

Fig. 4. The XLPE cable with a PD free 100 KV Transformer

Fig. 5. AC to DC rectifier circuit

PDs are detected through a HFCT sensor, clamping the ground wire as in Fig. 6, with the following characteristics: Its bandwidth ranges from hundreds of kHz to 25 MHz, sensitivity is 1 pC ± 1%. The data acquisition module is of National Instruments NI-PXI-5152 with the data rate of 2 GS/sec and having frequency range of 300 MHz as shown in Fig. 7.

Fig. 6. Calvus HFCT Sensor

Fig. 7. National Instruments NI-PXI-5152 System

A. *Artificial Defects & Partial Discharge*

Three main artificial defects are prepared in order to produce void discharge, surface discharge and corona discharge. Afterwards, they are connected to the sample cable terminal in order to produce PD for the experimental investigation at the laboratory.

i) Artificial defect for Void discharge

The presence of void in the cable insulation is imitated by the cavity introduced into the epoxy as shown in Fig. 8in a way to have the same electric field distribution as that of produced in real cable. [xxiii-xxvi] and then it has been put under applied DC voltage at the laboratory. Fig. 8 shows the artificial void defect containing cavity to imitate void and Fig. 9 is its schematic description.

Fig. 8. Artificial Void defect

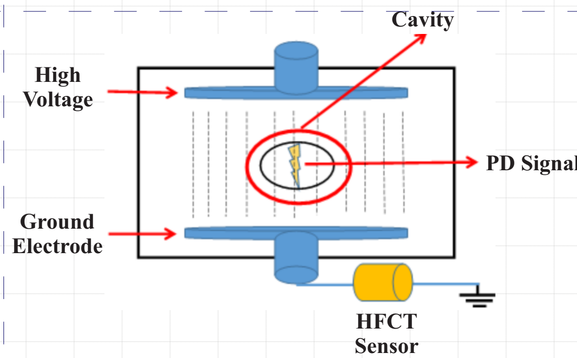

Fig. 9. Cavity imitating Void

ii) Artificial Defect for Surface discharge

The Surface discharge occur along the dielectric interfaces where ionization propagates orthogonal to the applied electric field. In order to simulate the discharge at the surface, a solid insulation polymer disk is placed between high voltage and ground terminal as shown in Fig. 10 [xxvii, xxviii].

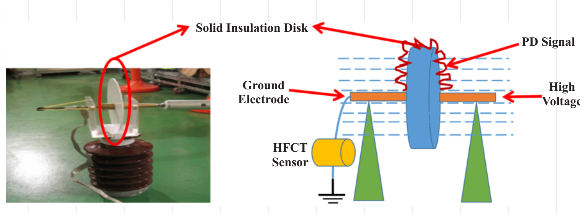

Fig. 10. Circular insulation disk for Surface Discharge showing tangential electric field

iii) Corona discharge defect

Corona discharge are produced as a result of high divergent electric field spots which are produced by use of a sharp steel wire intentioanlly located at the ned of sample cable terminal as shown in Fig. 11.

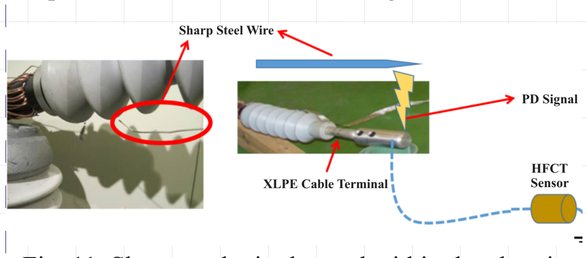

Fig. 11. Sharp steel wire located within the electric field of the terminal to produce Corona discharge

III. Neural Networks

A. *Process*

After getting the input feature vector of the size 1 × 3072 obtained by three CAPD pattern data, thepattern recognition is carried out by adopting three different neural network techniques which are the Multilayer perceptron (MLP), Self-Organizing Feature Mapping (SOFM) and Recurrent Network (RN). Fig. 12 shows the overall process for the pattern recognition of the defects [xxviii-xxxix].

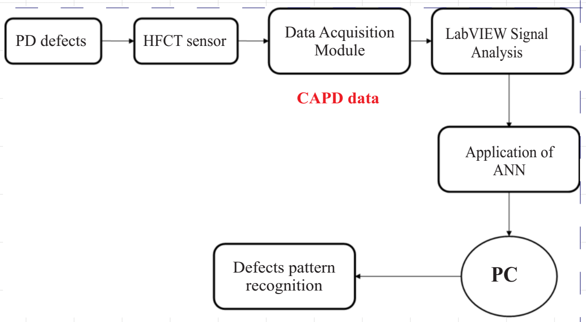

Fig. 12. Flow Diagram of pattern recognition process

B. Pattern Recognition Using Multilayer Perceptron (MLP) Neural Networks

The structure of MLP is shown in Fig. 13. The MLP system been has trained using three hidden layers and each layer has 50, 20 and 10 hidden nodes respectively to converges the system smoothly and quickly.

Fig. 13 shows the total number of input vectors i.e. 3072 along with the hidden layers and the output layer of MLP by showing the three type of outputs as well.

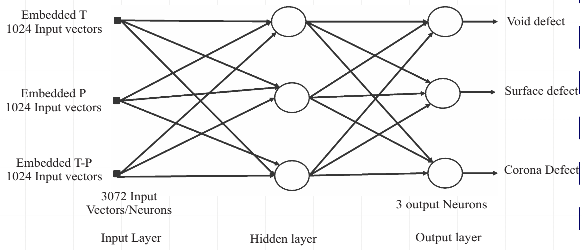

Fig. 13. Input and Output vectors for MLP Neural Networks

C. Pattern Recognition Using Self-Organizing Feature Map (SOFM) Neural Networks

It is a two-layer network that consists of an input layer in a line and an output layer made of neurons in a two dimensional grid as shown in Fig. 14. It uses the unsupervised learning in which the network has to train itself through its own classification without any external source.

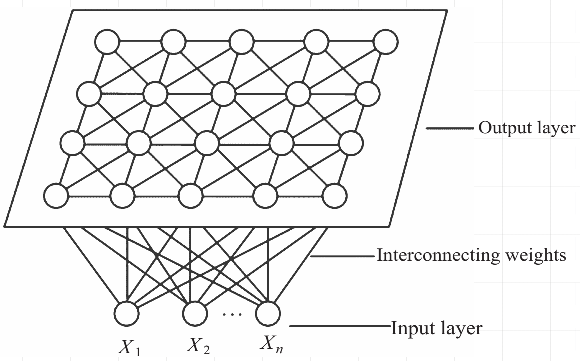

Fig. 14. The architecture of SOFM Neural Network

D. Pattern Recognition Using Recurrent Network (Elman Network)

The main characteristics of a Recurrent Neural Network (RNN) is that it contains at least one feed-back connection from output layer to the hidden layer, so that the activations can flow round in a loop. The learning scheme is the same as for the MLP network using gradient descent procedures similar to the back-propagation algorithm used in feed-forward networks. Every layer is connected to the previous layer making a temporary memory space. This network may use their internal memory to process their arbitrary sequences. There is feedback loop around each layer except the last layer. Fig. 15 shows the architecture of RNN showing the input layer, hidden layer and the output layer along with the feedback loop from the output to the hidden layer.

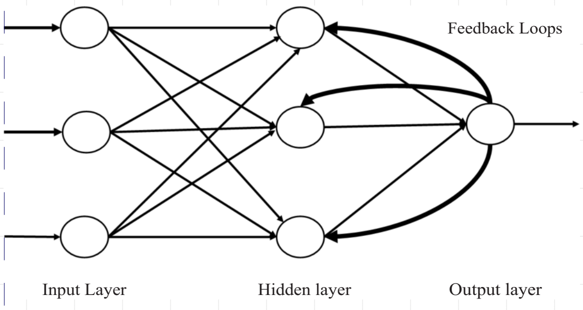

Fig. 15. The architecture of Recurrent Neural Network

E. Power spectrum data added with CAPD data

To get the feature vector from the power spectrum data, the value of PD signals in dBm is acquired from the data of spectrum analyzer using Lab VIEW software as shown in Fig. 16. The power value measured for each PD signal is shown in Fig. 17, which is normalized within the range of 0 to 1 by applying the formula as shown in Eq. 4. Afterwards, a feature vector is also made from these values of the size 1 ×1024 as shown in Fig. 18.

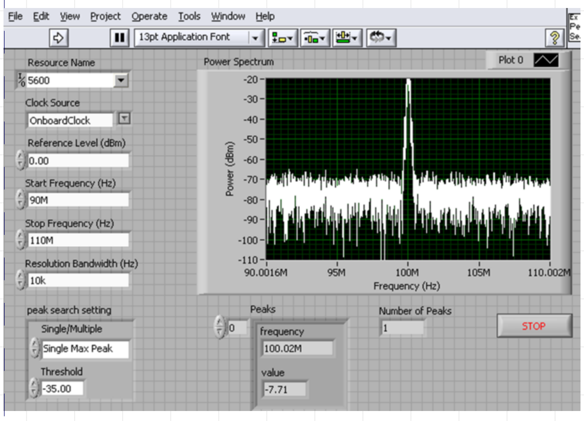

Fig. 16. Waveform of the Spectrum Analyzer in Lab VIEW

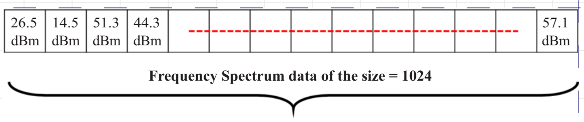

Fig. 17. Power values of Frequency Spectrum [dBm]

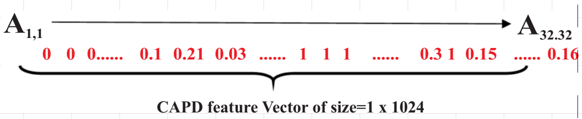

Fig. 18. Power Spectrum feature vector

$$p_f^* = \frac{p_f}{p_{f\max}} (0 \le p_f^* \le 1) \quad (1)$$

Where

- p^*_f = Normalised power of each PD signal
- p_f = Power of each PD signal [dBm]
- $p_{f\max}$ = Maximum power of any PD signal [dBm]

The spectral analysis is dependent on the nature of defects but by using this data alone, it is insufficient to recognize the defects producing any PD signals, however, if it is added with other PD signal data, a better recognition rate could be obtained. Thus, spectral feature vector is considered to be added with the feature vectors of CAPD data. The input vector obtained by combining these feature vectors is fed into the neural network to enhance the pattern recognition rate. For this purpose, the input vector is composed by adding the CAPD feature vector of the size 1 × 3072 and one feature vector of power spectrum data of the size 1 × 1024 by making input vector of the size 1 × 4096 which is used as a training data for NN as shown in Fig. 19. The block diagram showing the overall process of pattern recognition is shown in Fig. 20.

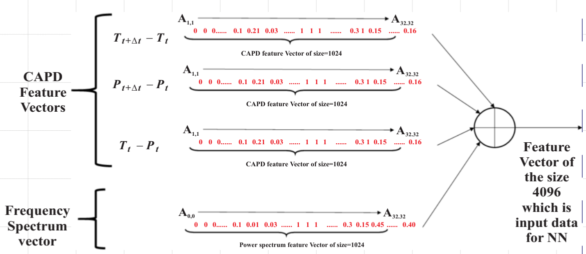

Fig. 19. Input feature vector of the size 1 × 4096

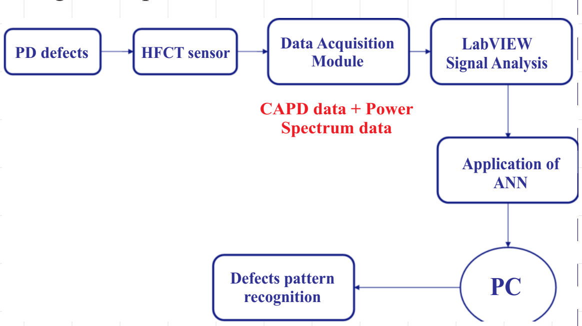

Fig. 20. Block Diagram of Pattern recognition process

The pattern recognition process is performed by adopting three different neural network techniques including Multilayer perceptron (MLP), Self-Organizing Feature Mapping (SOFM) and Recurrent Network (RN).

Fig. 21 shows the total number of input vectors i.e. 1 × 4096 along with the hidden layers and the output layer by showing the three outputs.

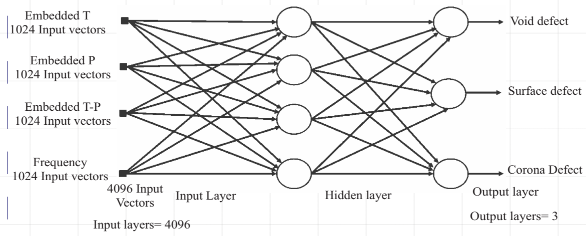

Fig. 21. Input and output vectors for Neural Networks

F. Comparison Of Results Based On CAPD Data With Power Spectral Data

The numbers training data and testing data for the three neural networks is summarized in Table I.

TABLE I
THE NUMBER OF TRAINING AND TESTING DATA

Defect Type	Data sets of Multilayer Perceptron (MLP)		Data sets of Self Organizing feature Map (SOFM)		Data sets of Recurrent Network (RN)	
	Training data	Testing data	Training data	Testing data	Training data	Testing data
Void	86	42	112	57	95	47
Surface	118	59	107	54	90	42
Corona	105	37	102	45	98	45

The input vector and objective output vector is shown in Table II. When the learning phase is completed, one of the three output of the defect is equal to '1' and the other two are equal to '0' showing the correct type of the defect.

TABLE II
THE OBJECTIVE OUTPUT VECTOR

Input Vector	Objective Output vector		
	Void	Surface	Corona
Void	1	0	0
Surface	0	1	0
Corona	0	0	1

G. Overall Comparison Of Recognition Rates

The overall comparison of MSEs of the defects using different NN techniques are compared for two cases obtained by only CAPD data and CAPD data combined with power spectrum data are shown in Table. II. The latter one is found to be lower as compared to that from the former one. And MLP technique has shown the results with least MSEs as compared to other two techniques when the CAPD data is combined with power spectrum data.

TABLE. III
MEAN SQUARE ERROR (MSE) DEPENDING USING ONLY CAPD DATA AND CAPD DATA WITH POWER SPECTRAL DATA

Neural Model	Mean Square Error (MSE)			
	CAPD Data + Spectral Data		Only CAPD data	
	Training	Testing	Training	Testing
Multilayer Perceptron (MLP)	**0.006**	**0.012**	0.034	0.043
Self-Organizing Feature Map (SOFM)	0.015	0.017	0.173	0.161
Recurrent Network (RN)	0.009	0.035	0.057	0.089

The overall comparison of recognition rates using different NN techniques are also compared for two cases obtained by only CAPD data and CAPD data combined with frequency spectrum data in Table IV. pattern recognition rate of the former is less as compared to that of the latter. Also as a whole, the MLP technique has shown the best performance.

TABLE IV
PATTERNS RECOGNITION RATES BY CONSIDERING ONLY CAPD DATA AND CAPD DATA WITH SPECTRAL DATA FOR THREE ANN TECHNIQUES (UNIT: %)

Type of Defects	Recognition Rate (%)					
	Multilayer Perceptron (MLP)		Self-Organizing feature Map (SOFM)		Recurrent Network (RN)	
	CAPD data + Spectral Data	Only CAPD Data	CAPD data + Spectral Data	Only CAPD Data	CAPD data + Spectral Data	Only CAPD Data
Void	97.31	76.14	87.41	77.34	95.14	89.65
Surface	95.85	80.45	83.57	69.12	90.34	84.23
Corona	99	83.34	84.79	68.76	91.25	73.56
Average	97.38	78.60	85.25	71.47	92.24	82.48

IV. RESULTS AND DISCUSSIONS

It could be concluded from these analyses that, in order to improve the recognition rate of PD defects, it is effective to combine the CAPD data with frequency spectrum data of PD signals: MLP technique has shown the best recognition rates and least MSEs.

V. CONCLUSION

The Partial Discharge (PD) under DC stress has been produced by use of artificial defects imitating vital insulation defects introducible into the cable system such as void, surface and corona. It has been generally conceived that their presence could give rise to a considerable service failure of the DC XLPE power cable system. By keeping this fact in mind, this work has been proposed to carry out an experimental investigation followed by the pattern recognition of the above defects by using CAPD method. For the latter, one more parameter, such as frequency spectrum data of the PD signal, has been additionally considered together with the CAPD data. Finally, the pattern recognition rate obtained by only CAPD data and CAPD data combined with spectral data has been compared, for which different NN techniques have been applied respectively.

In order to acquire the PD parameters using CAPD method, the magnitude of the PD pulses and the time interval between two consecutive pulses have been used to represent the related PD patterns. Three different type of patterns have been obtained from each defect of which the feature vectors are extracted from CAPD data patterns to obtain the pattern recognition rates. In order to get the feature vector, the 2-dimensional CAPD data patterns have been transformed into one dimensional feature-vector. Three feature vectors have been obtained for each type of defects and then are used for training data. Afterwards, different neural networks techniques have been applied for comparing the results: Multilayer perceptron (MLP), Self-Organizing Feature Map (SOFM) and Recurrent Network (RN).

In order to improve the recognition rate of PD defects, the frequency spectrum data is also added with CAPD data. The training is again performed by using three feature vector obtained from each CAPD defect data along with one feature vector obtained from frequency spectrum data by using different NN techniques like above.

Finally, the recognition rates of PD defects iscompared for both the data. It is shown that the data combining CAPD and spectrum data shows much better performance as compared to the previous case in term of low mean square error and better recognition rates. Also, the MLP technique has shown the best results among the three techniques.

In future, this idea can be applied to recognize different PD defects and as a result better recognition rate can be achieved which results in avoiding the power apparatus failures and to avoid heavy damages.

REFERENCES

[i] A. Cavallini, G.C. Montanari, F.Puletti., A. Contin 'A New Methodology for the Identification of PD in Electrical Apparatus: Properties and Applications', IEEE Trans. Dielectr. Electr. Insul, 2005, Vol. 12, pp. 203-215.

[ii] A. Cavallini, G. C. Montanari and F. Puletti., 'A

Novel Method to locate PD in Polymeric Cable systems based on the Amplitude –frequency (AF) Map', IEEE Trans. Dielectr. Electr. Insul, 2007, Vol. 14, pp.726-734.

[iii] S. Chandrasekar, C. Kalavanan, G.C. Montanari, A. Cavallini, 'Partial Discharge detection as a Tool to Infer Pollution Severity of Polymeric Insulators', IEEE Trans. Dielectr. Electr. Insul, 2010, Vo. 12, pp. 181-188.

[iv] A. Cavallini, S. Chandrasekar, and G. C. Montanari., F. Puletti, 'Inferring Ceramic Insulator Pollution by an Innovative Approach Restoring to PD Detection', IEEE Trans. Dielectr. Electr. Insul, 2007, Vol. 14, pp. 23-29.

[v] S. Chandrasekar, C. Kalaivanan, A. Cavallini., G. C.Montanari 'Investigation on Leakage Current and Phase Angle Characteristics of Porcelain and Polymeric Insulator under contaminated Conditions', IEEE Trans. Dielectr. Electr. Insul, 2009, Vol. 16, pp. 574-583.

[vi] Y. J. Lee, J. Y Kim, I. J. Seo., 'Frequency characteristics of Partial discharge in MV extruded cable using non-conventional Sensors', 8th International Conference on Insulated Power Cables, Versailles, France 2008.

[vii] W. Choi, I. J. Seo, Y. J. Lee, 'An Algorithm development for finding PD sources located in 154kV XLPE power cable system', International conference on Conditioning Monitoring and Diagnosis (CMD), Jeju, Korea, 2014.

[viii] J. Y. Koo, J. S. lee and J. T. Kim., 'A Study on the correlation between the PD pattern and the aspect of electrical trees propagation in the XLPE insulation of the underground power transmission cable', The 6th International Conference on Properties and Applications of Dielectric Materials, China, 2000.

[ix] J. T. Kim, D. U. Kim, Y. J. Lee, 'Analysis of Partial Discharge Inception Voltages for wrong positioning defects in the Joint of Distribution Power Cables', J Electr Eng Technol, 2013, Vol. 7, pp. 977-982.

[x] J. S. Lee, J. Y. Koo, Y. S. Lim., J. T. Kim, S. K. Lee: 'An analysis of the Partial Discharge pattern related to the artificial defects introduced at the interface in XLPE Cable joint using laboratory model', Conference on Electrical Insulation and Dielectric Phenomena, 2002.

[xi] J. T. Kim, D. U. Kim, G. J. Nam., 'Partial Discharge location using two sensors and Optical Fiber', IEEE International Conference on Condition Monitoring and Diagnosis, Indonesia, pp. 126-129, 2012.

[xii] Soo-Bong Lee, Tae-Ho Lee, Eui-Hwan Jung.,'Development status of HVDC XLPE cable in Korea', International Conference on Condition Monitoring and Diagnosis (CMD), Jeju, Korea, 2014.

[xiii] T. H. Lee, J. W. Choi, E. H. Jung, 'Development of the HVDC 80kV XLPE cable System and Construction of Test-bed in KOREA', CIGRE 2012.

[xiv] R. Sarathi, A. V. Giridhar, A. Mani., K. Sethupati 'Investigation of Partial Discharge Activity of Conducting Particles in Liquid Nitrogen under DC Voltages using UHF Technique', IEEE Trans. Dielectr. Electr. Insul, 2008, Vol. 15, pp. 655-662.

[xv] S. Wenrong, L. Junhao, Y. Peng, L. Yanming 'Digital Detection, Grouping and Classification of Partial Discharge Signals at DC Voltage', IEEE Trans. Dielectr. Electr. Insul, 2008, Vol. 15, pp. 1663-1674.

[xvi] P. H. F. Morshuis and J. J. Smit, 'Partial Discharge at DC Voltage: Their Mechanism, Detection and Analysis', IEEE Trans. Dielectr. Electr. Insul, 2005, Vol. 12, pp. 328-340.

[xvii] A. Cavallini, G. C. Montanari, M. Tozzi, X. Chen, 'Diagnostic of HVDC Systems Using Partial Discharge', IEEE Trans. Dielectr. Electr. Insul, 2011, Vol. 18, pp. 275-284.

[xviii] H. Q. Nui, A. Cavallini, G. C.Montanari, 'Identification of Partial Discharge Phenomena in HVDC Apparatus" IEEE Conference, 2008.

[xix] A. Cavallini, X. Chen, H. Niu., G. C. Montanari 'Strategies for PD Source Identification in HVDC System" IEEE Conference 2008.

[xx] F. H .Kreugar, "Industrial High DC Voltage", Delft, The Netherland, Delft Univ. Press, 1995.

[xxi] M. Y. A. Khan, I. J Seo, Y. J. Lee., J. Y. Koo.: 'An Insulation defect in HVDC XLPE Cable based on the analysis of PD Detection', International Symposium on High Voltage Engineering(ISH), Pilsen, Czech Republic, 2015.

[xxii] M. R. Rahimi. R. Javadinezhad, Mehdi Vakilian, "DC Partial discharge Characteristics for Corona, Surface and Void discharges", IEEE 11th International Conference on the properties and Applications of Dielectric Materials, 2015.

[xxiii] J. Y. Koo, J. S. Lee, Y. S. Lee, "Comparison of Diagnostic method for the pattern analysis due to artificial defects introduced at the interface in XLPE cable joint using laboratory Model", IEEE Conference 2012, pp. 1426-1430.

[xxiv] Y. Z., Arief, H. Ahmad and M. Hikita, "Partial Discharge characteristics of XLPE cable joint and interfacial phenomena with artificial defects", 2nd International conference on power and energy, Dec 1-3, Johor Baharu, Malaysia, 2008, pp. 1518-1523.

[xxv] J. S. Lee, J. Y. Koo, Y. S. Lim, S. K. Lee, "An analysis of the Partial Discharge pattern related to the artificial defects introduced at the interface in XLPE cable joint using laboratory Model", Annual Report Conference on

Electrical Insulation and Dielectric Phenomena, 2002, pp. 482-485.
[xxvi] Industrial High DC Voltage by F.H.Kreuger.
[xxvii]M. Florkowska, A. Zydron, "Interaction of conductor with Polymeric Materials (XLPE/EPR) at Partial discharges. IEEE Transction on Dielectric and Electrical Insulation, Vol. 19, No.6, Dec 2012.
[xxviii]Partial Discharge detection in High-Voltage Equipment's, By F. H. Kreuger.
[xxix] L. Satish, B.I. Gururaj 'Partial discharge pattern classification using multilayer neural network', 1993, IEE Proceedings-A, Vol. 140, No. 4, pp. 323-330.
[xxx] M. M. A. Salama, R. Bartknikas, 'Determination of Neural Network Topology for Partial Discharge Pulse Pattern Recognition', IEEE Transaction on Neural Network, 2002, Vol. 13, No. 2, pp. 446-456.
[xxxi] Amira A. Mazroua, M. M. A. Salama and R. Bartnikas., 'PD Pattern Recognition with Neural Network using multilayer Perceptron Technique', IEEE Trans. Dielectr. Electr. Insul, Vol.28 No. 6, pp. 1082-1089.
[xxxii]S. Y. Jung, C. H. Ryu, Y. S. Lim, 'Discrimination of Insulation defects in a Gas Insulated Switch Gear (GIS) by use of a Neutral Network based on a Chaotic Analysis of Partial discharge (CAPD)', Journal of Electrical Engineering & Technology, 2007, Vol. 2, No. 1, pp 118-122.
[xxxiii]L. Satish and Walter S. Zaengl, 'Artificial Neural Network for Recognition of 3-d Partial Discharge Pattern', IEEE Trans. Dielectr. Electr. Insul, 1994, Vol. 1 No. 2, pp. 265-275.
[xxxiv]Christian Cachin, and Hans Jurg Wiesmann, 'PD Recognition with Knowledge-based Preprocessing and Neural Networks', IEEE Trans. Dielectr. Electr. Insul, 1995, Vol. 2 No.4, pp. 578-589.
[xxxv]E. Gulski and A. Krivda, 'Neural Network as a Tool for Recognition of Partial Discharge', IEEE Trans. Dielectr. Electr. Insul, 1993, Vol. 28 No. 6, pp. 984-1001.
[xxxvi]H. Borsi, E. Gockenbach, D. Wenzel, 'Separation of Partial discharge from pulse-shaped noise signals with the help of Neural Network', IEE Proc. Sci. Meas. Technol, 1995, Vol. 142, No.1, pp. 69-74.
[xxxvii]Lefteri H. Tsoukalas, Robert E. Uhrig.: 'Fuzzy and Neural Approaches in Engineering', John Wiley and Sons, pp. 229-254.
[xxxviii]M. Y. A. Khan, J.Y.Koo," Neural Network based diagnosis of Partial discharge defects patterns at XLPE cable under DC stress", Electr Eng, Springer, 99, 119-132, 2017.
[xxxix]Soo-Bong Lee, Tae-Ho Lee, Eui-Hwan Jung., 'Development status of HVDC XLPE cable in Korea', International Conference on Condition Monitoring and Diagnosis (CMD), Jeju, Korea, 2014.

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Design and analysis of M-shape printed Monopole antenna for GPS/ISM/W-LAN applications

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Abstract-In this article M-shape multiband antenna is proposed for wireless communication systems such as GPS, WLAN and ISM. The proposed antenna resonates at four bands, I (1.436 GHz -1.586 GHz), II (2.313 GHz-2.50 GHz), III (4.844 GHz -5.150 GHz) and IV (5.714 GHz-5.951 GHz) with improved return losses and impedance matching. These bands covering GPS band 1.57GHz, WLAN bands 2.4GHz, 5.0GHz, and 5.8GHz and ISM bands 2.45GHz and 5.75GH with radiation efficiency 65.15%, 76.69%, 59.95%, 54.31%, 73.17% and 53.68% respectively and VSWR<2 for all bands. The antenna has size of 43.8mmx18.6mm with defected ground structure (DGS) and fed by 50ohm micro strip feed line. The antenna is designed on FR-4 substrate material with thickness of 1.6mm, relative permittivity is 4.3 and tangent losses are 0.025. The proposed design is simulated in CST (computer simulation technology) microwave studio. The proposed antenna is fabricated and results are measured with help of network analyzer. The measured and simulated results are compared.

Keywords-:Defecated Ground Structure (DGS), Parallel Rectangular Open Slots (PROS), Microstrip Patch Antenna (MPA)

I. INTRODUCTION

Antenna is the key component in wireless communication systems and plays a vital role in the design of wireless communication systems. So for many types of antennas such as wire antennas, Aperture antennas, micro-strip patch antennas (MPA), reflector antennas, lens antennas and array antennas have designed and developed for different uses in wireless communication systems like satellite communication, radar and airplane, smart phones, medical equipment, devices used for security systems, remote area control and telemetry units in industries etc. All antennas are good and suitable in accordance with their uses, however the micro-strip patch antenna [i] attracted attention of researchers and antennas developing community due to its low profile, conformability to a shaped surface, ease of fabrication, compatibility with integrated circuit technology, low power consumption, and inexpensive compared with other types of antennas. The disadvantages of MPA are narrow bandwidth, low gain and a potential decrease in radiation efficiency due to surface-wave losses. However many techniques have developed to improve the performance of MPA[ii]. So for lot of work has done to improve performance of multiband micro strip patch antenna. MPA having multi-strip with different shapes have used to achieve wide bandwidth [iii]. Different techniques have been proposed for gain enhancement [iv-vii]. To improve the efficiency of multiband MPA a design of rectangular patch with parasitic element is presented in [iv]. Excellent return losses have achieved while using square split ring resonator in [viii].

Two technique are used to feed MPA [ix]; connecting feeding and non-connecting feeding. Coaxial cable, and micro-strip line are connecting feeding techniques. Proximity coupling and aperture coupling are non-connecting feeding techniques. In the early stages MPA ware using in military sector due to low profile however with the rise of wireless mobile technology in communication systems it became more and more favorite in this area.

Wireless communication system is world of wireless devices. Some of the wireless devices dealing with single service and many of them like smart phones can support more than one service such as GPS, GSM, 3G, 4G, WLAN and WiMAX, concurrently. According to FCC each service operates in its own frequency band. To achieve this multi-service functionality of wireless devices a number of antennas will be required in a signal device, which enlarge the size, increase energy consumption and cost of device. To make the multi services function beneficial a multi-band antenna is best solution. Multiband antenna can operate simultaneously at more than one frequencies. Multiband antennas can reduce the number of antennas and remove the band pass filters used in a multiband system, which is critical for mobile devices to minimize the overall size [i], fit the severe physical space constraints, and save the cost [x-xiii]. The main challenging feature of multi-band antenna is its shape, size, volume, return losses, impedance matching, bandwidth, efficiency and energy consumption while keeping its performance in best conditions.

Till the date different methods and techniques have been studied and used to design a multi band MPA. Multi band MPA can be design using Defected Ground Structure (DGS). DGS was used to achieve multiband features, enhance bandwidth, and reduce the size of MPA. In DGS technique, slots of different shapes such as U-shape, E-shape, I-shape, L-shape, S-shape and Z-shape etc. etched in the ground of MPA. Many design have been proposed for MPA with DGS [iii, xiv-xviii]. Multi band feature of MPA can be achieved by etching slots in patch [xiv]. Split ring resonator SSR is one of the approaches used for multi band MPA [xix]. Many researcher have used more than one patches of different size and shape as a radiating element to design multi band MPA[xvi, xx].

Until now different shapes have been proposed for multi band MPA. A fractal Sierpinski triangle shape is used in [x-xii] where in [xiii] two strips of very small size, a feeding strip and shorting strip are used. An antenna is designed having rectangular patch surrounded by meander strip with L shape slot [xxi]. A planar rectangular patch monopole antenna with two L shape slots and a meandering strip have different width at its different part is proposed in [xxii]. The antenna designed in [xxiii] consisting three fractal s-shaped patches with different lengths. The materials, shape, size and feeding point of antenna has a great influence on its characteristics and performance. These aspects are studied in [xxiv].

Many researchers have worked on multiple MPA and designed a lot of multiple antennas. A trapezoidal shape multi band antenna with SRR is presented to cover three bands 2.4GHz, 3.5GHz and 5.8GHz[xix]. A multiband MPA, with multiple patches having different shapes and size, is proposed which accommodate three bands [iii]. Square Split Ring Resonator (SSRR) multi band MPA is proposed for UMTS/3G 2.1GHz and Wi-Fi/WLAN 2.4GHz application [viii]. A U-shape MPA with DPS (Defected Parasitic Structure) is used to achieve three bands 2.4GHz, 3.6GHz and 5.8GHz [xxv]. A rectangular patch MPA is designed with an L-shape slot and two I-shape slots to get five bands[xxvi].

In this article M-shape multi band MPA is presented for GPS, WLAN and ISM applications. The M-shape radiating patch is mounted on FR-4 substrate of relative permittivity ε_r=4.3 and ground on back sides of substrate with two PROS (parallel rectangular open slots). DGS is used for impedance matching. The proposed MPA has small size and improved return losses, bandwidth and efficiency comparatively to other design studied in literature survey.

The proposed design is compared with other antennas designed on FR-4 substrate in table 1, in term of size, gain, return losses and bandwidth of achieved bands. It is clear from the table that the proposed design has better return losses, more bands and wide bandwidth as compare to the other designs.

TABLE I
COMPARISON OF PROPOSED ANTENNA WITH LITERATURE

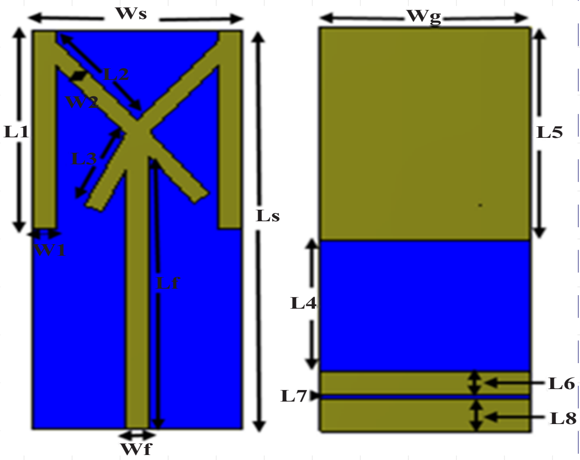
Ref	Size (mm^2)	f_r (GHz)	Return losses (dB)	Gain (dB)	Bandwidth (MHZ)
3	35x31	2.1 2.4	-27.10 -25.21	2.9 3.1	36.20 36.40
14	43.8x18.6	1.4 2.4 3.4 4.6	-12.86 -14.58 -22.69 -15.16	- - - -	15.17 21.40 19.35 13.43
Proposed antenna	43.8x18.6	1.5 2.4 5.0 5.8	-24.12 -15.52 -20.51 -18.77	1.42 1.58 1.74 1.53	155.60 181.13 300.80 238.15

II. ANTENNA DESIGN

To design the proposed M-shape antenna the main radiating patch is etched on top and the ground having two PROSs is etched on bottom of FR-4 substrate with dielectric constant ε_r=4.3 tangent losses of 0.025 and the thickness is 1.6mm. The dimensions of ground and substrate is 43.8x18.6mm^2 (LsxWs). Dimensions of side arms of "M" are L1xW1, middle arms are (L2 xW2) and legs of middle arms are (L3xW2). The M-shape patch is fed by 50Ω micro strip line of dimension LfxWf. Front view and back view of the proposed antenna is given in figure 1(a, b) with dimension's parameters. The prototype of proposed antenna is shown in Fig. 2.

As shown in Fig. 1 (b) two PROSs are adopted in ground to achieve multiband feature. Because of the versatile structure of patch the etched PROSs are also used for impedance matching. The PROSs etched in the ground has proper dimension. The position and dimension of the PROSs has a great impact on results. Furthermore the width and angles of M's arms has a remarkable influence on the antenna operating bands. All these parameters are studied and optimized to get best results.

The trial-and-error technique is typical approach used by many researcher and authors to design antenna. The maintained method is adopted to design and optimized the parameters and dimension of the proposed antenna to achieve the desired bands. Firstly, the PROSs and dimension of the patch elements is optimized to get multiple resonating frequencies and then the angles between the arms of M-shape patch and feed line are adjusted to achieve desired bands. All the optimized parameter are listed in Table II. And the angles are shown in Fig. 3. The two bands, 1.5 GHz (1.436 GHz -1.586 GHz), and 5.8GHz (5.714 GHz-5.951 GHz), are obtained by the middle arms Y-shape patch, 2.4 GHz (2.313 GHz-2.50 GHz) band is achieved by the side arms and 5GHz (4.844 GHz -5.150 GHz) band is results of two extra legs of middle arms of M-shape patch. When the length of M shape and Y shaped radiator increased, the respective bands are shifted toward lower frequencies and similarly when the length of same radiating patches decreased, the bands are moved higher frequencies, which is justified from Fig. 13.



(a) (b)

Fig. 1. Proposed antenna (a) front view (b) back view

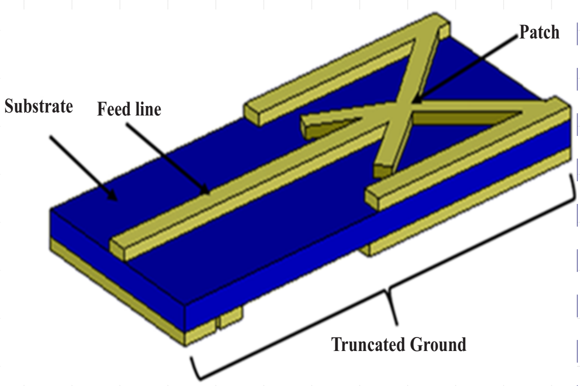


Fig. 2. Prototype of proposed antenna

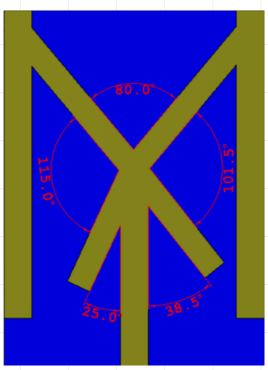


Fig. 3. Angles between arms and feed line of m-shape patch

TABLE II
OPTIMIZED PARAMETERS

Parameter	Valve (mm)	Parameter	Valve (mm)
Ls	43.8	L8	3.6
L1	21.9	Ws	18.6
L2	12.3	W1	2
L3	9.3	W2	1.75
L4	23	Wg	18.6
L5	14.3	Wf	2
L6	2.5	Lf	33.35
L7	0.3		

III. SIMULATION RESULTS AND ANALYSIS

The proposed antenna is designed and simulated in CST microwave studio which is based on Finite Integration Technique (FIT). The performance of the proposed antenna is studied in terms of Return loss, impedance matching bandwidth, and efficiency, gain, and radiation patterns.

A. *Return loss*

As shown in Fig. 4, the designed MPA have for bands for return losses < -10dB. 1.5GHz, 2.4GHz, 5.0GHz and 5.8GHz are the resonance frequencies. The reflection coefficient are -24.12dB, -15.52dB, -20.51dB and -18.77dB respectively

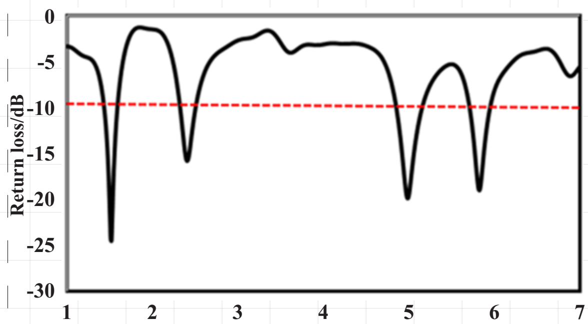


Fig. 4. Return losses of proposed antenna

B. *VSWR*

The voltage standing wave ratio (VSWR) describe impedance matching of transmission line. VSWR graph of the proposed antenna is shown in Fig. 5, the value of VSWR< 2 for all the resonance frequencies. VSWR is 1.1 for 1.5GHz, 1.3 for 2.4GHz, 1.2 for both 5.0GHz and 5.8GHz.

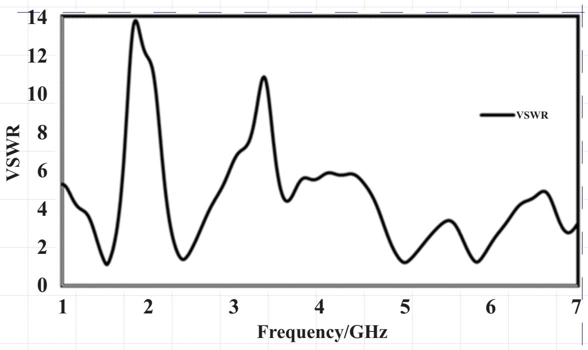


Fig. 5. VSWR of proposed antenna

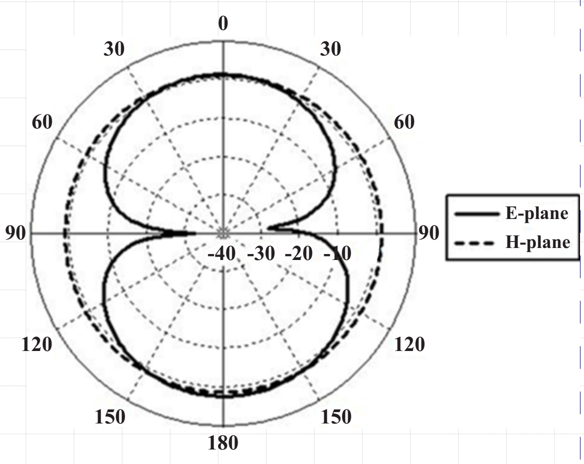
The characteristic parameters, frequencies, return losses, directivity, bandwidth, and efficiency of the proposed multiband MPA are given in Table III.

TABLE III
CHARACTERISTIC PARAMETERS OF PROPOSED ANTENNA

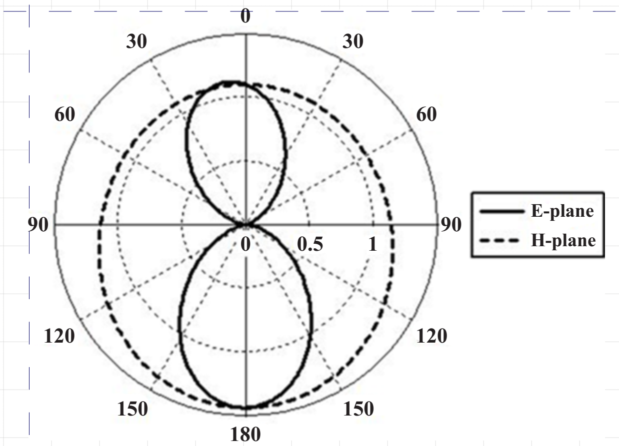
Frequency (GHz)	Return losses (dB)	Directivity	Bandwidth (MHz)	Efficiency (%)
1.5	24.12	2.205	155.60	65.15
2.4	15.52	2.667	181.13	77.63
5.0	20.51	3.891	300.80	60.89
5.8	18.77	4.059	238.15	55.86

IV. GAIN PLOTS

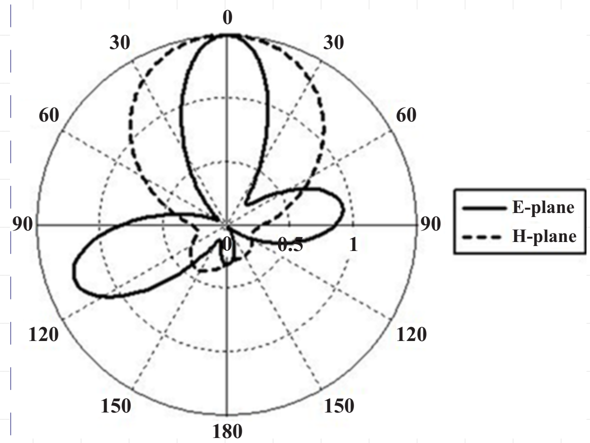
Gain plots for all four bands of proposed antenna are given in Fig. 6(a-d). It is depicted in Fig. 6 (a) and (b) that the suggested MPA behaves like a dipole for 1.5GHz and 2.4GHz and (c) and (d) show that antenna is vertically polarized for 5.0GHz and 5.8GHz.



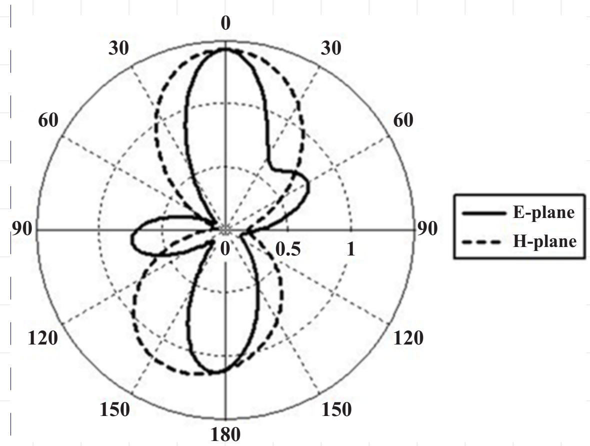
(a)



(b)



(c)



(d)

Fig. 6. Gain polar plots of proposed antenna (a) 1.5 GHz (b) 2.4GHz (c) 5.0 GHz (d) 5.8 Ghz

V. SURFACE CURRENT DISTRIBUTION

The current distribution of proposed antenna is shown in Fig. 7(a-d). At 1.5GHz current is distributed at middle arms and feed line. At 2.4 GHz current is dense

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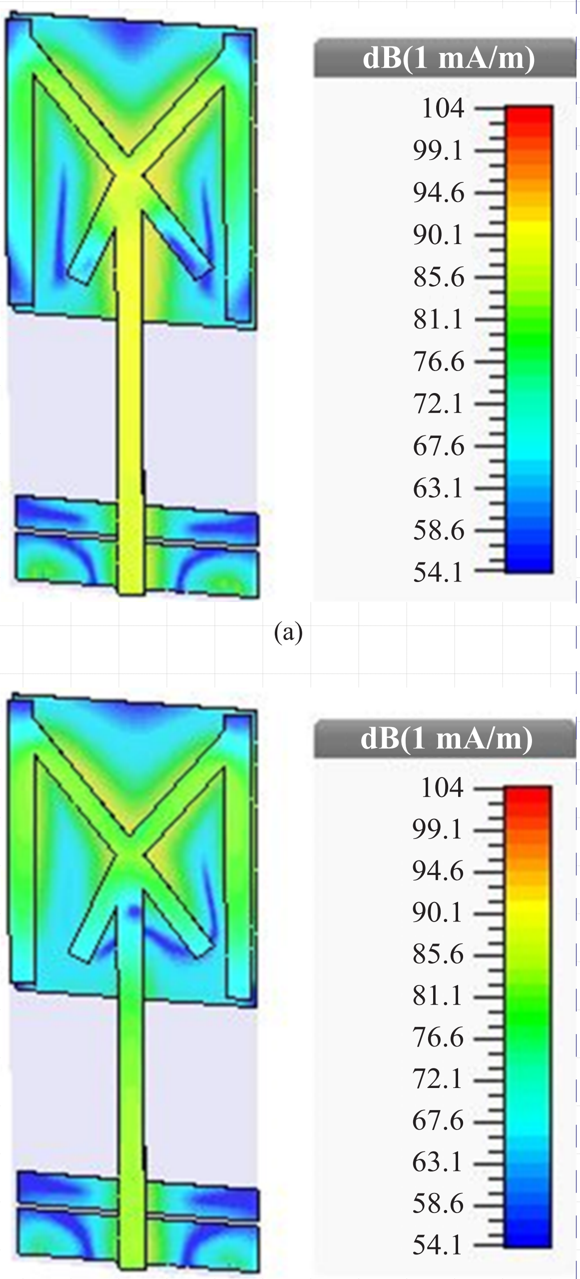
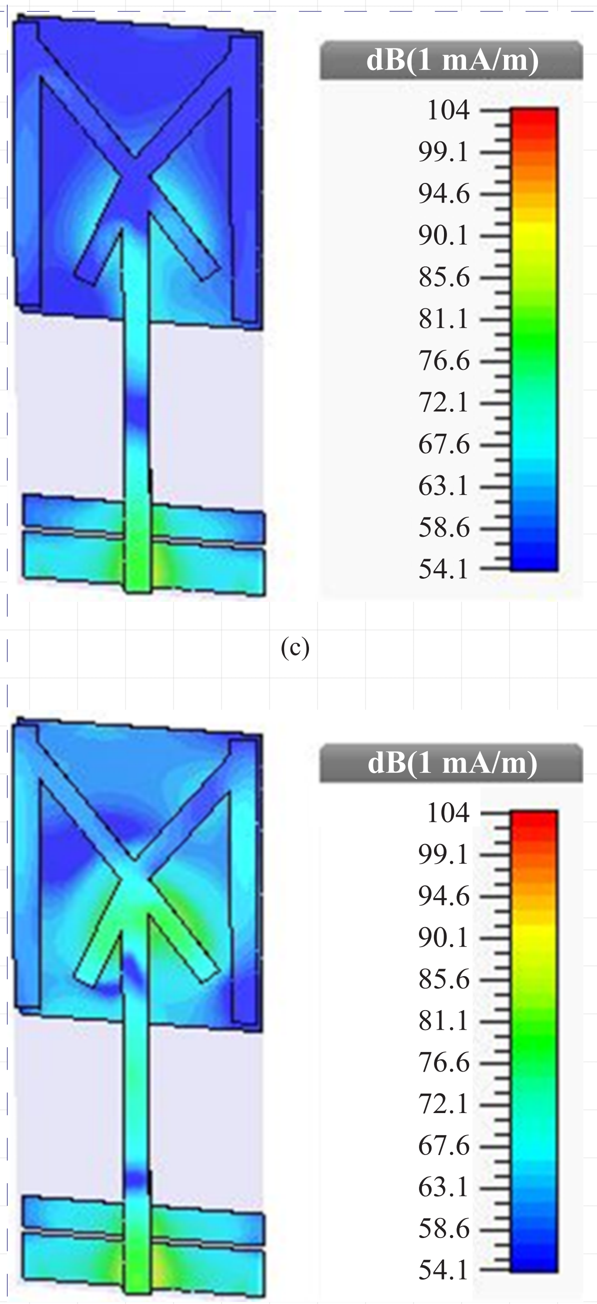
at bottom of feed line, side arms and middle arms. At 5.0 GHz surface current is dense at extreme bottom of feed line. At 5.8 GHz current is dens at bottom of feed line and extra legs of middle arms.

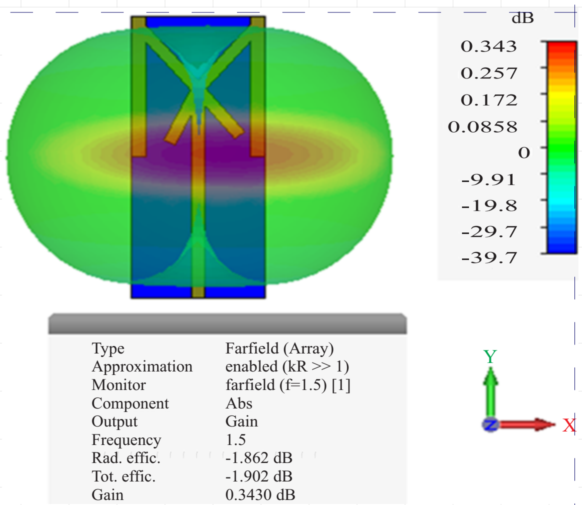


(b)

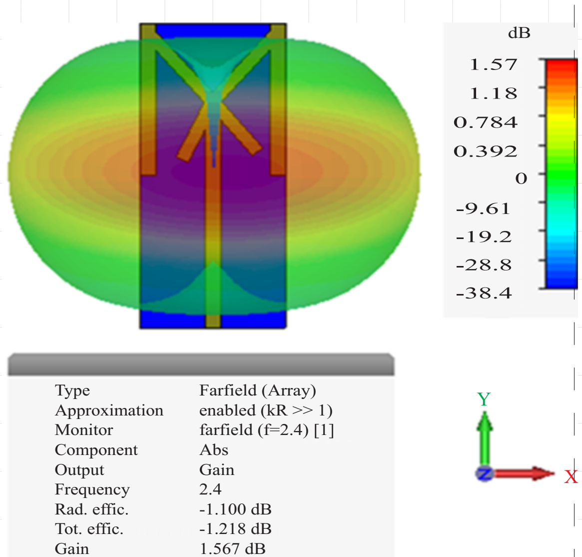


(d)

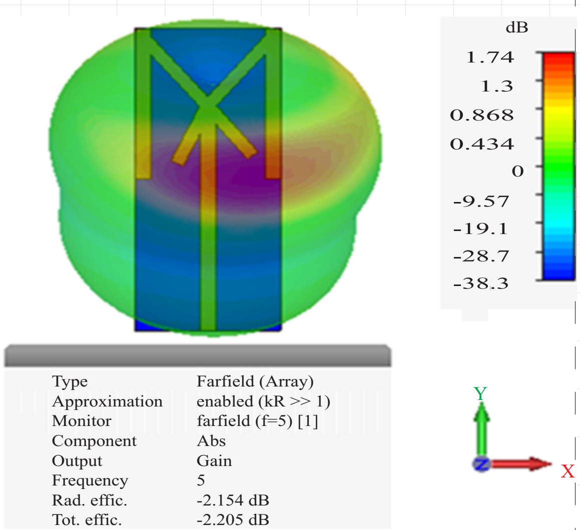
Fig. 7. Current distribution of proposed antenna (a) 1.5 GHz (b) 2.4 GHz (c) 5.0 GHz (d) 5.8 GHz



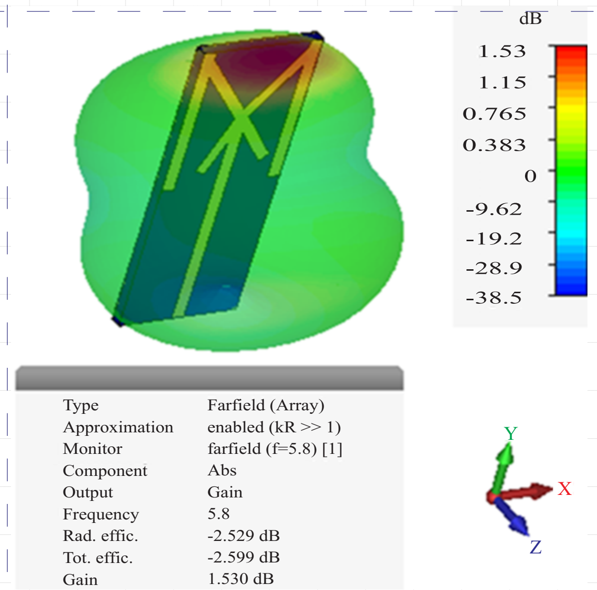
(a)



(b)



(c)



(d)

Fig. 8. 3D gain plots of proposed antenna (a) 1.5 GHz (b) 2.4 GHz (c) 5.0 GHz (d) 5.8 Ghz

VI. Fabrication and Measured Results

The proposed antenna is fabricated and results are measured with the help of network analyzer. Female SMA Connector is used to feed the fabricated antenna. The prototype of fabricated antenna is shown in Fig. 9 and the measured results are given in Fig. 10. VSWR is depicted in Fig. 11. The measured results show that three operating bands have return losses<-10. The operating bands are 1.42GHz, 5.15GHz and 6.16GHz with return losses of -22.98dB, -27.17dB and -37.72dB respectively. At 1.42GHz VSWR is 1.12, at 5.15GHz is 1.09 and at 6.16 is 1.03.

(a) (b)

Fig. 9. Fabricated prototype of proposed antenna (a) front view (b) back view

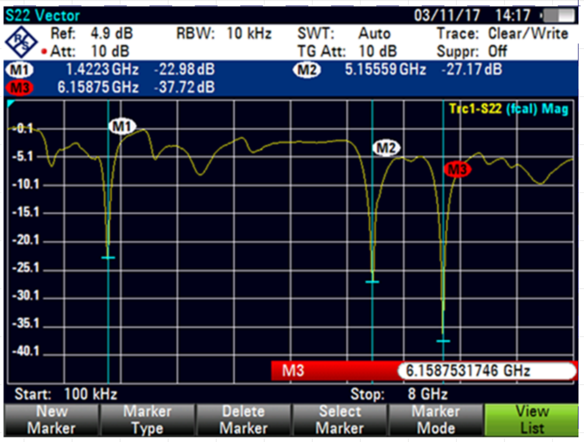


Fig. 10. Measured results of fabricated antenna

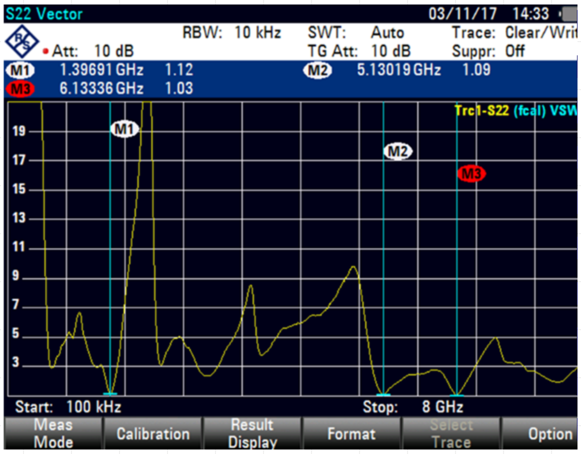


Fig. 11. VSWR of fabricated antenna

VII. Comparison of Simulated and Measured Results

The simulated and measured are compared in term of return losses and VSWR are compared and shown in Fig. 12 and 13 respectively. The measured results shows that the resonance frequencies are slightly shifted toward higher frequencies from simulated results. However the measured results have good return losses, wider bandwidth and VSWR values than simulated results. The compared results are tabulated in Table IV.

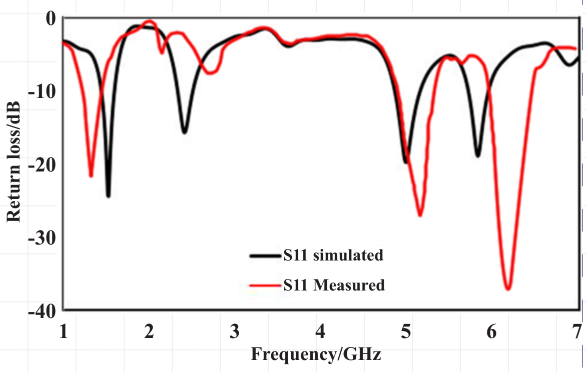


Fig. 12. Simulated and measured results

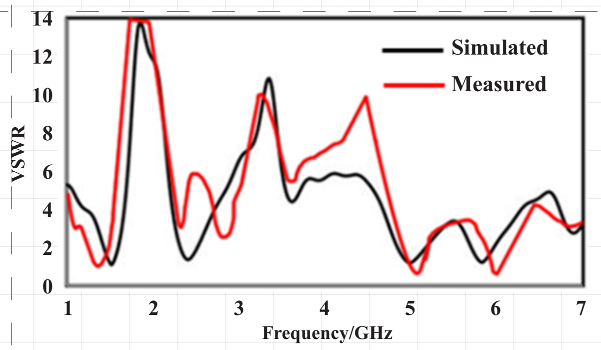


Fig. 13. Simulated and measured VSWR of proposed antenna

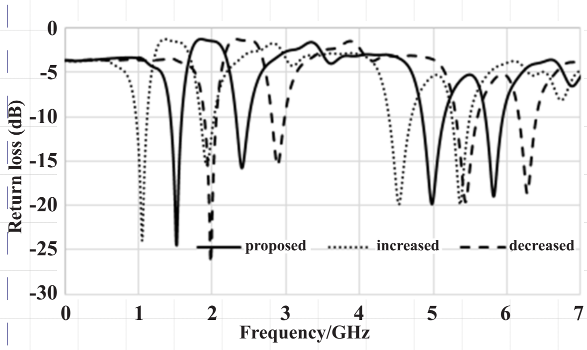


Fig. 14. Simulated return loss of proposed antenna for different values of radiator

TABLE IV
Compression of Simulated and Measured Results of Proposed Antenna

Results	Freq. Ghz	Return loss (dB)	VSWR	Bandwidth (MHz)
Simulated	1.5	-24.12	1.1	155.60
	2.4	-15.52	1.3	181.13
	5.0	-20.51	1.2	300.80
	5.8	-18.77	1.2	238.15
Measured	1.42	-22.98	1.12	180.98
	2.5	-8.650	1.09	170.63
	5.15	-27.17	1.67	324.86
	6.16	-37.72	1.03	260.51

VIII. Conclusion

In this article an M-shape multiband micro-strip patch antenna is presented. The antenna consists of M-shape main radiating patch, defected ground having two PROSs and single micro-strip feed line. To examine the performance in term of return losses, gain, efficiency, and radiation pattern; the proposed antenna is simulated in CST and fabricated as well. The simulated results show that the antenna resonates at four bands (1.436 GHz -1.586 GHz), (2.313 GHz-2.50 GHz), (4.844 GHz -5.150 GHz) and (5.714 GHz-5.951 GHz) with central frequencies 1.5GHz, 2.4GHz, 5.0GHz and 5.8GHz respectively. Simulated and measured results have good resemblance with a slight shift at higher frequency bands. Both the simulated and measured results show that proposed antenna has good return losses, peak gain of 1.57 and stable radiation pattern. The proposed antenna finds application in GPS, WLAN and ISM for wireless communication systems.

REFERENCE

[i] L. K. Fong, and K.F. Tong. "Microstrip patch antennas—basic characteristics and some recent advances." *Proceedings of the IEEE* 100, no. 7 (2012): 2169-2180.

[ii] G. Ramon, P. D. Maagt, and M.Sorolla. "Enhanced patch-antenna performance by suppressing surface waves using photonic-bandgap substrates." *IEEE Transactions on Microwave Theory and Techniques* 47, no. 11 (1999): 2131-2138.

[iii] P. F.Hugo, R. Antoine, and V. D.Capelle. "An impedance-matching technique for increasing the bandwidth of microstrip antennas." *IEEE transactions on antennas and propagation* 37, no. 11 (1989): 1345-1354.

[iv] A. Lamyae, O. Aghzout, H. J. D. Silva, and M. Essaaidi. "Design of Compact Multiband Antenna with Band-Rejection Features for Mobile Broadband Satellite Communications." *Progress In Electromagnetics Research C*68 (2016): 95-106.

[v] L. W. Jun, G. M. Liu, K. F. Tong, and H. B. Zhu. "Dual-band loop-dipole composite unidirectional antenna for broadband wireless communications." *IEEE Transactions on Antennas and Propagation* 62, no. 5 (2014): 2860-2866.

[vi] L. Y. Fang, M. J. Chang, H. M. Chen, and B. Y. Lai. "Gain enhancement of ground radiation antenna for RFID tag mounted on metallic plane." *IEEE Transactions on Antennas and Propagation* 64, no. 4 (2016): 1193-1200.

[vii] J. M. Jayasinghe, J. Anguera, D. N. Uduwawala, and A. Andújar. "High-directivity genetic microstrip patch antenna." *International Journal of Electronics Letters* 4, no. 3 (2016): 279-286.

[viii] A. K. Gangwar, and M. S. Alam. "A SSRR based multiband antenna for mobile phone." In *Communication (NCC), 2016 Twenty Second National Conference on*, pp. 1-4. IEEE, 2016.

[ix] B. Sourabh, S. Saini, V. Prakash, and B.Nautiyal. "Study The Various Feeding Techniques of Microstrip Antenna Using Design and Simulation Using CST Microwave Studio." *International Journal of Emerging Technology and Advanced Engineering* 4, no. 9 (2014).

[x] G. Rangel, R. Ivan , G. H. Valdez, A. Edgar , A. Gonzalez, M. R. Ayala, J. R. M. Tello, and J. Serrano-Chavez. "Relationship among resonant frequencies of Sierpinski multiband fractal antennas." In *ITM Web of Conferences*, vol. 9, p. 03012. EDP Sciences, 2017.

[xi] K. MReza, B. Zakeri, and A. Ebrahimzadeh. "Design and analysis of a multiband Sierpinski type monopole fractal antenna." In *Telecommunications Forum (TELFOR), 2013 21st*, pp. 675-677. IEEE, 2013.

[xii] P. Baliarda, C. J. Romeu, R. Pous, and A.Cardama. "On the behavior of the Sierpinski multiband fractal antenna." *IEEE Transactions on Antennas and propagation* 46, no. 4 (1998): 517-524.

[xiii] B. Y. Ling, Y. F. Qiang, Z. Chen, K. Kang, and L. W. L. Joshua "Low-profile narrow-frame antenna for seven-band WWAN/LTE smartphone applications." *IEEE Antennas and Wireless Propagation Letters* 13 (2014): 463-466.

[xiv] K. Alaknanda, A. K. Gautam, and K.Rambabu. "Design of a compact U-shaped slot triple band antenna for WLAN/WiMAX applications." *AEU-International Journal of Electronics and Communications* 71 (2017): 82-88.

[xv] Y. Ajay, S. Goyal, T. Agrawal, and R. P. Yadav. "Multiband antenna for Bluetooth/ZigBee/Wi-Fi/WiMAX/WLAN/X-band applications: Partial ground with periodic structures and EBG." In *Recent Advances and Innovations in Engineering (ICRAIE), 2016 International Conference on*, pp. 1-5. IEEE, 2016.

[xvi] V. P. Harsha, and N. Koteswaramma. "Patch antenna design with FR-4 Epoxy substrate for multiband wireless communications using CST Microwave studio." In *Electrical, Electronics, and Optimization Techniques (ICEEOT), International Conference on*, pp. 1811-1815. IEEE, 2016.

[xvii] Y. F. Cao, S. W. Cheung, and T. I. Yuk. "A multiband slot antenna for GPS/WiMAX/ WLAN systems." *IEEE Transactions on Antennas and Propagation* 63, no. 3 (2015): 952-958.

[xviii] T. Hazel. "Microstrip Antenna Design with Parallel Rectangular Open Slots Structure for Multiband Operation." (2016).

[xix] A. Tanweer, and R. Biradar. "A compact multiband antenna using λ/4 rectangular stub loaded with metamaterial for IEEE 802.11 N and IEEE 802.16 E." *Microwave and Optical Technology Letters* 59, no. 5 (2017): 1000-1006.

[xx] L. HanJiang, L. RongLin, Y. Pan, X.Quan, Li Yang, and Liang Zheng. "A multi-broadband planar antenna for GSM/UMTS/LTE and

WLAN/WiMAX handsets." *IEEE Transactions on Antennas and Propagation* 62, no. 5 (2014): 2856-2860.

[xxi] L. Gui, M. Fang, R. Zhi, Jin Bai, and Z. Zeng. "Compact CPW-Fed Multiband Antenna for TD-LTE/WLAN/WiMAX Applications." *Progress In Electromagnetics Research Letters* 65 (2017): 9-14.

[xxii] Y. Yuan, W. Chen, X. Chen, and Y. Junsheng. "Analysis and design of a novel multiband antenna for mobile terminals." *International Journal of Antennas and Propagation* 2015 (2015).

[xxiii] C. H. Ran, K. H. Yeap, Ko. C. Lai, P. C. Teh, and H. Nisar. "A compact CPW-fed antenna with fractal S-shaped patches for multiband applications." *Microwave and Optical Technology Letters* 59, no. 3 (2017): 541-546.

[xxiv] S. Pichitpong, C. M. Furse, and Y. C. Chung. "Design of implantable microstrip antenna for communication with medical implants." *IEEE Transactions on Microwave theory and techniques* 52, no. 8 (2004): 1944-1951.

[xxv] M. H. Ramli, M. A. Aziz, M. A. Othman, and A. H. Dahalan. "Design multiband planar printed monopole antenna with Minkowski and Lollipop defected parasitic structure (DPS) for wireless communication system." In *Radioelektronika (RADIOELEKTRONIKA), 2016 26th International Conference*, pp. 475-480. IEEE, 2016.

[xxvi] A. Mohamed, I. M. Rafiqul, S. Yasmin, and K. Badron. "Design of a Quintuple Band Microstrip Patch Antenna Using Multiple L-Slots." In *Computer and Communication Engineering (ICCCE), 2016 International Conference on*, pp. 30-35. IEEE, 2016.

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Performance Analysis of BICM and BICM-ID based Co-operative MIMO Network over different Fading Environment

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Abstract-In cooperative networks, the interference reduction techniques depend upon coordination among cells by setting up relays between multiple inputs multiple output (MIMO) configurations. The energy efficient technique, cooperative MIMO (C-MIMO) is employed in this paper. The bit inter-leaved coded modulation (BICM) and bit inter-leaved coded modulation with iterative decoding (BICM-ID) code are used to get the better performance of the system. The ½ coding rate is used over both fading and additive white Gaussian noise (AWGN) channels. The simulation outcomes show that the cooperative communication scheme outstrips the single input single output (SISO) technique for BICM and BICM-ID. The bit error rate (BER) of the system is examined under various statistical distributions like Nakagami-m, Rician-k and Rayleigh.

Keywords-SISO, MIMO, BICM, BICM-ID, Cooperative MIMO Network

I. INTRODUCTION

The wireless technology has survived as an essential telecommunication mean after its origination in the late 19th century. With the remarkable innovation of cellular phone, this technology has outnumbered the wired technologies in telecommunication field. Telecommunication industry is at the epoch of a new revolution where, high-speed digital signal processing (DSP) being applied to replace most of the analog circuitry used to modulate and demodulate the radio waves [i]. After this excogitation, many distinct, prosperous and adaptive solutions appeared that have improved the efficiency of wireless communication channels by coordinated multipoint (CoMP) transmission. The co-operative communication is exploited to encounter the multi-path fading by co-operating with each other in a wireless communication system. The major requirement for wireless networks is to improve the performance of cell edge and provide the multiple streams to edge users [ii]. The transmission reliability and network capacity can significantly be improved by the co-operative networking. Most of the current work is restricted to simple 3-node relay design and single antenna system. These limitations can be undone by optimal power allocation structure in MIMO cooperative networks (MIMO-CN) [iii - iv]. The primary prerequisites to apply OFDMA networks involve scheduling, spatial filtering and power control [v]. To meet future requirement and reducing past issues, different techniques are used to develop the wireless system such as diversity technique [vi] and to resolve the energy problems in wireless communication systems, the cooperative networks are proposed by many research groups. In MIMO cooperation, many users are associated to form virtual communication antenna array. Multi-hop cooperative MIMO network form a co-operation that uses intermediate node to forward the information from sender to receiver [vii].

The bit inter-leaved coded modulation is a combination of bit inter-leaver, channel encoder, and multilevel modulator [viii]. A turbo decoding process is supplemented by offering a feedback loop to the decoder/ demapper in order to increase the performance of this technique. This amended technique is called bit-interleaved coded modulation with iterative decoding [ix]. This approach improves the time diversity of coded modulation, which provides bandwidth-efficiency for fading channels. The decoding performance of BICM can be enhanced as a result of iterative decoding (ID). The BICM with iterative decoding (BICM-ID) takes advantages of iterative information exchanges between the channel decoder and provides excellent performances over both additive white Gaussian noise (AWGN) and Rayleigh fading channels [x]. The error floor can be minimized by applying doping techniques on BICM [xi]. The system performance can also be significantly enhanced due to code diversity. The path loss based on the co-operative MIMO network can be reduced by employing the conventional convolution based codes and bit interleaved coded modulation with iterative decoding (BICM-ID) [xii]. It will considerably improve the reliability and spectral efficiency of MIMO systems [xiii].

The Multiple Input Multiple Output (MIMO) technology is widely used for different wireless access networks primarily for wireless fidelity (WiFi), long term evolution (LTE) and worldwide interoperability for microwave access (WiMax) [xiv]. MIMO system using spatial multiplexing are increasing the number of b/s/Hz of allocated bandwidth, enhancing the performance through space-time coding and formation of beam forming. The performance analysis of BICM and BICM-ID based co-operative communication MIMO network is considered over Rician-K and Nakagami-m multipath fading environment [xv]. The MIMO techniques involve the large power utilizations and complex signal processing. Moreover, it is hard to achieve the real time carrying out of multiple antennas at a small relay node. To resolve these issues, a solution appears in the form of the cooperative MIMO (C-MIMO) [ii]. C-MIMO is a based on multiple inputs and outputs system through the cooperation of multiple relays nodes with better energy utilization. However, the scope of this paper is aimed to introduce the BICM-ID in MIMO cooperative system. The purpose is to increase the spectral efficiency and reliability of the system.

II. SYSTEM MODEL

The system model mainly comprises of a source terminal, a destination terminal and multiple relay nodes. All terminals are equipped with multiple antennas. The relays are operating in AF mode and MRC signal combining technique is used at the destination terminal.

A. Transmission Protocol

A MIMO system normally uses 'm' numbers of transmitting and 'n' receiving antennas. Every antenna receives only the direct path signal during the transmission over the same channel, but also the indirect path signal from the other antennas. The channel assumed to be narrowband. The direct path from antenna given by h_{11}, while the indirect path from antenna given by h_{21}. The transmission matrix H obtained with the dimension's n x m.

$$Y = HX + N \tag{1}$$

$$\text{Where, } H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \tag{2}$$

$$X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \tag{3}$$

$$N = \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{4}$$

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{5}$$

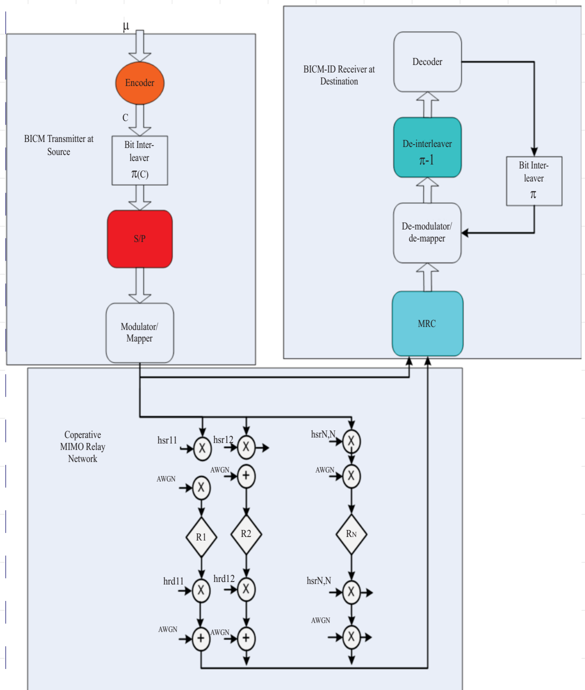

Fig. 1. Schematic diagram of C-MIMO Network

In the wireless channel model *n* numbers of relays nodes are used for cooperation. The transmission protocol used here is two time slot TDMA [v]. In this transmission protocol, the source transmitted signal x_1, x_2 and x_3 in the first time slot to the relay stations R_1 and R_2 respectively. The relay nodes firstly amplified the propagating signal and then forwarded it to the destination terminal. The incoming signals at the relay given by:

$$Y_{sr(i,j)} = h_{sr(i,j)} \sqrt{E_{sr(i,j)}} S_i + n_{sr(i,j)} \tag{6}$$

Where,
i denotes the relay $i =$ 1,2,3,...,N and j denotes the relays's antenna $j =$ 1,2,3,...,N.

In time slot 1, the source *S* propagates the unit signal *S(t)* to destination terminal *D* and to the relays *R* (*i=1,2,....,N*). The scheme used by relays is first amplify the signal and then forward (AF) it to the destination. The best relay will be chosen on the basis of highest SNR for the received signal.

$$y_{SR_{11}} = h_{SR_{11}}\sqrt{E_{SR_{11}}}S_1 + n_{SR_{11}} \quad (7)$$

$$y_{SR_{12}} = h_{SR_{12}}\sqrt{E_{SR_{12}}}S_1 + n_{SR_{12}} \quad (8)$$

$$y_{sd} = h_{sd}\sqrt{E_{sr}}S_2 + n_{sd} \quad (9)$$

$$y_{SR_{21}} = h_{SR_{21}}\sqrt{E_{SR_{21}}}S_3 + n_{SR_{21}} \quad (10)$$

$$y_{SR_{22}} = h_{SR_{22}}\sqrt{E_{SR_{22}}}S_3 + n_{SR_{22}} \quad (11)$$

Where:
h_{sr} = Channel co-efficient between source's' and relay 'r' at time slot 1
E_{sr} = Transmitted energy per bit
S_1 = M-PSK modulated signal-1
S_2 = M-PSK modulated signal-2
n_{sr1} = Gaussian distribution with power spectral density of 'N_0'

At time slot 2, it normalizes and retransmits the received signal to the destination node. The collected signal is elaborated as:

$$y_{r11d} = h_{sr11}\sqrt{E_{sr11}}y_{sr11n} + n_{r11} \quad (12)$$

$$y_{r12d} = h_{sr12}\sqrt{E_{sr12}}y_{sr12n} + n_{r12} \quad (13)$$

$$y_{r21d} = h_{sr21}\sqrt{E_{sr21}}y_{sr21n} + n_{21} \quad (14)$$

$$y_{r22d} = h_{sr22}\sqrt{E_{sr22}}y_{sr22n} + n_{22} \quad (15)$$

The signal is combined at receiver by using maximum ratio by combing (MRC) cooperative diversity.

Where, n_d = AWGN added at destination
A = Amplification factor

$$Y_{MRC} = (E_{sd}|h_{sd}|^2) + \frac{E_r E_{sr11}}{E_{sr11}\|h_{sr11}\|^2++1} \cdot \frac{|h_{sr11}|^2|h_{rd11}|^2}{E_{sr11}+|h_{sr11}|^2+1} + \frac{E_r E_{sr12}}{E_{sr12}|h_{sr12}|^2+1} \cdot \frac{|h_{sr12}|^2|h_{rd12}|^2}{E_{sr12}+|h_{sr12}|^2+1} + \frac{E_r E_{sr21}}{E_{sr21}|h_{sr21}|^2+1} \cdot \frac{|h_{sr21}|^2|h_{rd21}|^2}{E_{sr21}+|h_{sr21}|^2+1} + \frac{E_r E_{sr22}}{E_{sr22}|h_{sr22}|^2+1} \cdot \frac{|h_{sr22}|^2|h_{rd22}|^2}{E_{sr22}+|h_{sr22}|^2+1} \quad (16)$$

In this protocol source S propagates signal $S(t)$ to destination terminal D and relays R at the same time, which is graphically represented in Fig. 2:

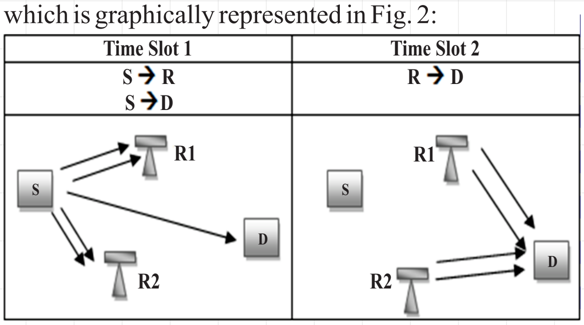

Fig. 2. Conceptual diagram of two-time slot TDMA based protocol.

$$y_{sr} = y_{r_1 r_2} \cdot \frac{g_1^*}{\|g_1\|^2} \quad (17)$$

The signal y_d received at destination from relay 1 in time slot 2 is expressed as:

$$y_d = \frac{\sqrt{E_{r_1}}.h_{sr0}.h_{sr_1}\sqrt{E_{sr_1}}s}{\sqrt{E_{sr_1}\|h_{sr_1}\|^2+1}} + \frac{\sqrt{E_{r_1}}.h_{sr1}.n_{r_1}}{\sqrt{E_{sr_1}\|h_{sr_1}\|^2+1}} + n_d \quad (18)$$

B. Path Loss Model

The main objective is to implement the path loss in the MIMO co-operative networks to show the novelty of the research work. Consider the projection of R_i as a straight line from the source to destination. The entire distance between source terminal T_1 and destination terminal T_2 is normalized to unity ($d=1$). The perpendicular distance between T_1 and R_1 is $d/4$ and the distance between T_1 and projection of R_1 on the horizontal line is d_1. The exact distances from T_1 and T_2 to the R_1 denoted by d_{11} and d_{12} respectively and given by Pythagorean theorem as:

$$d_{11} = \sqrt{{d_1}^2 + (0.25)^2} \quad (19)$$

$$d_{12} = \sqrt{(1-d_1)^2 + (0.25)^2} \quad (20)$$

Similarly symmetry is applicable while computing the exact distance from T_1 and T_2 to R_2.

The faded Signal attenuated by a factor $d_{11}^{-\mu}$ and $d_{12}^{-\mu}$ for the first and second time slot influenced by the path loss effect, respectively. The factor of the transmission medium is denoted by the empirical constant μ also known as path loss exponent. It explained the limits for various types of signal propagation depending upon the radio environment.
μ=2 (Empirical constant for free space).
μ=3 (Empirical constant for urban areas).
μ=5 (Empirical constant for outdoor propagation).

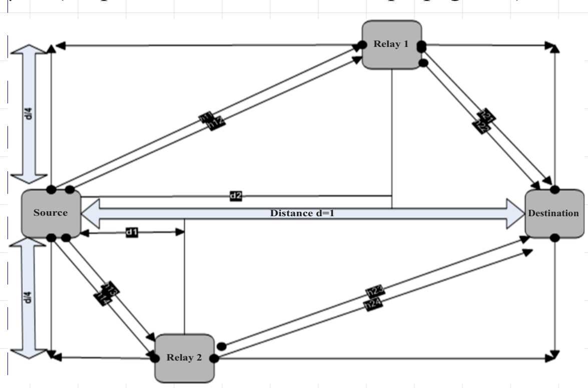

Fig. 3. Path loss Model in MIMO Co-operative Network

For the both terminals T_1, T_2 and the fading distribution of the link to the relay R_i are to be considered as independent and identical distributed (i.i.d) for Nakagami-m and Rician–K fading channels.

The mean channel power is given by $E\{|h_{ij}^2|\} = \Omega_{ij}$ over the path loss model $\Omega_{ij} \alpha\, d_{xy}^{-\mu}$.

Therefore, the performance analysis under path loss effect is considered. Multiple signals which are sent and got naturally mixed in the wireless channel and therefore exploited the multipath phenomena of the wireless channel. Amplification factor (βj) at the relay given below:

$$\beta_j = \sqrt{\frac{E_{rj}}{\Omega_{ij}E_1+\Omega_{2j}E_2+N_0}} \tag{21}$$

Where, E_{rj}= Average transmitted symbol energy at R_i

$E\{|h_{ij}^2|\} = \Omega_{ij}$ (Mean channel power)

$\Omega_{ij} \alpha\, d_{xy}^{-\mu}$ (Path loss model)

The amplification factor (βj) is used in input/output equation model.

III. Simulation Results & Discussions

The BICM, and BICM-ID based co-operative MIMO network over Rician-K fading channels are simulated under Monte Carlo technique. The magnitude of channel coefficients follows K=5, and 10 distributions for uniform phase distribution. Whereas, intermediate nodes (relays) are operating in amplify-and-forward (AF) mode with pre-defined gain value. From figure 4.5, it can be inferred that the cooperative MIMO has better energy conservation ability than SISO transmission. The simulation is taken for code rate r = 1/2.

A. Bit Error Rate

The C-MIMO compared with SISO system by using code rate 1/2. The code word length kept fixed and the number of decoder iteration is taken as 5. The bit error rate (BER) analysis is taken as performance factor in this paper. 8-PSK modulation with AWGN is used over Nakagami-m and Rician-K fading environment for the simulation. The cooperative MIMO gave the low bit error rate at the low value SNR by using 8-PSK, The analysis from Fig. 4 to figure 5. and in Fig. 6 to figure 7 gives lower BER value at lower value of SNR. This analysis shows the system is power efficient system.

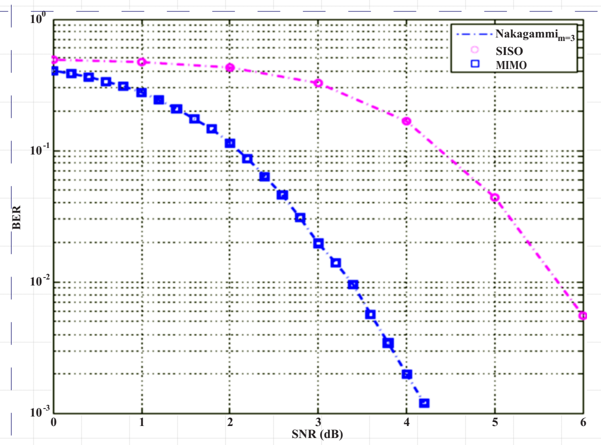

Fig. 4. Performance Comparison of BICM based cooperative MIMO network and SISO over Nakagammi-m channel

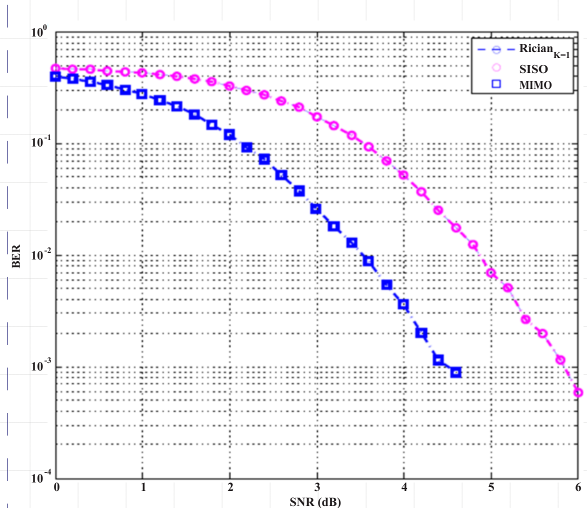

Fig. 5. Performance Comparison of BICM based cooperative MIMO network and SISO over Rician-k channels.

In Fig. 4 and Fig. 5, the comparison of BICM based cooperative MIMO network and SISO system over Nakagammi-m and Rician-k fading channels are analyzed. It can be inferred from the Figures that performance of the system varies by changing the different fading environments. The Nakagami-m fading channel gives the best BER as compare to the Rician-K and Rayleigh Channel. In the start at the 0 dB values are almost same but when we increase the SNR we got better result. In channel wise Nakagami-m fading channel is best among the others, and cooperative MIMO network give better performance as compared to the SISO.

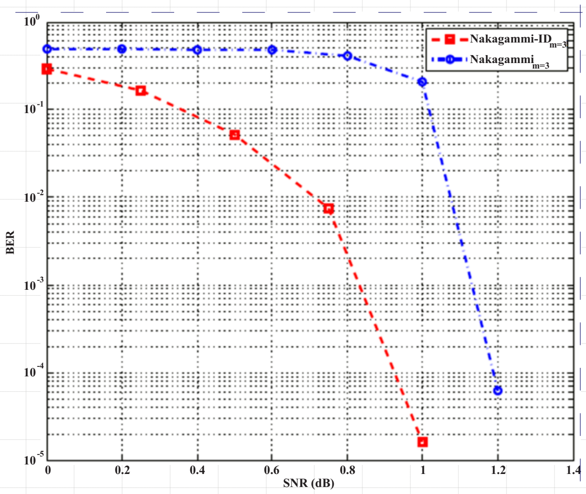

Fig. 6. Performance Comparison of BICM and BICM-ID based cooperative MIMO network over Nakagammi-m channels.

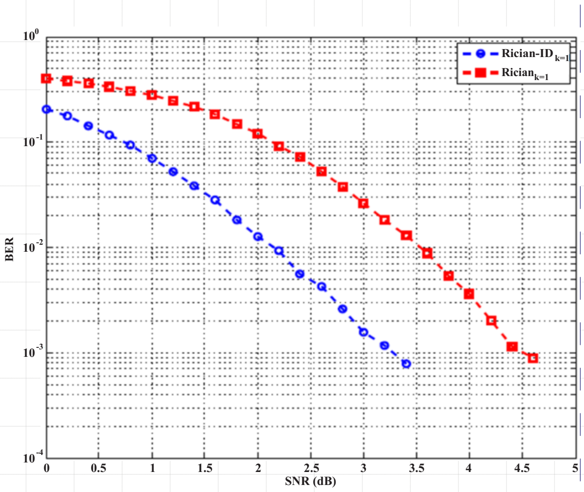

Fig. 7. Performance Comparison of BICM and BICM-ID based cooperative MIMO network over Rician-k channels.

In Fig. 6 and Fig. 7, the performance analysis of BICM and BICM-ID based multiple relay co-operative MIMO network analyzed. The asymptotic bit error rate (BER) bounds of the system using the 8-PSK SP mapped modulations over Nakagami-m, Rician-K and Rayleigh channels are obtained.

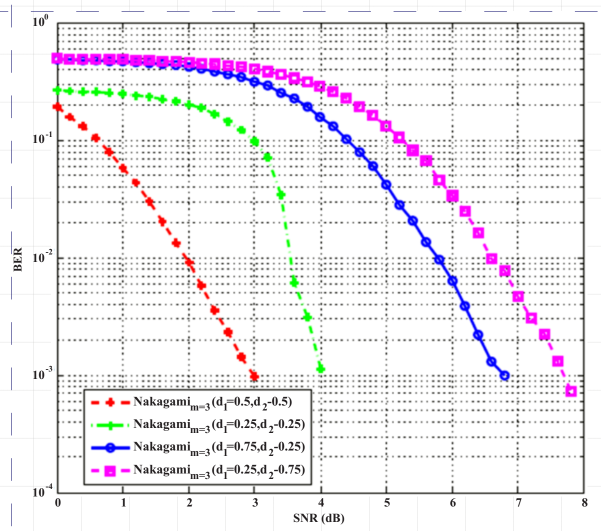

Fig. 8. Performance comparison of BICM based cooperative MIMO network over Nakagammi-k channels.

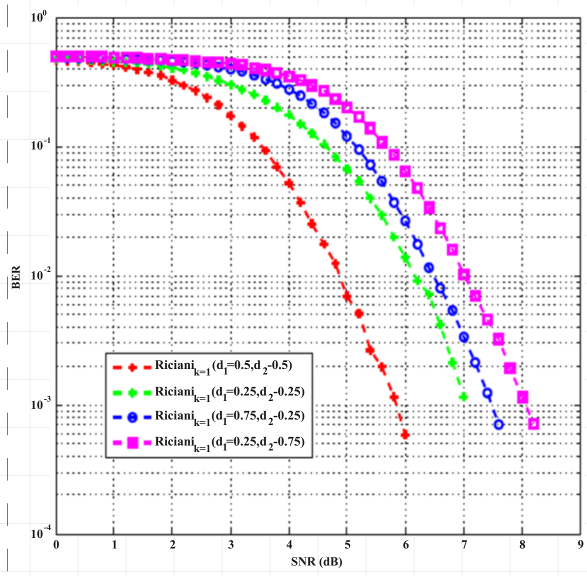

Fig. 9. Performance Comparison of BICM based cooperative MIMO network over Riciani-m channels.

In the analysis of channels with path loss, the proposed relay exactly lied between the source and the destination mean values of the d_1 and d_2 is equal to the 0.5. There are two major ways for placement of relay stations either permanent or any node start working as relay to connect the other portions of network in case of failure of any node. The requirement in such condition is to minimize the number of relay nodes to be deployed.

The proposed relays are moveable and several results are obtained by changing the location of the relays. However, the best result is observed at the center of the source and destination.

This data exchange step carried out during an additional slot exchange to transmit signals from relay to the destination under low power condition. The relays carrying highest SNR are involved in data exchange to reduce the propagation errors. Moreover, distributed transmit beam forming studied to maximize the ratio of coherently combined received signals. The proposed technique has improved outage behavior and data rate than traditional methods at the relay optimal location and for low SNR conditions.

IV. Conclusions

The simulation results have shown that the cooperative communication system outperforms SISO transmission when we applied error correction codes. By BER analysis of the cooperative MIMO system over different fading environment can be deduced that the cooperative communication system proves to be more energy efficient than SISO transmission system. It offers better BER value at the lower value of SNR. Therefore, the range, reliability and data rate can be increased with a very low transmit power and without increasing the number of antennas both at mobile user end and base station. A low cost and less complex system is achieved by this technique. Moreover, it is also concluded that the cooperative MIMO with BICM-ID is an optimal method for high quality signal reception.

References

[i] H. Yan, and H. H. Nguyen, " Distributed Linear Constellation Precoding withBICM/BICM-IDin Two-Way Relaying Communications". IEEE Transactions on Vehicular Technology 66 (1): 481 – 493, 2017.

[ii] B. Azari, O. Simeone, U. Spagnolini, and A. M. Tulino, "Hypergraph-Based Analysis of Clustered Co-Operative Beamforming With Application to Edge Caching". IEEE Wireless Communications Letters 5(1): 84 – 87, 2016.

[iii] L. Jia, N. B. Shroff, and H. D. Sherali, "Optimal Power Allocation in Multi-Relay MIMO Cooperative Networks: Theory and Algorithms", IEEE Journal on Selected Areas in Communications 30(2): 331-340, 2012.

[iv] M. R. Islam, and Y. S. Han, "Cooperative MIMO communication at wireless sensor network: An error correcting code approach". Journal of Sensors Actuator Networks, 11: 9887–9903, 2011.

[v] D. Gesbert, S. Hanly, H. Huang, S. S. Shitz, O. Simeone, and W. Yu, "Multi-Cell MIMO Cooperative Networks: A New Look at Interference". IEEE Journal on Selected Area in Communication, 28(9): 1380 - 1408, 2010.

[vi] S. Tanoli, U. Riaz, R. Abbasi, Q. J. Utmani, M. Usman, I. Khan, and S. Jan, "Hybrid TDMA-FDMA based inter-relay communication in cooperative networks over Nakagami-m fading channel", International Conference on Emerging Technologies : 1-5, 2012.

[vii] S. Anwer, S. A. Niazi, M. I. Imran, and A. Aziz, "Designing Wideband Patch Antenna by fusion of Complementary-Split Ring Resonator, Inter-digital Capacitor and Slot cutting Technique". Technical Journal, University of Engineering and Technology of Taxila, 21(4): 71-77, 2016.

[viii] Z. Sun, L. Chen, X. Yuan, and Y. Yakufu, " Design andAnalysisofBICM-IDfor Two-Way Relay Channels with Physical-LayerNetworkCoding". IEEE Transactions on Vehicular Technology 66(11): 10170 – 10182, 2017.

[ix] E. Zehavi, "8-PSK trellis codes for a Rayleigh channel," IEEE Transactions on Communications 40(5): 873–884, 1992.

[x] S. Brink, J. Speidel, and R. Yan, "Iterative de-mapping and decoding for multilevel modulation," In Proc. GLOBECOM: 579–584, 1998.

[xi] X. Li, A. Chindapol, and J. A. Ritcey, "Bit-interleaved coded modulation with iterative decoding and 8 PSK signaling", IEEE Transactions on Communications 50(8): 1250–1257 ,2002.

[xii] S. P. fletschinger, and F. Sanzi, "Error floor removal for bit-interleaved coded modulation with iterative detection". IEEE Transactions on Wireless Communication 5(11): 3174–3181, 2006.

[xiii] C. A. Rjeily, "Performance Analysis of FSO Communications with Diversity Methods: Add More Relays or More Apertures". IEEE Journal on Selected Areas in Communications 33(9): 1890 – 1902, 2015.

[xiv] C. S. Vaze, and M. K. Varanasi, " The Degrees of Freedom of MIMO Networks With Full-Duplex Receiver Cooperation but no CSIT". IEEE Transactions on Information Theory 60(9): 5587 – 5596, 2014.

[xv] S. N. Sur, and D. Ghosh, "Channel Capacity and BER Performance Analysis of MIMO System with Linear Receiver in Nakagami Channel". International Journal of Wireless and Microwave Technologies 1:26-36, 2013.

Section C

MECHANICAL, INDUSTRIAL, MATERIAL, ENERGY ENGINEERING, AND ENGINEERING MANAGEMENT

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Research Progress in Tidal Energy Technology-A Review

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Abstract-Tidal current energy is one of the most attractive renewable energy concepts due to its significant global potential and resources that are spread across the globe. Most of the countries have access to tidal energy resources available within their geographic boundaries. The tidal energy resource is predictable unlike some of the other renewable energy resources and hence is attracting significant research focus. Substantial research growth has taken place in the tidal energy technology over the past decade. This paper provides a review of the research progress leading to the development of tidal energy technology and explains the concepts and terminologies related to the subject area to provide a ready reference to the researchers. This work identifies new dimensions of the reviewed literature and also provides direction for future research with focus on areas, such as: performance prediction, structural loads, wake and tidal turbine arrays.

Keywords-Tidal Current Turbine, Marine Renewable Energy, Performance Predication of Tidal Turbines, Structural Loads in Tidal Turbines, Tidal Turbine Wake, Tidal Turbine Arrays.

I. INTRODUCTION

The society is faced with the issue of energy crisis and climate change and these two are susceptible to each other as the traditional fossil fuel energy production affects the climate while the later affects renewable energy like wind [i] and solar. The global energy consumption was 546 EJ in 2010 and is expected to grow by at least 27 percent till 2050 [ii]. The ever growing energy demand and the risks of carbon emissions associated with the traditional methods of burning fossil fuels are stressing the need for exploring alternate energy sources.

Renewable Energy Technologies are quickly maturing and in 2012 more than half of the new addition to global electrical power generation came from the renewable energy sector [iii]. The hydro, wind and solar energy sectors are witnessing a substantial growth. New concepts of Renewable Energy are also coming into the picture and extensive academic and industrial research is being conducted for the development of related technologies. It is expected that Renewable Energy will be able to replace fossil fuels in the near future. Tidal current energy is one such concept that is attracting a lot of interest from the developers and researchers all over the world. It is a form of hydrokinetic energy extracted from the water flow in the tidal channels. Such flow takes place due to the relative motion of the gravitational fields of the moon, sun and earth [iv] as depicted in Fig. 1.

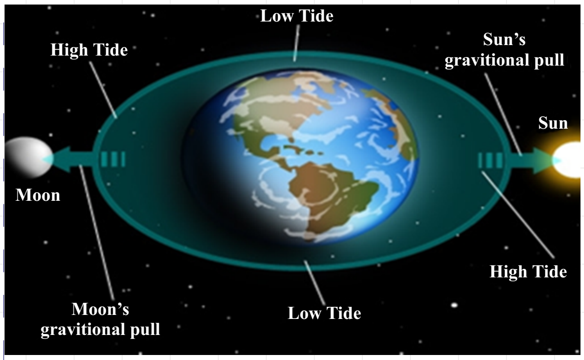

Fig. 1. Relative motion of the gravitational fields of the moon, sun and earth [v].

Normally the velocity of flow in tidal channels is very slow but in areas constrained with in the head lands and sea bed topography, narrow passages like creeks and estuaries, the currents are accelerated to higher velocities. Tidal current flow with velocities of 1.5-2 m/s are generally considered suitable for economic power production [vi, vii]. Efforts are being made to estimate the global tidal energy potential and several estimates are available in the current literature. One such estimate sets the value of global tidal energy potential to be in the range of 100-17500 TWh/yr [viii]. Other estimates show the figures of 8800 TWh/yr [ix] and 500-1000 TWh/yr [x]. Although these estimates are quite different from each other however, the potential can be safely assumed to be significantly greater than 100 TWh/yr [iv].

Tidal current turbine systems are generally classified as shown in Fig. 2. Some of the relative advantages and disadvantages of the horizontal axis tidal current turbines (TCT) are as in table 1.The tidal current energy has successfully advanced beyond the initial testing phase. Fig. 3 shows the technology readiness level (TRL) of tidal current energy. The full scale array demonstration projects are expected to be installed in 2016-17 [viii].

The initial research phase was focused on the resource characterization and site level resource assessments [xi-xxi] and development of prototypes or scaled models [xxii-xxxi]. As a result, forty new devices were introduced from 2006-2013 [vi] and the knowledge base of the technology was extended. The research focus then shifted to the development of commercial prototypes for real sea testing [iv, viii, xxxii]. Comprehensive information about the

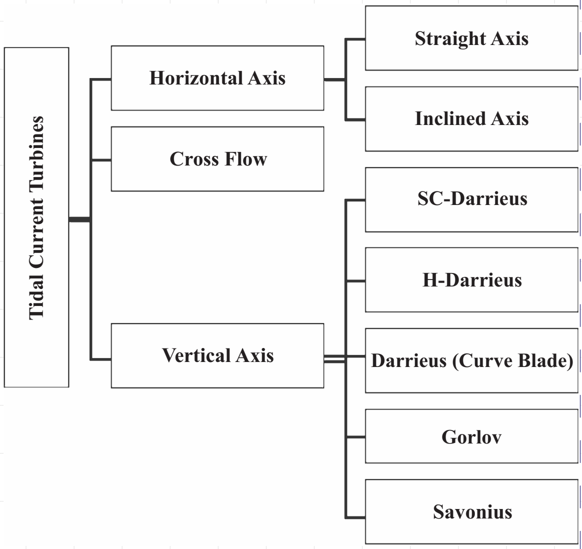

Fig. 2. Classification of Tidal Current Turbine Systems.

facilities for conducting real sea tests are available in [xxxiii]. These testing facilities are well established and the devices are now being tested in real sea conditions [xxxiv]. The results of most of these tests are encouraging with some exceptions. Some of the devices are successfully transmitting power to the grid as well [xxxv, xxxvi].

TABLE I
RELATIVE ADVANTAGES AND DISADVANTAGES OF TCT

Type	Advantages	Disadvantages
Horizontal Axis TCT	✓Rich knowledge base ✓Self-starting ✓Speed control ✓Annular ring duct augmentation ✓Large Capacity designs ✓Better Efficiency ✓Resistance to cavitation	×Complicated design ×Complicated blade manufacturing ×Under water placement of moisture sensitive parts ×Under water placement of power supply cable
Vertical Axis TCT	✓Simple design ✓Simple blade manufacturing ✓Moisture sensitive parts can be placed above water surface ✓Floating structures and ducts installation ✓Skewed flow	×Lower efficiency ×Poor self-starting ×Require additional starting mechanism ×Cavitation

This paper provides a review of the main research work that resulted in the current developments in the tidal energy technology. The review of the research progress will provide the direction for future research and identify new dimensions of the reviewed literature. Important concepts related to the subject have been explained to provide a reference to the researchers in this area. The paper is organized into five sections with section II giving the brief

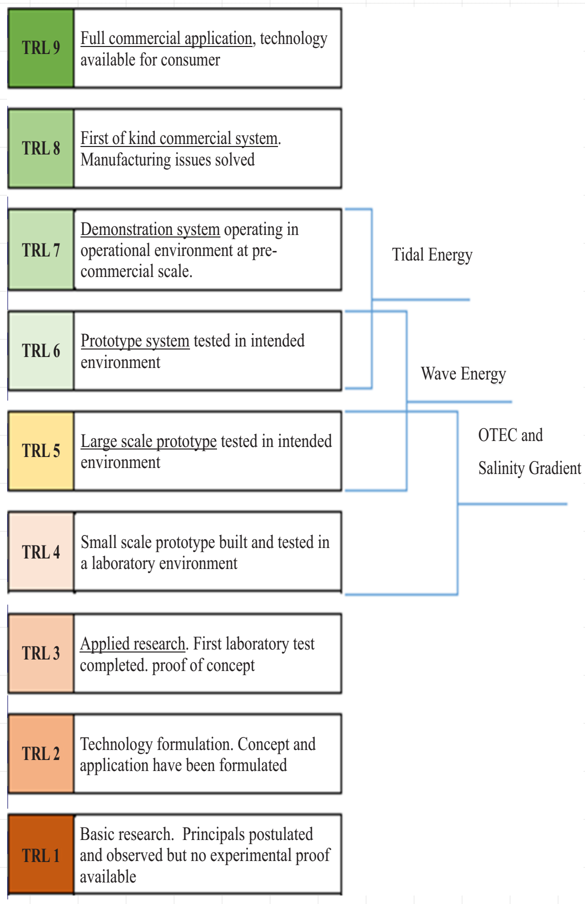

Fig. 3. TRL of ocean energy technologies [xxxvii]

historical background. Section III gives the performance prediction of the tidal current turbines followed by their structural load review in section IV. Section V gives wake of marine current turbine with the review of research carried out when the turbines are arranged in arrays in section VI. Finally the future research possibilities are given in section VII with concluding remarks in section VIII.

II. Historical Background

History reveals that the tide/water mills existed in the 7th century. Al-Muqadassi, a famous Arab geographer, described the tide mills operating in Iraq (Basra) in the 10th century [xxxviii]. Ocean energy, particularly the tidal energy, for the production of electricity was first suggested by Romanoski in 1950 [xxxix]. However, literature pertinent to the concept of energy from the ocean currents exist well before him. Generation of electricity from the Ocean currents is being investigated for the last forty years [xl]. The first major tidal barrage for the extraction of tidal energy, was the La Rance tidal power station established in France on November 26, 1966 [xli]. Although a functional tidal power station was available at the Boston Harbor in Massachusetts, USA in the latter part of the 19^{th} century, while another was operating in Husum, Germany that was dismantled in 1914 and another in China in 1958 [xxxviii]. The interest in research on generation of tidal electrical energy was also affected by the availability of fuel as the 1973 oil crisis provided the basis for increased interest in the Renewable Energy While on the other hand, the falling oil prices in 1980s caused a decline in the official support for developing Renewable Energy. In the mid-1990s, once again interest in the large scale deployment of Renewable Energy increased due to the perceived threat of global warming highlighted by the Koyoto Process [iv]. The world's first, 10 kW scaled model, tidal current turbine was tested on Loch Linnhe, a Scottish sea-loch, during 1994-95 by IT power UK [xl]. In 1998, the company initiated the world's first tidal current energy system called Seaflow. This 300 kW tidal turbine was installed in North Devon in May 2003[xlii]. Based on the concept of SeaFlow, Marine Current Turbine (MCT) installed a twin rotor steel mono pile mounted 1.2 MW commercial proto type turbine called SeaGen in July 2008[xl] that is still successfully providing power to the grid. The installation and successful operation of Seaflow in open sea proved to be the turning point for the present day development of tidal current technology.

III. Performance Prediction of Tidal Current Turbines

The design and performance prediction of Tidal Current Turbines (TCT) remained the focus of research during the initial research phase of its development. This research resulted in the development of performance prediction methods that enabled the description of physical and operational performance of the tidal turbines. The development of such methods helped a lot in the design, optimization and performance evaluation. The base for the research was provided by wind turbines. Batten et.al [xxii] developed a numerical model for the performance prediction of a TCT and span wise distribution of blade loads. Their model was based upon the well-known Blade Element Momentum (BEM) theory. BEM is based upon the combination of General Momentum and Blade Element theory [xliii]. The momentum theory is used for the calculation of axial and tangential induction factors while taking into account the tip losses. The Blade element theory divides the blade into a number of sections to calculate the torque and drag at each section. The integration of these sectional drag and torque gives the values of total blade torque and drag. This numerical model was successfully validated through experimental test in a cavitation tunnel and towing tank [xliv]. The experimental work suggested that the developed tool can provide satisfactory accuracy for design exercises and parametric studies. In BEM method the blade is discretized as shown in Fig. 4a. The blade parameters at different stations at a radius, r, are evaluated. Fig. 4b shows a single blade element taken from the blade at a radius, r. The blade properties determined at each blade section along the blade length are averaged. Every blade element experiences fluid forces as shown in Fig. 4c.

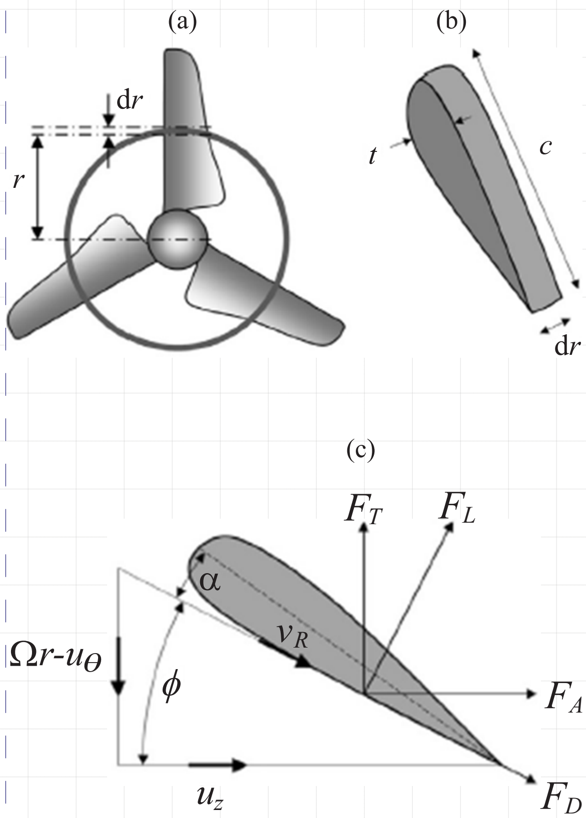

Fig. 4. [a]: Schematic diagram of the discretization of the rotor; [b]: cross-section of the blade; [c]: resolution of the lift and drag forces [xlv].

Xiao Zhang et.al [xlvi] performed the performance estimation of a dual rotor contra rotating turbine using computational fluid dynamics (CFD). CFD derives its basics from the fact that the physics of any fluid flow is described by three fundamental principles. These principals are the conservation of mass, momentum and energy. These fundamental principles, in their most general from, are expressed either in the form of integral or partial differential equations. CFD is the art for converting these integral or partial differential equations, governing the fluid flow, into its discretized algebraic form that can be solved numerically [xlvii]. These flow governing equations are called Navier Stokes equation. CFD utilizes various numerical schemes for the solution of Navier Stokes Equation to provide detail information of the fluid flow. The information about the fluid flow is translated into performance parameters of the TCT in different flow condition. The performance data includes thrust, torque and power estimates. CFD model maps the pressure distribution on the blade surface that enables the prediction of cavitation. The numerical model in [xlvi] was based upon the Incompressible Steady State Navier Stokes Equation. They used a computational CFD software package. The results of the study were not supported and validated through experimental work. Chul hee Jo et.al [xlviii, xlix] also used the Navier Stokes Equation model for the performance predication of an experimental model turbine. They used a finite volume solver of the commercial CFD software package ANSYS CFX. They predicted the optimum tip speed ratio and power co-efficient for their turbine in different flow velocities. The comparison between the numerical and experimental results has not been provided in the article. Patrick Mark Singh and Young-Do Choi [l] worked on the development of a hydrofoil and blade design having small chord lengths for the actual current data at the south-western region of Korea. They developed a new hydrofoil for working in rough conditions and studied the performance of rotors based on three different blade designs using CFD. The optimum TSR and power co-efficient was worked out. In order to compare the structural integrity of these blades against static loads, fluid structure Interaction (FSI) analysis were also carried out. For FSI analysis, the pressure mapped on the blade surface for performance analysis was coupled with a structural analysis system to perform the structural analysis. Chul-hee Jo et. al [li] conducted the performance analysis through FSI modeling of a tidal current turbine with pre-deformed blade. A pre-deformed blade is made with a built-in bend towards the current before the application of hydrodynamic loads. Once the flow exerts pressure, the blade regains it's unbend shape due to deformation. As such the deformation that was supposed to produce a power loss will be negated to create any power loss. The study compared the performance of two turbines having the same specification except that one was having the pre deformed blades. The power loss due to deformation of the blades was consequently estimated. The study used CFD analysis to model the fluid flow on the turbine blades and FSI analysis were performed to calculate the deformation of the blades.

The literature review presented above points out different approaches for the prediction of TCT performance. These approaches are not competing approaches but in fact they all have their own role in the research and development of TCT. The BEM approach is used in the preliminary design stage for the design and optimization of the hydrodynamic parameters of the TCT blade. The CFD approach is used later in the design stage for more detailed analysis and to reduce the load of experimental work. The experimental model is prepared after the implementation of first two approaches to get an optimized design for the preparation of a lab scale model. All these approaches have their own advantages and limitations. The BEM approach is quite easy to use and its computational cost is very low. But its limitations are that it cannot account for chord wise loading, variation in free stream flow and influence of rotor on the surrounding flow etc.[xliii, xlv]. Although, the addition of correction factors accounting for three-dimensional (3D) effects such as tip loss, rotational flow and dynamic stall to the originally proposed BEM method have improved the BEM predictions [lii, liii]. The 3D inviscid methods like lifting line, panel and vortex lattice methods [liv-lvi] can model the physics of the turbine hydrodynamics in more details as compared to the BEM method. But these models do not account for the viscous effects that are essential for the accurate prediction of turbine performance. In CFD simulations models the fluid flows using the first principal or laws of conservation and therefor, captures the viscous effects. CFD modeling accounts for the limitation of BEM and inviscid models but it is computationally expensive and have issues with turbulence modeling. The experimental approach have the scaling issues as well as the increased revolutions per minute of the scaled model produces swirl and pressure gradient that is not available in the real condition [lvii]. The research work conducted, related to performance, so far is invaluable and making ways for the future research. The coupling of the BEM and CFD numerical approach is currently being investigated for predicting the array performance [xlv, lviii].

IV. Structural Loads on Tidal Current Turbine

The wind and ocean current turbines have much in common but there are certain key differences. One of the differences is in the amount of structural loads and the sources as well as behavior of certain loads. Water being a denser fluid exerts more pressure on the turbine as compared to wind. As for as wind turbines are concerned, it is quite clear that TCT's will be subjected to a complex load regime. It is important to consider the effects of structural loads faced by various components of a TCT to ensure its reliable and safe design and operation. The most critical part of TCT subjected to structural loads is the turbine blade. Optimized design of blades is of utmost importance as its failures has been witnessed in some of the prototype test of TCT [lx]. Rotor of a TCT converts the kinetic energy of the flow into mechanical work governed by law of conservation of momentum. The exchange of momentum mainly takes place in the flow direction. Whereas, the power is produced in the rotor plane perpendicular to the stream direction. Lift and drag forces are caused by the fluid flow passing the turbine blade as shown in Fig. 5.The drag force is parallel, whereas the lift force is perpendicular to the resultant or relative flow velocity. The drag and lift force can be resolved into the axial force or thrust and tangential force or torque [lxi].

For a Horizontal Axis TCT, operating perpendicular to the flow, the thrust force acts in the direction of flow and induce bending movements. The torque acts around the rotor shaft and causes rotation. The possibility of failure due to constant thrust loads imposed by the flow can be easily eliminated, if properly accounted for in the design. Cyclic and stochastic loads caused by turbulence are

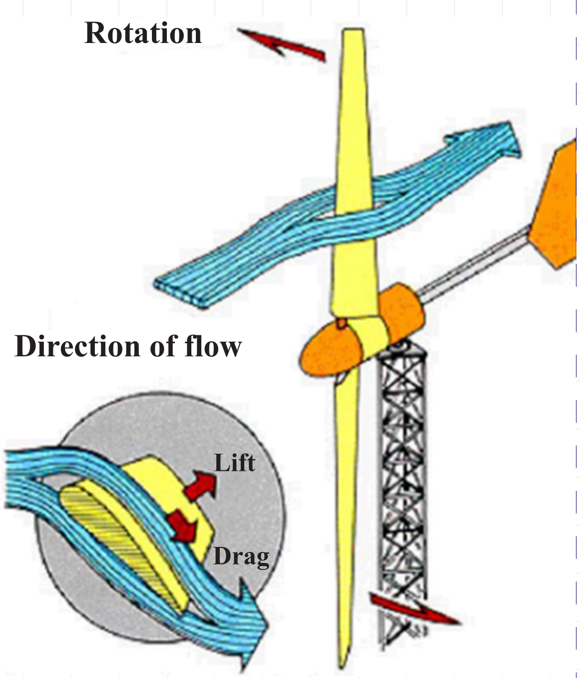

Fig. 5. Lift and Drag forces on TCT rotor [lix]

expected to cause most of the structural failure mainly due to fatigue. Turbulence, wave current interaction and some other situation specific phenomena like tower wake interaction or wake interaction with upstream turbines along with rotation of the turbine blades, randomness of ocean current, variation of current velocity with depths also called velocity shear are the sources of repeated cyclic loads on the TCT [lxii].

Numerous studies have been conducted during the last decade for static and dynamic analysis of TCT. Gunjit Bir et.al [lx] of the National Renewable Energy Laboratory performed the hydrodynamic and structural design of a composite TCT blade. The authors based their structural design on static structural loads and identified two extreme operating flow conditions and modeled them using CFD to compute the extreme loads. Simulation was carried out by taking the blade external geometry and the design load distribution as inputs to calculate the optimal design thickness of load-bearing composite laminates at each blade section using ultimate-strength and buckling-resistance criteria. The results also provided the optimum location for the webs. The dynamic loads, fatigue and stiffness criteria was not considered in this research work. Pascal W. Galloway et.al [lxiii] performed the experimental and numerical investigation of rotor power and thrust of a tidal turbine operating at yaw and in waves. A wave towing tank experiment and BEM code, including the effect of wave and yaw, was used for the investigation to understand the loading on the turbine rotor and blades. Results of the numerical investigation were in good agreement with the experimental results. Results of the study revealed that the wave current interaction will cause cyclic loading in a TCT that will cause an accelerated fatigue to the rotor and blade. The results also showed that a yaw drive is necessary to avoid the increased dynamic loading and power loss in a TCT. N Barltrop et.al [lxiv]also worked on the effect of wave current interaction on a TCT. In this study towing tank experiments and an extended BEM numerical model that included the wave effect was used. The numerical and experimental results were in good agreement. The study suggested that at lower current speeds the effect of wave will increase the torque and the thrust will not be affected. The change in wave height for longer waves will greatly affect the torque. At constant tip speeds the shorter waves may force a stall that will cause a sudden reduction in torque and increase in the thrust force. G. N. McCann [lxv] performed a parametric study on the sensitivity of fatigue loading experienced by a tidal current turbine due to the wave action and Turbulence caused by the sea-bed roughness and temperature effects etc. The study concluded that the fatigue load varies with mean flow turbulence and is very sensitive to the wave current interaction. The fatigue load due to flow turbulence and wave action may be duly considered in the design of TCT. Céline Faudot et.al [lxvi] used a quasi-state BEM theory combined with added mass force to numerically model the effect of waves on fatigue loads and life time of a TCT blade. The numerical model was also tested through tow tank experiments on a model TCT. Deviation between experimental and numerical results was observed. The study concluded that the consideration of extreme loads due to high and steep waves is necessary for the reliable design of TCT blade. The dynamic effects like dynamic stall and wake are important consideration for the estimation of loads in steep waves. The implementation of added blade mass is significant for elastic blade with the combination of hydro elastic model of the blade. Milne et.al [lxvii] investigated the blade root bending moment of TCT for oscillatory motion in a tow tank. The objective of the study was to analyze the role of unsteady hydrodynamic forces on the blade loads for their accurate prediction. It was established that unsteady bending moment is sensitive to oscillatory frequency and amplitude. The flow separation and dynamic stall caused unsteady loads are of higher magnitudes and cannot be predicted through quasi-steady state models. The prediction of such loads will require models accounting for unsteady flow and dynamic stall. Mohammad Wasim Akram [lxviii] computed the fatigue life of a composite TCT blade under the influence of random ocean currents due to turbulence and velocity shear. The Rain flow counting algorithm was used to count the number of cycles of loads within a specific mean and amplitude acting on the blade from random current data. The commercial Finite Element Code ANSYS was used to develop S-N diagram. Fatigue damage expected in thirty years of operation was estimated using Palmgren-Miner's linear hypothesis. In the analysis, fatigue loads due to velocity shear were considered. The contribution of fatigue loads due to velocity shear is quite low. On the other hand the fatigue loads due to wake was not considered. Fang Zhou et. al [lxii] in 2012 repeated the work using NREL dedicated codes due to their robustness as compared to ANSYS. The results showed that the designed blade have a fatigue life of more than twenty years. The study suggested that instead of using an NREL code CFD may be used for the calculation of loads for the computation of fatigue life. Junior Senat [lxix] used a combination of BEM and linear wave theory for the prediction of torque, thrust and blade root bending moments caused by wave current interaction. The study showed that in longer waves the torque is sensitive to the variation of wave height. The fluctuation in the in plane and out of plane bending movements is significant and can be predicted by linear wave theory combined with BEM theory. BEM theory with tip loss correction and 3D effects can analyze the power and thrust coefficient. Fang Zhou [lxx] developed a computational tool by integrating NREL odes, Sandia National Laboratories code NuMAD and ANSYS for the analysis of TCT. The aim of the study was to consider randomness of ocean currents, rotation of the blade and hurricane driven currents in the design, analysis and fatigue life prediction of composite TCT blade. In this study the dynamic response was computed by modifying the NREL codes AeroDyn and FAST. The tangential and normal forces were applied to ANSYS model to perform the static and buckling analysis for the identification of high stress regions. Useful life at various stress levels and ratios was calculated through Goodman diagram. Velocity time histogram of the experimental data was used to calculate the actual number of cycles. This enabled the calculation of damage and fatigue life of the blade was predicted using Palmgren-Miner's rule for cumulative fatigue.

V. Wake of Marine Current Turbines

Wake is the region of disturbed flow downstream of a solid body moving through a fluid or vice versa. A hydrokinetic turbine extracts momentum from the flow while the mass is conserved. The momentum loss downstream of the device creates a pressure jump and consequently an axial pressure gradient, an expansion of the wake and a decrease of the axial velocity. The wake is therefore characterized by a decrease in mean flow speed also called velocity/wake deficit and increased turbulence. Wake is a complicated and device specific phenomenon. The wake as shown in Fig.6is generally divided into near and far wake region to simplify the physics governing the wake structure [lxxi].

A strict distinction of near and far wake in terms of downstream distance may not be possible. In the wind turbine the near wake is from 1-2 rotor diameters downstream [lxxi], whereas for the TCT it is considered to be from 0-3/4 rotor diameter downstream [lxxii].

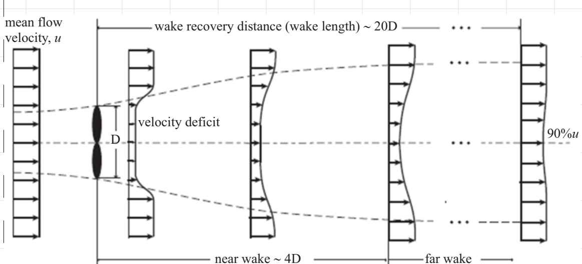

Fig. 6. Definition of wake characteristics [viii]

However, a clear understanding of the near wake is that it is the region where the geometry of the turbine has a direct effect on the fluid flow. A hydrokinetic turbine converts the energy extracted from the fluid flow into mechanical motion. The mechanical motion of the blades produce vortex shedding from the blade tip. Vortices shedding along with support structure has a direct effect on the flow in the near wake region. Shedding of the vortices by the blade tip creates sharp velocity gradients and peaks in turbulence intensity. On the contrary, the turbine geometry affects the far wake indirectly. The indirect effect of the geometry is in the form of decreased axial velocity and increased turbulence intensity. The wake structure is governed by convection and turbulent mixing. For a completely inviscid flow the volume of slow moving fluid will just be convecting downstream at a slower rate than the free stream flow. But due to the turbulent mixing the wake keeps on regaining energy and ultimately attains the free stream velocity farther downstream. In the near wake, the pressure field around the device is important whereas, in the far wake the turbulent mixing is important for the development of wake deficit. Mixing of the wake and recovery of the velocity deficit in the far wake takes place due to the turbulence and as result the overall turbulence decreases [lxxi, lxxiii]. Wake is one of the most extensively researched area of the tidal current energy. Wake studies are necessary to understand the effect of an upstream device on the performance and loading experienced by the downstream turbine. A brief review of research articles for better understanding of the wake is presented here.

A. S. Bahaj et. al [lxxii] carried out the experimental and theoretical investigations of the flow field around mesh disc rotor simulator in a tilting flume. The work was aimed to identify and investigate the parameters governing the wake structure and its recovery to free stream velocity profile. The identified governing parameters were intended to be used for the development of a numerical model for characterizing the wake of a tidal current turbine. The study concluded that porous disc experiments can effectively simulate the far wake of a TCT. The results showed that deficit is maximum in the immediate wake region and tends to recover with increasing downstream distance. However, the wake persists for quite a long distance and up to 20 rotor diameters only 90% of the velocity was recovered. The free surface and sea bed may restrict the vertical expansion of the wake. Hence further investigation was proposed to study the effect of water depth, proximity to the free surface and the influence of ambient turbulence on the initial condition and wake mixing. Luke Myers and A. S. Bahaj [lxxiii] further extended their work by testing the 1/30th scale model TCT in a circulating water channel. Performance and wake structure of the turbine was investigated at different flow speeds and thrust coefficients. An increase in surface turbulence was observed with increase in flow velocity. Between the rotor and the side of the channel, the velocity of flow was greater than the inflow velocity for all flow speeds. The effect was more pronounced for increased inflow velocities. The phenomenon was termed as blockage effect. Due to the blockage effect, an increase in channel head upstream of rotor and an immediate decrease due to extraction of energy in the downstream was observed. It was suggested that the blockage effects and variation in channel head may not be so exaggerated at full scale because Froude numbers will be much lower. However, it may still be significant. It was observed that the expansion of the wake took place downstream of the rotor and ultimately reached the surface. This will either increase the channel head further downstream or will mix with the wake of another adjacent TCT. Rate of wake recovery is dependent upon the ambient turbulence intensity and thrust coefficient of the rotor. MacLeod et. al [lxxiv] through CFD modeling also established that rate of wake recovery increases with increasing turbulence intensity and that higher thrust coefficient will cause slower wake recovery rate. F. Maganga et. al [lxxv] experimentally established the fact that the wake recovery is faster in the areas of greater turbulence intensity. The blockage effect may place restrictions on the maximum diameter of a TCT for a specific channel. The study suggested further investigation of the blockage effect, wake expansion and Froude number scaling with in TCT arrays. In another study L. Myers and A. S. Bahaj [lxxvi] measured the wake characteristics of a 1/20th scale TCT in a water channel. In this experiment the channel base flow and wake downstream of the turbine was mapped with laser and acoustic Doppler velocimeters. Wake mapping of both a stationary and rotating rotor was conducted to observe the effect of support structure on the flow properties in the near wake. Results of the experiment showed that the support structure has a noticeable effect on the near wake along with a synergetic effect from both the rotor and support structure near the center plane of the rotor in the downstream. This effect diminishes with increasing distance along the lateral direction of the channel. The higher turbulence intensity made it difficult to determine the flow properties in the near wake region. Luke Myers and A. S. Bahaj [lxxvii] also studied Flow boundary interaction effects for marine current energy conversion devices through mesh rotor disc experiments in a flume and circulating water channel. This experimental work concluded that TCT operating in shallow waters will produce a different wake structure than those operating in deep waters. A satisfactory wake recovery will not be possible, if the depth underneath the rotor is infinite. In 2010, Luke Myers and A. S. Bahaj [lxxviii] studied the wake characteristic of a TCT through mesh disc rotor simulator in a laboratory flume. It was observed that the wake velocity in the near wake region will decrease with increasing thrust. The results also validated the fact that the far wake recovery is a function of the ambient turbulence. Distance of the rotor from open surface and sea bed have an influence on the far wake recovery. The sea bed roughness contributes to the decrease in the downstream wake velocity. The results concluded that a number of interdependent variable can affect the wake recovery rate.

Apart from the experimental investigations presented above, various numerical studies have also been performed to characterize the wake of a TCT. M. E. Harrison and W. M. J. Batten along with L. E. Myers and A. S. Bahaj [lvii] used a commercial CFD software package to characterize the wake of mesh disc rotor and compare the CFD results with experiment. A good agreement between the CFD and experimental results was observed. The CFD results revealed that the main factors affecting the wake structure are the device thrust, ambient turbulence and potentially the disc induced turbulence. However, difference in turbulence intensity between the numerical and experimental results were observed. The results concluded that with further improvements in the CFD modeling techniques, CFD analysis of mesh disc rotors may be an accurate and valid numerical modelling method for TCT. Blackmore T along with Batten and Bahaj [lxxix] used large eddy simulation (LES) to study the effect of inflow turbulence on the wake of a rotor disc simulator of TCT. The simulation showed that an increase in the flow turbulence reduces the velocity deficit and the maximum velocity deficit shifts closer to the rotor. Higher inflow turbulence also results in faster wake recovery in the downstream. Recently, some work has been done to analytically model the wake of a TCT. Wei-Haur Lam et. al [lxxx] developed two analytical equation for the prediction of mean wake velocity of a TCT. One of the equation used for the prediction of initial velocity is based on the axial momentum theory and dimensional analysis. Whereas the other equation is used to predict the lateral velocity and it is based on the Gaussian probability distribution. Results of the equations were compared with other numerical and experimental results that showed some deviation. However, it was claimed that these equations will provide the basis for the formulation of an analytical model. Later the same author succeeded to develop an analytical wake model and presented his work in [lxxxi]. Results of the developed analytical wake model was compared with well accepted experimental results. The presented results showed that the analytical model can predict the wake profile for different turbulence intensities. More recent work related to the wake studies of TCT focuses on the wake interaction between devices or the effect of the wake of upstream devices on the downstream devices. Some of this work will be discussed in the next section.

VI. Tidal Turbine Arrays

A huge portion of the global tidal energy potential is available in the narrow channels [lxxii, lxxix]. Efforts are required to fully utilize the available space and extract maximum energy from these sites. The concept of tidal turbines arrays or farms seems to be the ultimate solution to the problem. In addition, only tidal array can make the technology commercial and justify the cost of grid connection along with establishing, maintenance and navigation facilities [lxxxii]. A standalone turbine cannot justify this huge cost [lxxiv].

Tidal arrays are classified into large and small arrays [lxxxii]. The term large array does not mean that channel will have a huge number of turbines. If the turbines extracts large portion of the channel potential, the array will be large irrespective of the number of turbines. A few turbines in a small channel can constitute a large array. Conversely, a number of turbines in a large channel can be a small array. A large array affects the "channel-scale dynamics" or improves the power co-efficient of turbines through "duct-effect". Whereas a small array is one that cannot significantly affect the "channel-scale dynamics" and the performance of the individual turbine is not affected by other turbines or proximity to channel sides. It is essential to understand the dynamics of turbines with in large arrays for the development of tidal turbine arrays and the design of turbines in arrays [lxxxiii]. An array has two competing effects on the dynamics of flow in a tidal channel. One is the "channel-scale dynamics" and the other is the "duct-effect". The channel-scale dynamics refers to the finite head loss as shown in Fig. 7 due to power extraction from a channel [lxxxiv].

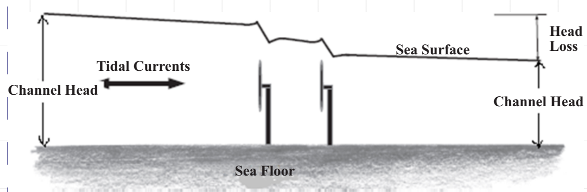

Fig. 7. Finite Head Loss due to power extraction from a tidal channel [lxxxii].

This finite head loss causes additional drag and reduces free stream flow that limits the array power output. Due to this the turbines in a channel interacts with each other even if they are far enough from the wake effects of each other. In addition, any Bitz turbine operating in an array, causes the array to lose 1/3 of its energy to turbulent mixing behind the turbine or near wake region [lxxxv]. About 5-10% of the energy is lost to the support structure [lxxxvi] and about 11% goes into electromechanical losses that imposes significant portion of the structural loads on the turbine. The proportion of these loads highly depends upon the number of turbines, their arrangement and tuning in the array. On the other hand, the duct-effect shown in Fig. 8, increases the free stream flow. Duct-effect improves the turbine thrust and power co-efficient of the turbine in the array. It is possible for the turbines operating in array to operate at higher thrust and power co-efficient than that of a Bitz turbine [lxxxiii].

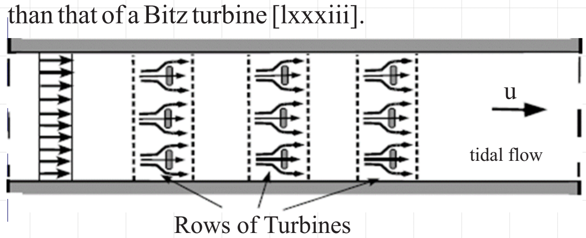

Fig. 8. Channel forming a duct around the turbines [lxxxvii].

In addition to these two effects, the design of array will dictate the amount of power output of the individual turbine. In an experimental study L.E. Myers and A. S. Bahaj [lxxxviii] established the fact that flow can be accelerated between two laterally adjacent porous discs causing an increased thrust and power for the downstream disc in a staggered array. Chul-Hee Jo et al. [lxxxix] also observed that staggered arrays are more productive as compared to the longitudinal arrays. Because in the staggered array, the downstream rotor can avoid the wake interference of the upstream rotors. In the axial array, increasing the inter device spacing reduces the power loss of the downstream devices. Chul-Hee Jo et al. [xc] through experiments and CFD simulation showed that downstream devices, in an axial array, received a reduced flow velocity at varying longitudinal spacing. As a result the predicted power output of the individual turbines in the array was much less than their designed power output. Rami Malki et al. [xlv] used a coupled BEM-CFD model for the simulation of tidal turbine array. The simulation revealed that the longitudinal and lateral spacing between the turbines in array have a significant influence on the velocity and turbulence intensity of the flow. The flow velocity increased between a pair of laterally adjacent devices. The authors observed a maximum turbulence intensity when the upstream devices were closely spaced in lateral direction and downstream turbine at increased longitudinal spacing. This increased turbulence intensity is critical for the structural integrity of the turbines and can only be modeled with an FSI modeling approach.

VII. FUTURE PERSPECTIVE

A turbine operating in array will experience different flow, will have a different power and thrust coefficient and will experience different structural loads than when operating as standalone. Therefore, the criterion used to design turbines needs to be adopted accordingly. A turbine must be designed for an array configuration rather than for isolated use. Power output of the individual turbine affects the total array output, which in turn affects the flow experienced by each turbine, the loads on the turbine and their outputs. In addition, for turbines operating in array, considerable loading will also come from the operation of the upstream turbine. Therefore, it is necessary to model the effect of operation of upstream device on the structural loads encountered by the downstream device and its fatigue life. The load forces will follow the trend of power output per turbine. The load will be distributed over the turbine blades and fixing arrangement as well as power train and mooring system. It is very imperative to understand the contribution of all the loads along with drag caused by power extraction for developing structural design specification. Increased power output from a turbine will produce higher structural loads on the turbine and thus the turbine should be more robust having a higher construction cost and vice versa.

Most of the current research is focusing the tidal turbine array Micro and Macro design/optimization to maximize the total array output. The other important array associated impacts of varying structural loads have not been investigated in details so far. The investigation of structural loads and the integrity/safety of the turbine against these loads is very important for the development of structural design specification. Other important consideration is the associated manufacturing cost. If the array associated structural loads is not given due consideration then the devices will either be over designed or under designed. Both the possibilities will make the technology costly and unreliable at the array scale.

The investigation of structural loads on the turbine in an array and their effect on the useful life of the turbine through numerical modeling and experiments should be the focus of future research for the development of large tidal arrays. Over the years substantial growth in the availability of computational resources has taken place. Due to which the numerical modeling technique of Fluid Structure Interaction (FSI) can be very useful for modeling such problems. FSI is a multi-physics problem. When a fluid flow exerts pressure on an elastic structure, the structure deforms. In return, the deformed structure disturbs the fluid flow. This disturbed fluid flow now exerts another form of pressure on the structure in a repetitive manner. This kind of interaction is called Fluid Structure Interaction (FSI). FSI is based upon the fundamental principle of dynamics (FPD), or Newton's second law, applied to the mechanical system. Some researchers have adopted the FSI modeling approach for other aspects of Tidal/wind turbine. CH Jo et al. [xci] performed the FSI analysis for the investigation of deformation along offshore pile structure of tidal current power and for the Performance Analysis of 200kW Tidal Current Power Turbine with Pre-deformed Blades [li]. R. F. Nicholls-Lee [xcii] used FSI for the performance analysis of TCT with bend twist coupled blades. B. S. Kim et al. [xciii] assessed the structural integrity of 50kW helical ocean current turbine using fluid structure interaction analysis. Ming-Chen Hsu and Yuri Bazilevs [xciv] performed the Fluid–structure interaction modeling of a full wind turbine. All these studies suggest that a coupled CFD and structural model (i.e., FSI Model) can provide satisfactory results for modeling the deformation of the TCT structures due to fluid loads imposed by the tidal currents.

VIII. CONCLUSION

The paper presented a thorough review of the tidal energy technology including all the modules like

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performance prediction, structural load analysis, wake effects and installation of the turbines in arrays. Based on the review, future research directions are also outlined addressing three key issues. These include investigation of structural loads and the integrity/safety of the turbine against these loads for the development of structural design specification. Another issue that need the focus of research community is the effect of structural load on the useful life of the turbine particularly in tidal arrays and the requirement of developing proper numerical and experimental models. The numerical modeling technique of FSI can be very useful though computationally expensive for modeling the above problem but can benefit from the computational power of current electronic device.

REFERENCE

[i] S. Pryor and R. Barthelmie,"Climate change impacts on wind energy: a review,"*Renewable and sustainable energy reviews*, vol. 14, pp. 430-7, 2010.

[ii] C. Frei, R. Whitney, H. Schiffer,K. Rose, D.A. Rieser, A. Al-Qahtani, P. Thomas, H. Turton. M. Densing, E. Panos, and K. Volkart,"World Energy Scenarios Composing energy futures to 2050,"*London World Energy Council*, 2013.

[iii] K. Beckman, "Insights from and for the WEC's global leadership community," *World energy focus*, pp. 9.

[iv] P. Fraenkel, "Marine current turbines: pioneering the development of marine kinetic energy converters," *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy,* vol. 221, pp. 159-69, 2007.

[v] How Ocean Currents Work, *http://science.howstuffworks.com/environmental/earth/oceanography/ocean-current4.htm* (accessed date 22-11-2016).

[vi] R. Kempener and F. Neumann, "Tidal energy technology brief," *International Renewable Energy Agency (IRENA)*, 2014.

[vii] F. Rourke, F. Boyle, and A, Reynolds, "Tidal energy update 2009' " *Applied Energy*, vol. 87, pp. 398-409, 2010.

[viii] N. D. Laws and B. P. Epps, "Hydrokinetic energy conversion: Technology, research, and outlook," *Renewable and Sustainable Energy Reviews*, vol. 57, pp. 1245-59, 2016.

[ix] A. G. L. Borthwick, "Marine Renewable Energy Seascape," *Engineering,* vol. 2, pp. 69-78, 2016.

[x] R. Pelc and R. M. Fujita, "Renewable energy from the ocean," *Marine Policy*, vol.26, pp. 471–9, 2002.

[xi] A. Bahaj and L. Myers, "Fundamentals applicable to the utilisation of marine current turbines for energy production," *Renewable energy*, vol. 28, pp. 2205-11, 2003.

[xii] A. Bahaj and L. Myers, "Analytical estimates of the energy yield potential from the Alderney Race (Channel Islands) using marine current energy converters," *Renewable Energy*, vol. 29, pp. 1931-45, 2004.

[xiii] I. Bryden, T. Grinsted and G. Melville, "Assessing the potential of a simple tidal channel to deliver useful energy," *Applied Ocean Research*, vol. 26, pp. 198-204, 2004.

[xiv] I. Bryden and G. Melville, "Choosing and evaluating sites for tidal current development,"*Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, vol. 218, pp. 567-77, 2004.

[xv] I. Bryden and S. J. Couch, "ME1—marine energy extraction: tidal resource analysis,"*Renewable Energy*, vol. 31, pp. 133-9, 2006.

[xvi] I. Bryden and S. J. Couch, "How much energy can be extracted from moving water with a free surface: A question of importance in the field of tidal current energy?,"*Renewable Energy*, vol. 32, pp. 1961-6, 2007.

[xvii] S. Couch and I. Bryden, "Tidal current energy extraction: hydrodynamic resource characteristics," *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, vol. 220, pp. 185-94, 2006.

[xviii] S. Couch and I. Bryden, "The impact of energy extraction on tidal flow development," *3rd International Conference on Marine Renewable Energy*, Blyth, 2004.

[xix] C. Garrett and P. Cummins, "The power potential of tidal currents in channels," *Proceedings of the Royal Society of London A:Mathematical, Physical and Engineering Sciences: The Royal Society*, pp. 2563-72, 2005.

[xx] R. H. Karsten, J. McMillan, M. Lickley and R. Haynes, "Assessment of tidal current energy in the Minas Passage, Bay of Fundy," *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, vol. 222, pp. 493-507, 2008.

[xxi] G. Sutherland, M. Foreman and C. Garrett, "Tidal current energy assessment for johnstone strait, vancouver island," *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, vol. 221, pp. 147-57, 2007.

[xxii] W. Batten , A. Bahaj, A. Molland and J. Chaplin, "The prediction of the hydrodynamic performance of marine current turbines, "*Renewable energy*, vol. 33, pp. 1085-96, 2008.

[xxiii] W. Batten , A. Bahaj, A. Molland and J. Chaplin, "Experimentally validated numerical method for the hydrodynamic design of horizontal axis

tidal turbines," *Ocean Engineering*, vol. 34, pp. 1013-20, 2007.

[xxiv] J. A. Clarke, G. Connor, A. Grant, C. Johnstone and D. Mackenzie "Development of a contra-rotating tidal current turbine and analysis of performance," *7th European Wave and Tidal Energy Conference2007*.

[xxv] D. Coiro, A. De Marco, F. Nicolosi, S. Melone and F. Montella"Dynamic behaviour of the patented kobold tidal current turbine: numerical and experimental aspects,"*Acta Polytechnica*, *45(3)*, 2005.

[xxvi] D. Coiro, U. Maisto, F. Scherillo, S. Melone and F. Grasso, "Horizontal axis tidal current turbine: numerical and experimental investigations," *Proceeding of Offshore wind and other marine renewable energies in Mediterranean and European seas, European seminar, Rome, Italy*, Citeseer; 2006.

[xxvii]C. Douglas, G. Harrison and J. Chick, "Life cycle assessment of the Seagen marine current turbine," *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, vol. 222, pp. 1-12, 2008.

[xxviii]Y. Li and S. M. Calisal, "Modeling of twin-turbine systems with vertical axis tidal current turbines: Part I—Power output," *Ocean Engineering*, vol, 37, pp. 627-37, 2010.

[xxix] S. Ma, W. Li, H. Liu and Y. Lin, "A 25 kW stand-alone horizontal axis tidal current turbine," *Dianli Xitong Zidonghua(Automation of Electric Power Systems)*, vol. 34, pp.18-22, 2010.

[xxx] F. Ponta and P. Jacovkis, "Marine-current power generation by diffuser-augmented floating hydro-turbines," *Renewable Energy*, vol. 33, pp. 665-73, 2008.

[xxxi] X. Sun, J. Chick and I. Bryden, "Laboratory-scale simulation of energy extraction from tidal currents," *Renewable Energy*, vol. 33, pp. 1267-74, 2008.

[xxxii]S. E. Ben Elghali, M. E. H Benbouzid, and J. F. Charpentier, "Marine Tidal Current Electric Power Generation Technology: State of the Art and Current Status," *IEEE International Electric Machines & Drives Conference*, 2007.

[xxxiii]The Executive Committee of Ocean Energy Systems, "Annual Report Ocean Energy System 2015," p. 10.

[xxxiv]OES Annex V, "Ocean Energy Device Project Information and Experience," *Ocean Energy Systems (OES)*, p. 34, 2013.

[xxxv]SeaGen enters final stage of commissioning, *http://www.marineturbines.com/3/news/article/14/seagen_enters_final_stage_of_commissioning (accessed date 09-09-2016)*.

[xxxvi]Press Release, "Open Hydro Becomes First Tidal Energy Company to Generate Electricity onto the UK National Grid", *http://www.openhydro.com/news/OpenHydroPR-270508.pdf (accessed date 09-09-2016)*.

[xxxvii]D. Magagna and A. Uihlein, "2014 JRC Ocean Energy Status Report," *European Commission Joint Research Centre*.

[xxxviii]H. Roger, Charher, L. Menanteau, M. Chaineux, "The rise and fall of the tide mill," pp. 315-38.

[xxxix]R. H. Charlier, "Re-invention or aggorniamento? Tidal power at 30 years," *Renewable and Sustainable Energy Reviews*, vol. 1, pp. 271-89, 1997.

[xl] P. Fraenkel, "Development and testing of Marine Current Turbine's SeaGen 1.2 MW tidal strean turbine," *3rd International Conference on Ocean Energy*, 2010.

[xli] J. P. Frau, "Tidal energy: promising projects: La Rance, a successful industrial-scale experiment,"*IEEE Transactions on Energy Conversion,* p. 552-8, 1993.

[xlii] J. Thake, "Development, installation and testing of a large-scale tidal current turbine,"*U.K: IT Power*, 2005.

[xliii] E. Kulunk, "Aerodynamics of Wind Turbines, Fundamental and Advanced Topics in Wind Power,"*In: Dr., Carriveau R, editors*, 2011.

[xliv] A. Bahaj, A. Molland , J. Chaplin and W. Batten, "Power and thrust measurements of marine current turbines under various hydrodynamic flow conditions in a cavitation tunnel and a towing tank," *Renewable energy*, vol. 32, pp. 407-26, 2007.

[xlv] R. Malki, I. Masters, A. J. Williams and T. Nick Croft, "Planning tidal stream turbine array layouts using a coupled blade element momentum – computational fluid dynamics model," *Renewable Energy*, vol. 63, pp. 46-54, 2014.

[xlvi] X. Zhang, X. Zhang, X. Mingqi, Z. Wanqiang and J. Chen, "Numerical Calculation of the Hydrodynamic Performance of Con-horizontal Tidal Current Self-pitch Turbine with Dual Rotor,"*Journal of Computational Information Systems*, vol. 9-10, pp. 4193–200, 2013.

[xlvii] J. D. Anderson, "Computational Fluid Dynamics- The basics with application, "*McGraw-Hill, Inc*, p. 23-5, 1995.

[xlviii]J. Ch, J. Yim , K. Lee and Y. Rho, "Performance of horizontal axis tidal current turbine by blade configuration," *Renewable Energy*, vol. 42, pp. 195-206, 2012.

[xlix] C. H. Jo, S. J. Hwang, J. H. Lee and K. .H Lee, "Design Procedure and Performance Estimation of tidal current power systems," *7th International Conference on Asian and Pacific Coasts*, 2013.

[l] P. M. Singh and Y. D. Choi, "Shape design and numerical analysis on a 1 MW tidal current turbine for the south-western coast of Korea," *Renewable Energy*, vol. 68, pp. 485-93, 2014.

[li] C. H. Jo, K. H. Lee, S. J. Hwang and D. Y. Kim, "Performance analysis of 200kW tidal current power turbine with pre-deformed blades," *15th International Conference on Environment and Electrical Engineering (EEEIC), IEEE*, p. 472-7, 2015.

[lii] W. Z. Shen, R. Mikkelsen, J. N. Sorensen and C. Bak, "Tip loss corrections for wind turbine computations," *Wind Energy*, vol. 8, pp. 457-75, 2005.

[liii] T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, "*Wind energy handbook*, John Wiley & Sons, 2001.

[liv] B. Epps, M. Stanway and R. Kimball, "OpenProp: an open-source design tool for propellers and turbines," *Society of Naval Architects and Marine Engineers Propeller/ Shafting '09 Symposium*,2009.

[lv] P. Liu, "A computational hydrodynamics method for horizontal axis turbine–Panel method modeling migration from propulsion to turbine energy," *Energy*, vol. 35, pp. 2843-51, 2010.

[lvi] S. A. Kinnas, W. Xu, Y. H. Yu and L. He, "Computational methods for the design and prediction of performance of tidal turbines, "*Journal of Offshore Mechanics and Arctic Engineering*, vol. 134, pp. 011101, 2012.

[lvii] M. E. Harrison, W. Batten, L. Myers and A. Bahaj, "Comparison between CFD simulations and experiments for predicting the far wake of horizontal axis tidal turbines," *IET Renewable Power Generation*, vol.4, pp. 613, 2010.

[lviii] S. R. Turnock, A. B. Phillips, J. Banks and R. Nicholls-Lee, "Modelling tidal current turbine wakes using a coupled RANS-BEMT approach as a tool for analysing power capture of arrays of turbines," *Ocean Engineering*. Vol. 38, pp. 1300-7, 2011.

[lix] Dynamics and structural loading in wind turbines, *http://mragheb.com/NPRE%20475%20Wind%20Power%20Systems/Dynamics%20and%20Structural%20Loading%20in%20Wind%20Turbines.pdf (accessed date 20-11-2016).*

[lx] G. S. Bir, M. J. Lawson and Y. Li, "Structural design of a horizontal-axis tidal current turbine composite blade," *ASME 30th International Conference on Ocean, Offshore and Arctic Engineering: American Society of Mechanical Engineers*, p. 797-808, 2011.

[lxi] I. Masters, J. Chapman, M. Willis and J. Orme, "A robust blade element momentum theory model for tidal stream turbines including tip and hub loss corrections," *Journal of Marine Engineering & Technology*, vol. 10, pp. 25-35, 2011.

[lxii] F. Zhou, G. M. Alsenas, H. Mahfuz and H. P. Hanson, "Fatigue analysis of composite turbine blades under random ocean current," *Oceans: IEEE*, p. 1-7, 2012.

[lxiii] P. Galloway, "Performance quantification of tidal turbines subjected to dynamic loading," *University of Southampton*, 2013.

[lxiv] N. Barltrop, K. Varyani, A. Grant, D. Clelland and X. Pham, "Investigation into wave—current interactions in marine current turbines," *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, vol. 221, pp. 233-42, 2007.

[lxv] G. McCann, "Tidal current turbine fatigue loading sensitivity to waves and turbulence–a parametric study," *Proceedings of the 7th European Wave and Tidal Energy Conference*, 2007.

[lxvi] C. Faudot and O. G. Dahlhaug, "Prediction of wave loads on tidal turbine blades," *Energy Procedia*, vol. 20, pp. 116-33, 2012.

[lxvii] I. A. Milne, A. Day, R. N. Sharma, R. G. Flay and S. Bickerton, "Tidal turbine blade load experiments for oscillatory motion," *9th European Wave and Tidal Energy Conference (EWTEC)*, 2011.

[lxviii] M. W. Akram, "Fatigue modeling of composite ocean current turbine blade," *Journal of Material Science Engineering*, vol. 34, pp. 147-60.

[lxix] J. Senat, "Numerical simulation and prediction of loads in marine current turbine full-scale rotor blades," *Florida Atlantic University,* 2011.

[lxx] F. Zhou, "Development of an Integrated Computational Tool for Design and Analysis of Composite Turbine Blades under Ocean Current Loading," *Florida Atlantic University*, 2013.

[lxxi] G. Larsen, H. Madsen, F. Bingol, K. Hansen, and T. Larsen, "Dynamic wake meandering modeling. Technical Report R-1607," *Riso National Laboratory: Technical University of Denmark*; 2007.

[lxxii] A. Bahaj, L. Myers, M. Thomson and N. Jorge, "Characterising the wake of horizontal axis marine current turbines," *Proceedings of the 7th European wave and tidal energy conference,* p. 9, 2007.

[lxxiii] L. Myers and A. Bahaj, "Wake studies of a 1/30th scale horizontal axis marine current turbine," *Ocean Engineering*, vol. 34, pp. 758-62, 2007.

[lxxiv] A. MacLeod, S. Barnes, K. Rados and L. Bryden, "Wake effects in tidal current turbine farms," *International conference on marine renewable energy*, p. 49-53, 2002.

[lxxv] F. Maganga, G. Germain, J. King, G. Pinon and

E. Rivoalen, "Experimental characterisation of flow effects on marine current turbine behaviour and on its wake properties," *IET Renewable Power Generation*, vol. 4, pp. 498, 2010.

[lxxvi]L. Myers and A. Bahaj, "Near wake properties of horizontal axis marine current turbines," *Proceedings of the 8th European Wave and Tidal Energy Conference,* p. 558-65, 2009.

[lxxvii]L. Myers, A. Bahaj, G. Germain and J. Giles, "Flow boundary interaction effects for marine current energy conversion devices," *World Renewable Energy Congress X*,2008.

[lxxviii]L. Myers and A. Bahaj, "Experimental analysis of the flow field around horizontal axis tidal turbines by use of scale mesh disk rotor simulators," *Ocean Engineering*, vol. 37, pp. 218-27, 2010.

[lxxix]T. Blackmore, W. Batten and A. Bahaj, "Influence of turbulence on the wake of a marine current turbine simulator," *Proc R Soc A: The Royal Society*, p. 03-31, 2014.

[lxxx] W. H. Lam and L. Chen, "Equations used to predict the velocity distribution within a wake from a horizontal-axis tidal-current turbine," *Ocean Engineering*, vol. 79, pp. 35-42, 2014.

[lxxxi]W. H. Lam, L. Chen and R. Hashim, "Analytical wake model of tidal current turbine," *Energy*, vol. 79, pp. 512-21, 2015.

[lxxxii]R. Vennell, S. W. Funke, S. Draper, C. Stevens and T. Divett, "Designing large arrays of tidal turbines: A synthesis and review," *Renewable and Sustainable Energy Reviews*, vol. 41, pp. 454-72, 2015.

[lxxxiii]R. Vennell, "Exceeding the Betz limit with tidal turbines," *Renewable Energy*, vol. 55, pp. 277-85, 2013.

[lxxxiv]R. Vennell, "The energetics of large tidal turbine arrays," *Renewable Energy*, vol. 48, pp. 210-9, 2012.

[lxxxv]G. Corten, "Heat generation by a windturbine," *14th IEA symposium on the aerodynamics of wind turbines,* p. 1-8, 2000.

[lxxxvi]C. Garrett and P. Cummins, "Limits to tidal current power," *Renewable Energy*, vol. 33, pp. 2485-90, 2008.

[lxxxvii]R. Vennell, "Realizing the potential of tidal currents and the efficiency of turbine farms in a channel," *Renewable Energy*, vol. 47, pp. 95-102, 2012.

[lxxxviii]L. Myers and A. Bahaj, "An experimental investigation simulating flow effects in first generation marine current energy converter arrays," *Renewable Energy*, vol. 37, pp. 28-36, 2012.

[lxxxix]C. H. Jo, K. H. Lee and J. Y. Yim, "A study on the interference effects for tidal current power rotors," *Science China Technological Sciences*, vol. 53, pp. 3094-101, 2010.

[xc] C. H. Jo, K. H. Lee, J. H. Lee and C. Nichita, "Wake effect on HAT tidal current power device performance," *International Journal of Ocean System Engineering*, vol. 1, pp. 144-7, 2011.

[xci] C. H. Jo, D. Y. Kim, Y. H. Rho, K. H. Lee and C. Johnstone, "FSI analysis of deformation along offshore pile structure for tidal current power," *Renewable energy*, vol. 54, pp. 248-52, 2013.

[xcii] R. Nicholls-Lee, S. Turnock and S. Boyd, "Application of bend-twist coupled blades for horizontal axis tidal turbines," *Renewable Energy*, vol. 50, pp. 541-50, 2013.

[xciii] B. Kim, S. Bae,W. Kim, S. Lee and M. Kim, "A study on the design assessment of 50kW ocean current turbine using fluid structure interaction analysis," *IOP Conference Series: Earth and Environmental Science: IOP Publishing*, pp. 420-37, 2012.

[xciv] M. C. Hsu and Y. Bazilevs, "Fluid structure interaction modeling of wind turbines: simulating the full machine," *Computational Mechanics*, vol. 50, pp. 821-33, 2012.

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Section D

TELECOMMUNICATION, COMPUTER, SOFTWARE ENGINEERING AND COMPUTER SCIENCE

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Fault Tolerance Techniques in Cloud and Distributed Computing- A Review

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Abstract-Computing System is a combination of different computers and associated software which can share common memory. In cloud and distributed computing the defective infrastructure is the main issue. Fault Tolerance (FT) techniques minimize the failure effect on computing environment. This study discusses and presents a comprehensive analysis of the current FT techniques in cloud and distributed environment. A comparison and critical evaluation of common FT techniques in cloud and distributed computing is also performed. An intensive literature review was adopted to identify current FT techniques in both environments. This study contributes in a fashion by identifying that few fault tolerance techniques are common in both cloud and distributed computing .Moreover this study also pinpoints Check-pointing as the most optimal FT technique. Result shows that FT techniques are crucial for reliability and availability of data thus FT method is necessarily required to be endorsed to escort the system from failures.

Keywords-Fault Tolerance, Cloud Computing, Distributed Computing, Replication, High Availability, Reliability.

I. Introduction

Cloud computing is the result of increasing demand of flexibility in computing resources and storage technologies in cost-effective manner. Cloud computing provides reliable services which include storage, servers and networks. A cloud system is developed by connecting computing resources and extensive data centers provided over the internet as on-demand service with the help of virtual machines. Distributed Computing System (DCS) is a single coherent system of independent computers. A DCS connect computers at different locations using local networks[i].Although cloud and distributed computing has been extensively used in the industry, still there is a need to completely report several research issues such as fault tolerance, workflow management, workflow scheduling and security etc. [ii].One of the crucial issues is Fault Tolerance (FT) which permit a system to endure faults pertaining in the system after development.

FT computing means if hardware/software failures occur the job can be done correctly. FT abilities are necessary to overcome the effect of system failures[iii]. One of the major benefits of applying fault tolerance in cloud and distributed computing may include improving reliability, recovery from failure, 24/7 availability, lower cost, improved performance metrics etc. [iv]. However, for application to be installed in cloud or distributed system, a complete fault tolerance solution is difficult to design that can combine the failure impact and system architecture. In distributed computing failures or faults are limited and the hardware/software redundancy approaches are famous methods of fault tolerance. Hardware techniques assure the accumulation of hardware components like memory, I/O devices, communication media and CPUs. Software FT techniques include special programs to protect system from faults. A well-organized FT tool assists to identify and recover from faults.

The remainder of the paper is planned as follows: Section II describes literature review. In Section III fault tolerance techniques and types in cloud and distributed computing are deliberated. Section IV gives a comparison of different fault tolerance techniques in cloud and distributed computing. Critical evaluation about the techniques is performed in Section V and the last but not least Section VI expose the limitations of the study whereas Section VII delineates the conclusion and explore the future directions.

II. Literature Review

With the passage of time various researchers came up with different FT techniques that are common with cloud and distributed computing.

FT techniques and challenges in cloud environment are discussed in [ii], [v]. An autonomic FT system and cloud virtualized system architecture has been proposed in [ii] using HA Proxy and My SQL to implement proposed FT system which can deal with several software faults for server applications. Whereas some of FT algorithms which share workload between resources such as multiple computers or a computer cluster, central processing units, disk drives or network links are identified in [v] to attain optimal resource utilization, minimize response time, maximize throughput and avoid overload. A FT framework for High Performance Computing (HPC) in cloud is presented in [vi-vii]. A FT framework presents in [6] is implemented on Linux which perform parallel job, event logging, environmental, and resource monitoring to analyze reliability of HPC system. Framework base on proactive FT method to avoid failures and is able to gather and analyze data and cause migration. A Framework is proposed in [vii] using Process Level Redundancy (PLR), FT policy and live migration. The proposed framework reduces the execution time and ensures that Message Passing Interface (MPI) implemented with computational intensive applications run smoothly. According to [viii] an innovative, modular and system level perspective is proposed to create and manage FT in Cloud systems. A comprehensive high-level approach propose to highlight the FT techniques' implementation details to users and application developers through a dedicated service layer. In distributed environments the Low Latency FT (LLFT) middleware deployed within a cloud and data center environment provided in [ix] by means of the leader/follower replication method. The LLFT middleware retains strong replica consistency, achieves low end-to-end latency and offers application transparency. A brief overview is presented in [x] for the need to perform FT in cloud computing. An outline of the prevalent architectures and the existing techniques for FT in cloud computing has been analyzed and compared. The primary concepts of FT techniques used according to the policies like Reactive and Proactive, and the related FT tools used on various types of faults are highlighted in [xi], [xii]. A comprehensive taxonomy of faults, errors and failures is also presented in [xi]. The practice of taxonomy and survey identify the similarities as well as the areas needing for future research. Whereas [xii] discusses and implements various fault tolerant methods, frameworks and algorithms which will assist to build a robust FT technique in Cloud environment. Authors of [xiii] critically analyze the Integrated Virtualized Fail over Strategy (IVFS) model and present a new model which tolerate faults of each virtual machine based on reliability. The results show an increase in pass rates and use diverse software tools to deliberate forward/backward recovery. Simulation results of this research highlight a noble performance as compared to the existing models. Experimental study with a critical analysis is used for validation, laying the foundation for a FT IaaS Cloud system. A survey based on FT implementation tools is conducted in [xiv] about the crucial FT technique in cloud computing, and list various FT methods. Cloud Computing is a fresh field of research than other technologies particularly in developing a standalone FT method. Several FT methods of this field are proposed by the research experts. The document [iii] presents a proactive FT framework which can implement several proactive FT techniques such as pause/unpause and migration. As well as allow the implementation of new proactive FT policies. Presented work implement and experiment proactive FT on system-level virtualization and results are compared with simulation results. Understanding of FT mechanisms have been proposed in [xv] which are used to manage faults in clouds and deals with existing FT model. Now a days a number of proposed models provide mechanisms to improve the system performance. But still there is a need to concern about every frame work. The objective of[xvi] is to propose a fault tolerant model and fault detection algorithm to overcome the holes of previously applied algorithms using Artificial Neural Network, provided in cloud computing. To detect faults in cloud systems artificial Neural Network is used which first detect the faults and then appropriate proactive FT technique such as pre-emptive migration or check-pointing apply to keep the system fault tolerant. Exhaustive study has been presented in [xvii] on FT in cloud, and introduce FT types and limitations. Furthermore, this study represents how much dependable the FT system will be for the real time environments. Results shows that an autonomic FT technique is needed to handle faults, when one of the machines stop working while several instances of an application are running on multiple machines.

The article [xviii] emphasized the different FT techniques for multiple system failures prevention by considering high availability, high redundancy and replication in distributed computing. The levels of FT are also addressed such as the hardware FT ensures additional backup hardware and software FT systems includes rollback recovery mechanisms and checkpoints storage. A survey on several FT techniques and issues in distributed environment has been done in [xix]. The survey results help to explore the future guidelines about FT mechanism. Important issues about FT tools such as adaptive, confidence, completeness, accuracy, fastness, and able to detect several faults. Faults, failures and errors categorization has been presented briefly in [xx] which are encountered in a distributed system. Furthermore, different techniques for fault tolerance and identification offered in Grid and Clustered Computing systems has been examined. It is also proposed that a standard FT framework should be proficient to handle all the recognized faults, failures and errors. Fault identification and foretelling in the view of Clusters is concentrated in [xxi] and efforts are done to develop a method that predicts the faults based on temperature in clustering systems. A comparison of fault detection and FT techniques in distributed environment is also performed. Various techniques for FT in distributed computing systems are provided in [xxii]. Every technique has some pros and cons. Check pointing can be used to improve performance and makes system fault tolerant during the case of node mobility and node failure. Various approaches for FT are discussed in [xxiii] and concluded that FT keeps system dependable and more reliable. Two stages in FT are the fault detection and fault recovery. Furthermore it is concluded that FT improves performance to achieve reliability. Centralized logging process described in [xxiv] by using message logging for message losses. Proposed logging process has three central parts failure detection, overload detection and failure recovery. Proposed system sustains monitor nodes in cluster for all nodes. All monitor nodes can perform task as a cluster node at the time of node failure as well as also during the system functioning properly. Concurrent replication with canceling are explored in [xxv] and a stochastic model is proposed to study replication affects in the cluster Service Level Objectives (SLOs). The proposed model is reliable as well as defines the regions of the utilization. Additionally, the model can support resource provisioning decisions with response time guarantees and reliability. Several issues associated to check pointing in distributed and mobile computing systems are discussed in [xxvi]. For distributed systems a survey is performed about some check pointing algorithms. Results of survey support check pointing technique as an effective FT technique for this reason it require minimum storage and avoids the domino effect. Nowadays, storage and manipulation of huge amount of data is done by cloud computing environment. For the reason availability and reliability is the major concern for manipulation of data. Different FT mechanisms and techniques to manage resources, available in cloud infrastructure are discussed by [xxvii]. The comparison of two state-of-the-art FT techniques is performed by [xxviii]. The comparison is done in terms of energy cost to cloud employers and availability of services to customers. The study concluded that proactive FT policy redundancy is remarkable in terms of cost to cloud manipulators and provides availability and services to customers. Cloud computing architecture (servers, networks), key concepts and application components are highlighted in [xxix]. Furthermore a qualitative overview of failures that occur in cloud infrastructure is also highlighted. Moreover cloud computing architecture resiliency techniques are categorized in the proposed study. Efforts to inspect FT techniques are analyzed in [xxx]. A taxonomy of faults and FT aspects are presented in the study. Moreover, different failure models, tools, metrics and support systems are classified. Weaknesses and strengths of current FT techniques are also discussed. In today's world cloud computing is a developing field but still faces some major problems. Such as fault tolerance, resource discovery, security and load balancing. A detailed summary of techniques to optimize load balancing is provided by [xxxi]. Swarm based and evolutionary algorithms are discussed to reduce the resource utilization and optimization problems. A new model is proposed with results in [xxxii] to provides FT for cloud framework. The proposed model is able to tolerate the faults by making the adaptive decision. The decision is made by utilizing the resource allocation of the jobs with a new technique in real time cloud locality.

Literature review illustrates that previous work on fault tolerance in cloud and distributed environment is about fault tolerance techniques, their uses, surveys and analysis. In this study a comprehensive analysis of various FT techniques in cloud and distributed computing have been done. Additionally this study also contributes in a way by comparing different FT techniques which have been commonly proposed for both cloud and distributed computing. Furthermore we critically evaluate common FT techniques in cloud and distributed computing.

III. Fault Tolerance

Fault Tolerance (FT) considered as a setup or configuration that precludes a network device or a computer system from getting failed due to any system failure or error in the system and consider effective steps to prevent from failure [viii]. FT quickly repair and replace the faulty devices to keep the system in working state. A fault tolerant system is associated to dependable system. Dependability contains few valuable requirements such as Reliability, Availability, Safety and Maintainability in a fault tolerant system: [xviii].

Availability: Availability concerned with working systems in time at given instant. System should be in ready state to facilitate users.

Reliability: Ability of a system to do job uninterruptedly with no chance of failure occurrence. Reliability concerned with time interval as an extremely reliable system works constantly without interruption for long time period.

Safety: Safety concerned with system failure when its operations are incorrect and cannot complete its processes correctly.

Maintainability: Maintainability of a system shows excessive measurement of accessibility when the system failure can be detected and fixed automatically.

A. *Types of Fault Tolerance*

Fault tolerance is categorized in two categories [x]. Hardware FT can be attained by implementing extra hardware such as communication links, processors and other resources. Software fault tolerance deals with fault messages when added into the system.

1) Hardware Fault Tolerance:

Hardware FT provide delivery of supplementary hardware backup like Memory, CPU, Power Supply Units and Hard disks. Hardware fault tolerance cannot deal with accidental interfering and errors within software programs. This technique have focused towards structuring systems that can recover themselves from the faults, and involves splitting a computing system into modules which can backed up with a self-protective redundancy to continue its function if failure occurs.

2) Software Fault Tolerance:

Software FT also apply dynamic or static redundancy approaches like hardware fault tolerance. Rollback recovery and checkpoints storage are software FT methods. The effectiveness of software FT is to develop an application to keep checkpoints repeatedly for required system.

B. Fault Tolerance Techniques

For real-time applications two types of Fault Tolerant (FT) polices are available.

1) Reactive Fault Tolerance Policy

Reactive approaches decrease the fault effects by taking essential actions. Some fault treatment policies can also be used to prevent faults from being reactivated.

2) Proactive Fault Tolerance Policy

Proactive approaches predict errors, faults and failures and replace the suspected components.

C. Fault Tolerance Techniques in Cloud Computing

Usually, one of the pillars of software reliability is fault avoidance. Since cloud architecture is very complex and built on cloud data centers that consist of multiple interconnected servers. Hence considering fault prevention techniques in developing stage is quite monotonous. Fault avoidance techniques help to detect and remove fault but not sufficient to achieve reliability, so fault tolerant system is necessary. FT in cloud computing is the capability to resist with changes occurred due to network congestions and hardware/software failures. Several factors to classify cloud computing faults are as follows: [xxxiii] xxvii, [xxxiv]

Network fault: Network faults occur due to the reason of packet corruption, destination failure, network partition, link failure, and packet loss etc.

Process faults: Software bugs and shortage of resources are reasons behind process fault.

Processor faults: When operating system crashes processor fault occurs.

Physical faults: Hardware fault are physical faults such as storage, memory and CPU failure etc.

Service expiry fault: Service expiry faults occurs if during processing a resource service time expires.

Media faults: Media head crashes and some other media factors cause's media faults.

Fault tolerance techniques in cloud environment are classified into various types[xi] as shown in Fig. 1.

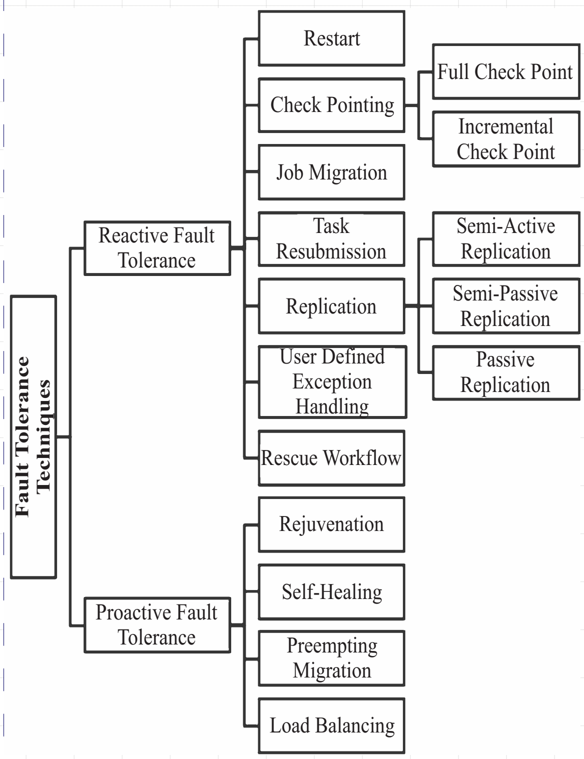


Fig. 1. Cloud Computing Fault Tolerance Techniques

1) Reactive Fault Tolerance Technique

Failure of application execution can be reduced by Reactive FT. It helps in recovery of system state from an unstable state to stable state so that the system can again start working to provide desired results. The major techniques under this category are as follows:

i) Restart

Restart functions on application level or on programs. A task is suspected to have aborted, failed and restarted, if not completed within a given time period[xxxv].

ii) Check pointing

In Check pointing system's state save in regular or irregular time intervals. Check pointing is done on every change in a system. At whatever time a job failure occurs, recent checked point state is used to restart the job. Check pointing technique is additionally categorized as follows.

- *Full Checkpoint*

Checkpoints are applied to a running process after a fixed time interval and the process state save on some media. If process failure occurs during execution then last saved checkpoint state is used to recover.

- *Incremental Checkpoint*

This mechanism helps in reducing the checkpoint overhead by saving those pages in which there have been any change instead of saving the whole process

iii) Replication Replication means producing copies of similar data and run them on multiple resources. Replication can be further classified as follows.

- *Semi-Active Replication*

Each replica is provided by input or state information. The primary and backup replica accomplish execution on the provided input and main replica produces the output. If the main replica goes down, backup replica produces the output. VM ware's FTis an example of semi-active replication group.

- *Semi-Passive Replication*

State information is moved to all the backup replicas in semi-passive replication mechanism. Main replica save input parameters between checkpoints. Backup replica save the newest state gained by primary replica. When primary replica fails backup replica starts and is updated as primary replica. Example of semi-passive replication is Remus.

- *Passive Replication*

Virtual machine instance state information is stored regularly as a backup. If failure occurs, FT manager restores the last saved state by recommission another Virtual Machine (VM) instance. The backup can share the state of some VM instances or can be used for a specific application. Example of passive replication is VM ware's High Availability solution.

iv) Job Migration

HA-Proxy is used to migratea task to another machine during failure.

v) Task Resubmission

The failed task is resubmitted to a new or same resource when failure of task occurred.

vi) User Define Exception Handling

User's predefined actions are used whenever fault is detected. Such as user define the behavior of a task when failure occurs.

vii) Rescue Workflow

Workflow is an order of connected steps that complete execution without gap or delay, earlier then successive stage may commence [v]. When a task fails, rescue workflow allows the task to continue until or unless it is not possible to execute without considering the task which failed.

2. Proactive Fault Tolerance Technique

Proactive FT procedures helps to neglect faults by foretelling before faults occur and replacing doubted constituents with other operational constituents before they actually occur. The major techniques are as follows:

i) Rejuvenation

Rejuvenation is issued before the system fails. The system is designed for sporadic reboots. Whenever any failure occurs the system is restarted with new clean and fresh start.

ii) Self-Healing

Self-healing method based on divide and conquer technique, several parts of an application runs on different VMs and failures are handled automatically.

iii) Preemptive Migration

In preemptive migration executing job is based on feedback loop control technique. Before migration system save the current state of job and then transferred to other system.

iv) Load Balancing

When memory and CPU load exceeds a specific limit, the load is migrated to other CPU.

Also, there are mainly some other techniques that can be used for fault tolerance.

These are:

- *Safety bag checks*

In safety bag checks the commands which does not fulfill the safety requirements are blocked.

- *Retry*

In order to complete the task on one virtual machine only, retry method is used and the task is implemented repeatedly on the same resource.

- *S-Guard*

S-Guard is based on rollback recovery and is less tempestuous to regular stream processing.

- *Alternate resource*

This technique allows to find an alternate resource for current virtual machine instead of retrying the same resource or changing virtual machine instance.

D. Fault Tolerance Techniques in Distributed Computing

Real time distributed systems are highly responsible on deadline such as robotics, grid and nuclear air traffic control systems. A system can fail if any mistake in real time distributed system is not accurately detected and recovered in time. Fault tolerance is a way to keep the system in working condition during failure. In distributing computing system hardware and software infrastructure delivers dependable, consistence and inexpensive high end computations[xxxvi]. Many FT techniques available in distributed environment are represented in Fig. 2.

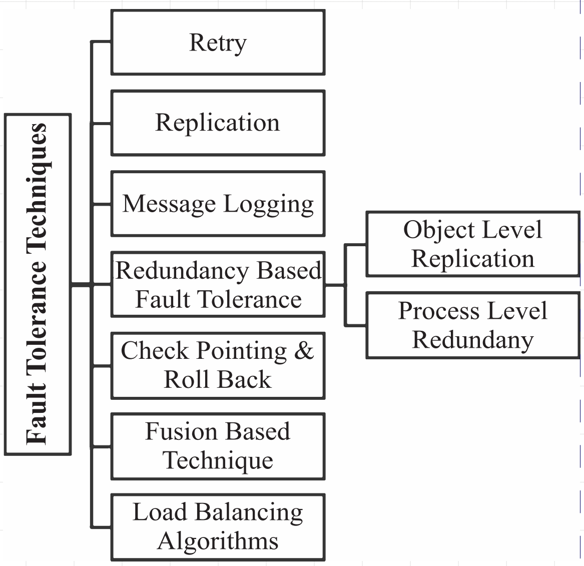


Fig. 2. Cloud Computing Fault Tolerance Techniques

i) Retry
The ordinary failure recovery mechanism in which the outcome will not be affected in succeeding repeats without considering the cause of failure[37].

ii) Replication
Replication is the method of creating and maintaining various copies of data objects and processes. In replication based procedure duplicate copies of a task runs on various machines until all replicated tasks are not crashed[xxxvii].

iii) Message Logging
In message logging technique all contributing nodes log received messages to constant memory so that a consistent global state is computed when a failure encountered. Algorithms of this methodology can be categorized into optimistic and pessimistic message logging[xxxviii].

iv) Redundancy based fault tolerance
Redundancy is having more than one functionally ready components of a system other than a component that actually provides the service. Process level and data or object level are the two levels in which we can implement the redundancy. This approach uses replication based technique to create redundancy[xxii].

- *Object Level Replication Based Technique*

Replication is making several copies of related data on the servers [xxxix]. In replication based technique, client request is promoted from a collection of replicas to one of replica. Object level replication is proxy based monitoring technique which has two approaches; Active or Passive and supports to improve performance of the system and remove complexity and overhead. It is a well-known method used to improve the availability. Replication increases redundancy and inconsistency in system. In this technique system will not fail if some nodes will fail and hence fault tolerance is accomplished as shown below in Fig. 3. [xviii].

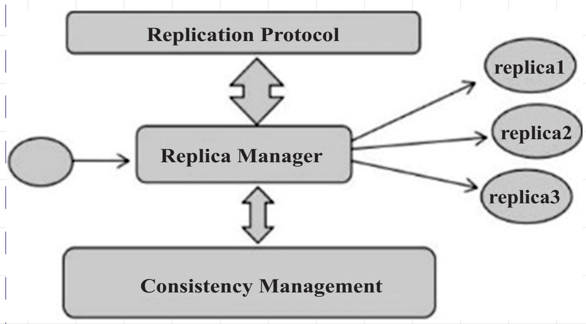


Fig. 3. Object Level Replication Based Technique

- *Process Level Redundancy*

Process Level Redundancy (PLR) is a method of creating duplicate processes for each application process as shown in Fig. 4 [xl]. PLR is transient fault tolerance which is software based technique. Transient faults are difficult to handle and identify and they are evolving as a serious matter for reliability of distributed environment. PLR analytically compares the processes to assure correct execution and permits the operating system to program the processes with presented hardware resources. PLR offers enhanced performance with 16.9 percent over current transient FT mechanism with additional fault detection overhead[xli].

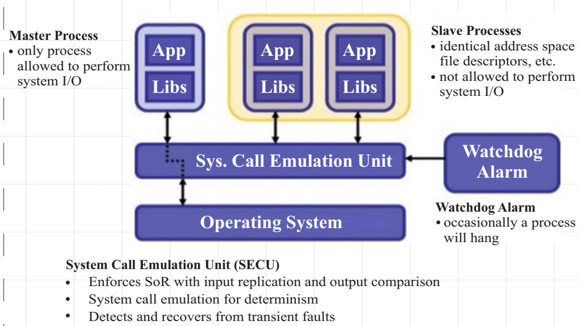
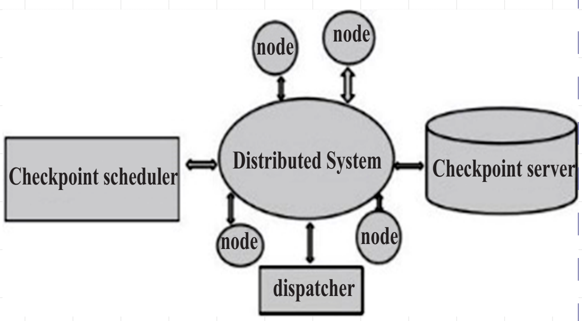


Fig. 4. Process Level Redundancy

v. Check Pointing and Roll Back

Checkpoint is more famous method to restore the process after failure at certain points. This technique saves the present stage of computation in constant memory to be used when node failure occurs. Checkpoints are periodically recognized during the execution of program. The checked or stored information contains the process state and register's value. The process rolls back to last saved state when error is detected. Fig. 5. gives an idea about this method[xviii].



vi. Fusion Based Technique

Fusion based techniques overcome the problem of backups created in replication method as managements of multiple backups is so much expensive. Fusion based technique is evolving as a famous procedure to deal with various faults as it requires a few backup machines which can be managed easily. Back up machines (fusion corresponding machine) [xlii] are cross product of original machines. Overhead increases during recovery from faults in fusion based technique. Fig. 6 represents the basic idea of fusion based technique[xxii].

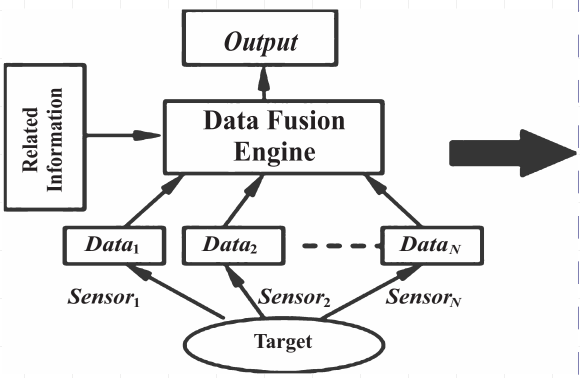


Fig. 6. Fusion Based Technique

vii. Load Balancing Algorithms

During execution time load balancing algorithms reallocate the processes among the processors. The algorithm improves the performance of the system by allocating task from heavy weighted task to light weighted task. Dynamic load balancing schemes has some drawback such as[xliii]:

- Runtime overhead; since the information of load is transported between processors.
- The transmission delay; since the job relocate to itself.
- Decision making process; the choice of processors and processes for transfer of job.

IV. COMPARISON

Choice and evaluation of a fault tolerance technique is based on some factors. These factors are consistency management, multiple faults handling, working procedures efficiency, multiple failure detection and appropriate performance for a system is the major task. The performance can enhanced by working on the critical issues discussed in this section on the basis of comparison performed in Table III.

A. Comparison of FT Techniques in Cloud Computing

Comparison of FT techniques in cloud computing is illustrated in Table I. A detailed comparison of both Reactive and Proactive polices is highlighted. Comparison is performed on the basis of tools, programming framework, environment used, type of fault and application type. Furthermore key features are also discussed in order to elaborate the comparison between techniques. Therefore on the basis of comparison as shown in Table I, it can be safely concluded that FT techniques in cloud are reliable and have the capability of detecting and handling multiple faults.

TABLE I
COMPARISON OF FT TECHNIQUES IN CLOUD COMPUTING

FT Techniques	Polices	Tools used	Programming Framework	Environment	Type of Fault Detected	Application Type	Key Features
Replication	Reactive	HA-Proxy, Hadoop, AmazonEC2	JAVA, Amazon Map, Amazon Machine Image	Virtual Machine	Node failure, Process failure	Load Balancing, Fault Tolerance	• The task runs on various VM Instances at the same time. • More resource utilization.
Check Pointing	Reactive	Assure, SHelp	JAVA, SQL	Virtual Machine	Application Failure	Fault Tolerance	• Effective for long running applications. • Provides efficient resource utilization
Retry	Reactive	Assure	JAVA	Virtual Machine	Host failure, Network failure	Fault Tolerance	• Job is retried on the same resource. • Time inefficient.
Job Migration	Reactive	Hadoop, HA-Proxy	JAVA, HTML, CSS	Cloud Environment	Application failure, Node failure, Process failure	Data intensive	• If job cannot be executed on same machine then it can be migrated to different machine. • More resource utilization • Time efficient
Task Resubmission	Reactive	AmazonEC2	Amazon Machine Image, Amazon Map	Cloud Environment	Application failure, Node failure	Load balancing, Fault Tolerance	• Job is retried on same or different resource. • Time inefficient and more resource utilization.
S-Guard	Reactive	Hadoop, AmazonEC2	JAVA, HTML, CSS	Cloud Environment	Application failure, Node failure	Data intensive	• Less tempestuous to ordinary stream processing. • Centered upon rollback recovery.
Self-Healing	Proactive	HA-Proxy, Assure	JAVA	Virtual Machine	Host failure, Network failure	Load balancing, Fault Tolerance	• Larger task is divided into subtasks. • Good overall performance.

A. Comparison of Fault Tolerance Techniques in Distributed Computing

Comparison of FT techniques in distributed computing is illustrated in Table II. A detailed comparison of Reactive FT techniques is highlighted. Comparison is performed on the basis of major factors such as working, multiple faults handling, performance, N-faults, multiple failure detector and consistency management. Techniques used for comparison are replication based technique, check pointing, roll back, fusion based techniques and process level redundancy.

TABLE II
COMPARISON OF FT TECHNIQUES IN DISTRIBUTED COMPUTING

Major Factors	Fusion Based Technique	Checking Pointing and Roll Back	Replication Based Technique	Process Level Redundancy
Working	Machine Back up	State saved for recovery on stable storage	Forwarded to replica	A collection of duplicate process
Multiple Faults Handling	Affected by number of back up machines	Affected by Check pointing scheduling	Affected by degree of replica	Affected by set of duplicate processes
Performance	Decrease due to faults as high recovery cost	Decrease by size and frequency of checkpoint	Decreases when number of replicas increases	Decrease when faults appears disappear
N-Faults	N backups machine required to handle extra N faults	Uncoordinated, Pessimistic and N level disk less used for N-1 Faults	N replicas ensure n-1 faults	Scaling the number of process and majority voting
Multiple Failure Detector	Reliable, Accurate and Adaptive.	Reliable, Accurate and Adaptive.	Reliable, Accurate and Adaptive.	Reliable, Accurate and Adaptive.
Consistency management	Has to be implemented among backup machines	Avoiding orphan messages	Strategies like active or passive replication	Can be easily implemented

C. Comparison of Common FT Techniques in Cloud and Distributed Computing

Comparison of FT techniques in both cloud and distributed computing is illustrated in Table III. A detailed comparison of Reactive FT techniques and common in both types of computing is highlighted. Comparison is performed on the basis of crucial features and type of fault detected. Comparison is done on retry, replication, check pointing, job migration and task resubmission.

TABLE I
COMPARISON BETWEEN CLOUD AND DISTRIBUTED COMPUTING FT TECHNIQUES

FT Techniques	Cloud Computing		Distributed Computing	
	Type of fault detected	Key Features	Type of fault detected	Key Features
Retry	• Host failure • Network failure	• Job is retried on the same resource. • Time inefficient.	• Task Crash failure	• Cannot handle user defined exceptions
Replication	• Process • Node Failure	• The task runs on various VM Instances at the same time. • More resource utilization.	• Host crash • Network failure	• Exploiting task's stateless and idempotent nature • Enhance performance and availability. • Multiple copies available • Inconsistency • Expensive
Check Pointing	• Application failure	• Effective for long running applications. • Provides efficient resource utilization	• Application failure	• Bigger application will take more time • Consistency. • Identification of user in some cases such as user triggered check pointing.
Job Migration	• Application failure • Node failure • Process failure	• If job cannot be executed on same machine then it can be migrated to different machine. • More resource utilization • Time efficient	• Host crash • Network failure • K crash	• Does not support diverse failure recovery mechanism
Task Resubmission	• Application failure • Node failure	• Job is retried on same or different resource. • Time inefficient • More resource utilization.	• Host failure • Network failure	• Cannot handle user defined exceptions

D. Discussion

It is found through intensive literature review that two basic polices of FT are proactive and reactive FT. However reactive FT policy is considered only for comparison of cloud and distributed computing. Some reactive fault tolerance techniques are common in both type of computing such as Retry, Replication, Check pointing, Job migration and task resubmission.

Retry in cloud computing is time inefficient and host and network failure are type of faults detected. Retry in distributed computing cannot handle user defined exceptions and task crash failure is a type of fault detected. When Replication is used, type of fault detected in cloud computing is process and node failure and in distributed computing is host crash and network failure. In Cloud computing replication can run task on various VM instances at a time and more resources are utilized. In distributed computing replication exploits task stateless and in idempotent nature. It enhances performance and availability but is inconsistent and expensive. Check Pointing is a technique in which application failure occur in both type of computing as a type of fault. Check pointing is effective for long running applications and provides efficient resource utilization when used in cloud computing and is consistent when used with cloud computing as well. Check pointing may provide identification of user in some cases. Application, node and process failure occur in cloud computing and host crash, network failure and K crash occur in distributed computing in case of Job Migration. Job migration is time efficient but utilizes more resources and job can be migrated to other machine in cloud computing. It does not support diverse failure recovery mechanism in distributed system. In cloud computing application and node failure may occur. Task resubmission is done which is time inefficient and it requires more resources as well as job is retried on same or different resource. In distributed computing task resubmission cannot handle user defined exception and host and network failure are types of faults that are detected.

V. CRITICAL EVALUATION

A comparison of common fault tolerance techniques in cloud and distributed computing is performed and critically evaluated as follows:

- *Cloud Computing*

The cloud systems still cannot provide there liability, robustness and quality required for the processing of numerous work flows[ii]. Fault tolerance techniques are complex and inter-dependent which need careful analysis and consideration. An autonomic fault tolerance mechanism is needed by using various constraints in cloud systems. Through the intensive literature review and comparative analysis several limitations of fault tolerance integration of cloud environment are stated below;

Different genres of systems in the cloud environment is the major difficulty to focus on the faults. During job migration job is transferred to different machines, if it cannot be executed on same machine. So an efficient fault tolerance technique is needed. FT technique will not be effective if different VMs run multiple instance of a job[xxxiv]. Replication is a technique which divides task on various machine and causes more resource utilization. When processing is completed on remote computers, error chances are increased. When task resubmission is used job is retried on same or different machine which is inefficient and utilizes more resources. Interpretation of changing system state is difficult since cloud environments are dynamically scalable, provide virtualized resources as a service. Check pointing will be difficult to save system state in regular and irregular time intervals.Host and network failure is the major issue of retry technique of cloud computing based on network connection. If network breaks down whole communication of data will stop.

- *Distributed Computing*

Taking checkpoint in distributed environment is a difficult task as any random set of checkpoints cannot be used for recovery. Since the checkpoints used for recovery must form a reliable global state. Replication enhances redundancy in a system. Duplicate copies give rise to inconsistency as various users may update diverse files. A huge number of replicas is required for high level of consistency since low quantity of replicas affect the performance and scalability. The main disadvantage is duplication of backups since the backups increase and the management cost upsurges to a great extent when faults are higher. Drawback of using retry or task resubmission technique is that it cannot handle user defined exceptions. Job migration does not support diverse failure recovery mechanism.

IV. LIMITATIONS

The study is limited to focus on reactive FT techniques only. A detailed study on proactive fault tolerance techniques is required to be done to pinpoint the most effective and potent technique.

V. CONCLUSION

Cloud and distributed computing has become influential computational technology over the last few years. Reliability and availability of the systems are of the most important requirements. Since a competent FT method is necessary to guards the system from failures or faults. FT system is one of the foremost parts of any system as it guarantees the system to continue its working during fault or failure. Two major components of fault tolerance are failure detection and recovery. In this study different stages of fault tolerance are highlighted. Hardware fault tolerance guarantees the extra backup of hardware such as CPU and memory. Software FT ascertain rollback recovery mechanisms and checkpoint storage. Every technique has some pros and cons. Some techniques are advantageous while the others are costly. In this study some of the fault tolerance techniques that are common in both cloud and distributed computing have been identified and critically evaluated.

It is concluded that reactive FT policy check-pointing is the optimal among all the techniques in both type of computing. The study also affirms that proactive FT policy redundancy is remarkable in terms of availability. In case of node agility or node failure check pointing improve performance and makes system fault tolerant. Furthermore, it depicts that there is necessity of a more effectual and reliable technique which is cheaper than the prevailing techniques. In all these techniques, accurate, reliable, and pure adaptive multiple failure detector mechanism is needed. To achieve reliability, future work will primarily be motivated to evaluate the benefits of FT services over a cloud and distributed environment.

REFERENCE

[i] T. Dimovski and P. Mitrevski. "*Connection Fault-Tolerant Model for distributed transaction processing in mobile computing environment in Information Technology Interfaces (ITI),*" Proceedings of the ITI 2011 33rd International Conference 2011. IEEE.

[ii] A. Bala and I. Chana, "*Fault tolerance-challenges, techniques and implementation in cloud computing.*"IJCSI International Journal of Computer Science Issues, 2012. 9(1): p. 1694-0814.

[iii] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. H. Katz, A. Konwinski, G. Lee, D. A. Patterson, A. Rabkin, I. Stoica and M. Zaharia. "*Above the clouds: A berkeley view of cloud computing*, Technical Report UCB/EECS-2009-28, EECS Department, University of California, Berkeley. 2009.

[iv] G. Vallee, K. Charoenpornwattana, C. Engelmann, A. Tikotekar, C. Leangsuksun, T. Naughton and S. L. Scott. "*A framework for proactive fault tolerance.*" Third International Conference on Availability, Reliability and Security, 2008. ARES 08. 2008. IEEE.

[v] Y. M. Essa, "*A Survey of Cloud Computing Fault Tolerance: Techniques and Implementation.*" International Journal of Computer Applications, 2016. 138(13).

[vi] A. Litvinova, C. Engelmann, and S. L. Scott. "*A proactive fault tolerance framework for high-performance computing.*"Proceedings of the 9th IASTED International Conference. 2009.

[vii] I. P. Egwutuoha, S. Chen and D. L. B. Selic, "*A fault tolerance framework for high performance computing in cloud.*" Proceedings of the 2012 12th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (ccgrid 2012). 2012. IEEE Computer Society.

[viii] R. Jhawar, V. Piuri and M. Santambrogio, "*Fault tolerance management in cloud computing: A system-level perspective.*" IEEE Systems

Journal, 2013. 7(2): p. 288-297.

[ix] W. Zhao, P. M. Smith, and L. E. Moser, "*Fault tolerance middleware for cloud computing*." IEEE 3rd International Conference on Cloud Computing (CLOUD). 2010. IEEE.

[x] P. D. Kaur and K. Priya, "*Fault tolerance techniques and architectures in cloud computing-a comparative analysis*." International Conference on Green Computing and Internet of Things (ICGCIoT). 2015. IEEE.

[xi] H. Agarwal and A. Sharma, "*A comprehensive survey of Fault Tolerance techniques in Cloud Computing*." 2015 International Conference on Computing and Network Communications (CoCoNet). 2015. IEEE.

[xii] A. Ganesh, M. Sandhya and S. Shankar, "*A study on fault tolerance methods in cloud computing*." Advance Computing Conference (IACC), IEEE 2014.

[xiii] B. Mohammed, M. Kiran, I. U. Awan and K. Maiyama, "*An Integrated Virtualized Strategy for Fault Tolerance in Cloud Computing Environment*." Ubiquitous Intelligence & Computing, Advanced and Trusted Computing, Scalable Computing and Communications, Cloud and Big Data Computing, Internet of People, and Smart World Congress (UIC/ATC /ScalCom/CBDCom/IoP/SmartWorld), 2016 Intl IEEE Conferences. 2016. IEEE.

[xiv] S. M. Ataallah, S. M. Nassar and E. E. Hemayed. "*Fault tolerance in cloud computing-survey*." 11th International Computer Engineering Conference (ICENCO), 2015. 2015. IEEE.

[xv] D. Mittal, and N. Agarwal, "*A review paper on Fault Tolerance in Cloud Computing*." Computing for Sustainable Global Development (INDIACom), 2015 2nd International Conference. 2015. IEEE.

[xvi] Z. Amin, H. Singh, and N. Sethi, "*Review on fault tolerance techniques in cloud computing*." International Journal of Computer Applications, 2015. 116(18).

[xvii] P. Gupta and S. Banga, "*Topic-Review of Cloud Computing in Fault Tolerant Environment With Efficient Energy Consumption*."IJSRM 2013.

[xviii] Sari, A. and M. Akkaya, "*Fault Tolerance Mechanisms in Distributed Systems*." International Journal of Communications, Network and System Sciences, 2015. 8(12): p. 471.

[xix] S. Bansal, S. Sharma, and I. Trivedi, "*A detailed review of fault-tolerance techniques in Distributed System*." International Journal on Internet and Distributed Computing Systems, 2011. 1(1): p. 33.

[xx] S. Haider, N. R. Ansari, M. Akbar, M. R. Perwez and K. M. U. Ghori, "*Fault tolerance in distributed paradigms*." International Conference on Computer Communication and Management, Proc. of CSIT. 2011.

[xxi] S. Haider and N. R. Ansari, "*Temperature based fault forecasting in computer clusters*." 15th Multitopic International Conference (INMIC), 2012. IEEE.

[xxii] P. Kaur and K. Mahajan, "*Various Techniques for Fault Tolerance in Distributed Computing System- A Review*." International Journal of Computer Science and Mobile Computing, 2015. 4(5, May 2015): p. 754 – 759

[xxiii] A. Shwethashree, D. V. Swathi, "*A Brief Review Of Approaches For Fault Tolerance In Distributed Systems*." International Research Journal of Engineering and Technology (IRJET) 2017. 4(2-Feb-2017).

[xxiv] A. Patil, A. Shah, S. Gaikwad, A. A. Mishra, S. S. Kohli and S. Dhage, "*Fault Tolerance in Cluster Computing System*." International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC), 2011. 2011. IEEE.

[xxv] Z. Qiu, and J. F. Pérez, "*Enhancing reliability and response times via replication in computing clusters*." *IEEE Conference on Computer Communications (INFOCOM), 2015*. 2015. IEEE.

[xxvi] R. Garg, and P. Kumar, "*A Review of Checkpointing Fault Tolerance Techniques in Distributed Mobile Systems*." International Journal on Computer Science and Engineering, 2010. 2(04): p. 1052-1063.

[xxvii] S. Dhasarathapandian, K. Dhanalakshmi and S. Somasundaram, "*A survey on various fault tolerant and resource management techniques in cloud computing framework*." Advances in Natural and Applied Sciences, 2017. 11(7): p. 301-306.

[xxviii] A. M. Sampaio and J. G. Barbosa, "*A Comparative Cost Study of Fault-Tolerant Techniques for Availability on the Cloud*." *International Symposium on Ambient Intelligence*. 2017. Springer.

[xxix] C. C. Meixner, C. Develder, M. Tornatore and B. Mukherjee, "*A survey on resiliency techniques in cloud computing infrastructures and applications.* IEEE Communications Surveys & Tutorials, 2016. 18(3): p. 2244-2281.

[xxx] D. Poola, M. A. Salehi, K. Ramamohanarao and R. Buyya, "*A Taxonomy and Survey of Fault-Tolerant Workflow Management Systems in Cloud and Distributed Computing Environments*." Software Architectures for Cloud and Big Data Book, 2016.

[xxxi] A. Dave, B. Patel and G. Bhatt, "*Load balancing in cloud computing using optimization techniques: A study*." International Conference on Communication and Electronics Systems

(ICCES), 2016. IEEE.

[xxxii]P. K. Patra, H. Singh, R. Singh, S. Das, N. Dey, A. D. C. Victoria, "*Replication and Resubmission Based Adaptive Decision for Fault Tolerance in Real Time Cloud Computing: A New Approach*." International Journal of Service Science, Management, Engineering, and Technology (IJSSMET), 2016. 7(2): p. 46-60.

[xxxiii]L. M. Vaquero, L. R. Merino, J. Caceres and M. Linder, "*A break in the clouds: towards a cloud definition*. ACM SIGCOMM Computer Communication Review, 2008. 39(1): p. 50-55.

[xxxiv]G. Chen, H. Jin, D. Zou, B. B. Zhou, W. Qiang and G. Hu, "*Shelp: Automatic self-healing for multiple application instances in a virtual machine environment*." IEEE International Conference on Cluster Computing (CLUSTER), 2010. IEEE.

[xxxv]K. Wolter, "*Stochastic Models for Fault Tolerance: Restart, Rejuvenation and Checkpointing*." Springer Science & Business Media, 2010.

[xxxvi]A. Costan, C. Dobre, F. Pop, C. Leordeanu and V. Cristea, "*A fault tolerance approach for distributed systems using monitoring based replication*. IEEE International Conference on Intelligent Computer Communication and Processing (ICCP), 2010. 2010. IEEE.

[xxxvii]S. Hwang and C. Kesselman, "*A flexible framework for fault tolerance in the grid*." Journal of Grid Computing, 2003. 1(3): p. 251-272.

[xxxviii]A. P. Sistla and J. L. Welch, "*Efficient distributed recovery using message logging*." Proceedings of the eighth annual ACM Symposium on Principles of distributed computing. 1989. ACM.

[xxxix]M. Wiesmann, F. Pedone, A. Schiper, B. Kemme and G. Alonso, "*Understanding replication in databases and distributed systems*." 20th International Conference on Distributed Computing Systems, 2000. IEEE.

[xl] A. Shye, T. Moseley, V. J. Reddi, J. Blomstedt and D. A. Connors, "*Using process-level redundancy to exploit multiple cores for transient fault tolerance*." 37th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, 2007. DSN'07. 2007. IEEE.

[xli] A. Shye, J. Blomstedt, T. Moseley, V. J. Reddi and D. A. Connors, "*PLR: A software approach to transient fault tolerance for multicore architectures*. IEEE Transactions on Dependable and Secure Computing, 2009. **6**(2): p. 135-148.

[xlii] V. K. Garg, "*Implementing Fault-Tolerant Services Using State Machines: Beyond Replication*."DISC. 2010. Springer.

[xliii] R. Singh and M. Dave, "*Using host criticalities for fault tolerance in mobile agent systems*."2nd IEEE International Conference onParallel Distributed and Grid Computing (PDGC), 2012 2012. IEEE.

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Scheduling Hard Real-Time Tasks in Cloud Computing Using Differential Evolution Algorithm

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Abstract-The cloud computing environment, in which virtual resources/machines are made available over the Internet, is a smart option for many real-time applications. However, there are a number of critical problems that need to be addressed to successfully use cloud computing for real-time applications. One of the challenges is the allocation and scheduling of real time tasks on the virtual machines. In this paper, we modeled the task allocation and scheduling problem as a binary optimization problem. The differential evolution (DE) algorithm has been customized to solve the problem. A detailed experimental study has been conducted to investigate the solution quality of DE algorithm. The results show that DE performs better than the greedy and the genetic algorithm (GA).

Keywords-Cloud Computing, Real-time Systems, Task Scheduling, Genetic Algorithm, Differential Evolution

I. INTRODUCTION

Cloud computing enables virtual access to shared computing over the Internet on the basis of usage cost [i] making it an appealing option for many organizations [ii - iii]. Cloud-computing services are offered in three standard models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) [i]. In IaaS model, a service provider provides automated and scalable computing infrastructure by hosting applications and making them available to customers on the Internet.

A PaaS model offers hardware resources such as server & networking infrastructure and software resources such as operating system & application programs for the application development. The SaaS deals with the management and deployment of software through a virtual environment that can be rented by the users as per demands. This study focuses on IaaS model in which cloud resources can be subscribed in the form of Virtual Machines (VMs) to execute a number of real-time tasks. A VM provides an application environment comprising of a certain computational power, storage, and communication resources. The VMs may be heterogeneous, that is, they may have different computational capabilities. The cloud computing is a smart option for many real-time applications (e.g., object detection, navigation control, complex applications, monetary systems, etc.) [iv]. A real-time application may comprise of a number of tasks precedence constraint and deadlines, that is, a task can execute only after the completion a number of other tasks. A careful scheduling of tasks on VMs is important to utilize computing resources effectively [v]. This gives rise to a well-known NP-complete problem referred as task-allocation problem [vi].

This paper models the task allocation and scheduling as an optimization problem. The model captures both the processing and data transmission costs. The task precedence relationships and deadlines are considered as constraints. This paper adapts differential evolution (DE) algorithm for the problem. A two-dimensional topology preserving solution encoding scheme is used. The DE algorithm has been empirically studied and compared with a number of other algorithms for their relative solution quality.

The remaining paper is organized as follows. Literature review is presented in Section 2. Section 3 presents our system model and problem. The proposed algorithm is presented in Section 4. The performance and comparison of results is given in Section 5. Finally, conclusion is given in Section 6.

II. LITERATURE REVIEW

Numerous research studies on task allocation and scheduling in cloud-computing environment have been reported in the literature. These studies are primarily focused on optimized use of energy/power, make span, economic cost, and achieving the required level of quality of service (QoS) [vii - x]. A scheduling algorithm improvising QoS metrics, such as load balancing, average latency, and make span, have been proposed by Wu et al. [viii]. In their approach, tasks (processes) having higher priority are allocated first. A multi-objective QoS workflow scheduling algorithm is proposed in [xi]. Jang et al. proposed a genetic algorithm to deal with task scheduling problem and maximize overall QoS [xii]. The profit maximization was addressed by Lee et al. [ix] who worked on maintaining adequate level of QoS by using scheduling algorithms.

An efficient task-scheduling algorithm based on non-linear programming method is proposed by Razaque et al. [xiii].They used the availability of network bandwidth for task scheduling and allocation to VMs. In [xiv], Min-Max and Min-Min algorithms are proposed. The algorithms proposed in [xv] by Li. et al. dynamically adjust resource allocation at the run time. A differential evolution algorithm to reduce make span and overall cost is proposed by Tsai et al. [xvi]. Cuckoo Search Algorithm, Bat algorithm and many other meta heuristics algorithms have also been proposed for the task allocation problem [xvii - xx]. All the work mentioned before does not explicitly models allocation and scheduling of real-time tasks.

Liu et al. [xxi] proposed a procedure for dealing with real-time tasks. The objective is to maximize the total utility in a non-preemptive scheduling environment. Their proposed algorithm showed better performance as compared to traditional scheduling algorithms and Earliest Deadline First (EDF) strategy. The real-time task allocation problem was addressed by Kumar et al.[iv]. The constrained optimization modeling was based on execution speed and cost on different VMs. The authors then proposed a temporal overlap using a greedy approach. They, however, did not consider the communication cost in their model. Deniziak [xxii] proposed the scheduling scheme of soft and real-time applications. The objective is to reduce the total cost by using genetic algorithm.

Unlike the previous work, our work is focused on minimizing total communication and processing costs for real time tasks. The operators of differential evolution algorithm have been specialized for the problem and two dimensional solution encoding scheme.

III. SYSTEM MODEL AND PROBLEM

Suppose there are finite number of real-time tasks, $T = \{t_1, t_2, \ldots t_N\}$ to be assigned and scheduled on M virtual machines. The computation speed (measured in clock cycles/unit time) and cost of a virtual machine m_k are denoted by s_k and c_k respectively. Each task $t_i \in T$ is characterized a pair (w_i, d_i) where w_i is workload (total clock cycles required) and d_i is the deadline. Task in T may have precedence relationship. The quantity of data transferred from t_i to t_j is denoted by v_{ij}. We further define $Pre(t_i) = \{t_j | t_j \in T, e_{ji} \in E\}$ and $Succ(t_i) = \{t_j | t_j \in T, e_{ij} \in E\}$ as sets of tasks that are immediate predecessors and are immediate successors of t_i, respectively. Also, $aPre(t_i) = \{t_j, t_k, t_l, \ldots, t_p\}$ is the set of predecessors of task t_i, if $\{e_{jk}, e_{kl} \ldots e_{(p-1)p}, e_{pi} \in E$ and $Pre(t_j) = \phi\}$.

Now, the time required to execute task $t_i \in T$ on a virtual machine m_k, denoted by ET_{ik}, is given by [xx- xxiv]

$$ET_{ik} = \frac{w_i}{s_k} \tag{1}$$

Where s_k denotes is the speed of the VM m_k. The *Latest Start Time* (LST_i) of task t_i and *Earliest Start Time of task* t_i (EST_i) can be given by Equation (2) and (3), respectively [xx- xxiv].

$$LST_i = d_i - ET_{ik} \tag{2}$$

$$EST_i = \begin{cases} \max\limits_{j \in Pre(t_i)} \{FT_j\} \\ 0 \quad \text{if } Pre(t_i) = \phi \end{cases} \tag{3}$$

If ST_{ik} and Et_{ik} denote the actualstart time and processing time of task t_i on the VM m_k, respectively, then the finish/completion time of task t_i (FT_i) is can be calculated by the following equation [xx]:

$$FT_i = ST_i + ET_{ik} \tag{4}$$

Since a cloud service providers charge a cost of C_k for leasing a VM m_k for at least L units of time in minutes and hours etc. irrespective of the actual usage, the execution cost of task t_i on m_k, in case no other task is reserved on the same VM, is given by

$$EC_{ik} = \left\lceil \frac{ET_{ik}}{L} \right\rceil \times C_k \tag{5}$$

The total cost of executing all the tasks is given

$$CC(X) = \sum_{i=1}^{N} \sum_{j \in Pre(t_i)} \sum_{k=1}^{M} \sum_{l=1}^{M} x_{ik} \times x_{jl} \times v_{ij} \times b_{kl} \tag{6}$$

Where X represents a matrix of MXN order whose entry $x_{ik} = 1$ if task t_i is booked on VM m_k, and $x_{ik} = 0$ otherwise. The parameter b_{kl} denotes the data transmission cost/unit data between VMs m_k and m_l. If two VMs reside on the same server, then data transmission cost is taken as zero

The total execution cost for the task set T is given by:

$$EC(X) = \sum_{i=1}^{N} \sum_{k=1}^{M} x_{ik} \times EC_{ik} \tag{7}$$

Total cost, $TC(X)$, can be calculated by adding

$CC(X)$ and $EC(X)$, that is

$$TC(X) = CC(X) + TC(X) \tag{8}$$

The objective is finding an X that minimizes *TC(X)* [xx - xxiv].

That is,

Minimize $TC(X) = CC(X) + TC(X)$
Subject to:

$$\sum_{k=1}^{M} x_{ik} = 1 \text{ for each } i,\ 1 \le i \le N \tag{9}$$

$$FT_i \le d_i \text{ for each } i,\ 1 \le i \le N \tag{10}$$

$$ST_i \ge EST_i \text{ for each } i,\ 1 \le i \le N \tag{11}$$

The limitation of reserving and scheduling each task on exactly one VM is represented by equation (9). The constraint (10) specifies that each task must meet its deadline and the last constraint (11) ensures that a task can start only after predecessor tasks.

IV. PROPOSED ALGORITHM

Differential Evolution (DE) is a population-based algorithm adapted to solve our problem [xxii]. The algorithm itself consists of three main operators, namely the mutation, crossover and selection. The mutation and crossover operators are used to produce new vectors (solutions), and the selection operator determines whether a vector can move to the next iteration or not. Since it is a population-based algorithm, the initialization of solutions is required to start executing. Fig. 1 shows the adapted DE algorithm. The solution encoding, generation of initial solution, and DE specific operators are discussed in the following sub-sections.

Step 1 Generate initial population
Step 2 Evaluate the fitness of each vector
Step 4 while (not termination condition) {
Step 5for each parent x_i^k {
Select the target vector x_3^k randomly
Select two distinct vectors x_1^k, x_2^krandomly
for each element *j* produce the trial vector
v_i^{k+1} using

$$v_{ij}^{k+1} = x_{3j}^k + F(x_{1j}^k - x_{2j}^k)$$

}
Step 6 for each element *j* produce the offspring u_{ij}^{k+1} using

$$u_{ij}^{k+1} = \begin{cases} v_{ij}^{k+1} & if\ rand < CR \\ x_{ij}^k & Otherwise \end{cases}$$

Step 7 Replace x_i^k with u_{ij}^{k+1} if u_{ij}^{k+1} is feasible and better

}

Fig. 1. The proposed DE algorithm

A. *Solution representation and initial population generation*

In the proposed DE algorithm, a solution is embodied by a two dimensional array. The first row of a chromosome represents tasks in their topological order (from left to right) and the second row represents the corresponding virtual machine number on which a task is to be executed, as shown in Fig. 2. The topological ordering of tasks ensures that a schedule conforms to the task precedence constraint. Initial population is generated (step 1 of the DE algorithm) using the algorithm given in [xxiii].

Task	T0	T1	T2	T3	T4
VM	1	5	0	2	5

Fig. 2. A representation of schedules in terms of a chromosome.

B. *Mutation Operator*

For each parent x_i^k in generation k, a target vector x_3^k is selected along with two other vectors x_1^k and x_2^k belonging to the same generation k, with $i_1 \neq i_2 \neq i_3$ (Step 5 of the DE algorithm). The mutant vector v_1^{k+1} is calculated at step 5 using the following formula:

$$v_i^{k+1} = x_3^k + F(x_1^k - x_2^k) \tag{13}$$

Where, F (($F \in [0, 2]$) is the mutation factor used to control the amplification of the differential variation. Fig. 3 shows an example of producing a mutant vector. Since our problem is a discrete optimization problem, we take only the absolute integer part of each v_{ij}^{k+1} to denote the virtual machine number.

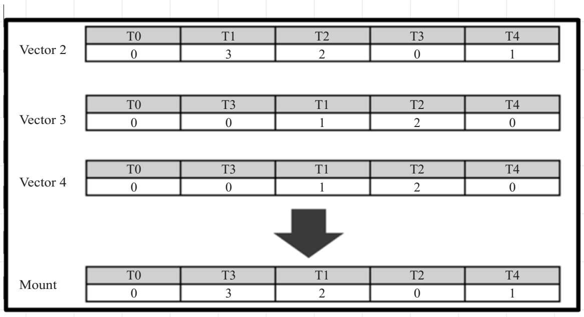

Fig. 3. DE mutation performed on three distinct vectors assuming F=0.5

C. *Crossover operator*

The crossover operator combines elements from parent x_i^k and the mutant vector v_i^k in order to create an offspring u_i^k (Step 6). This step is applied with a probability *CR* using the following formula:

$$u_{ij}^{k+1} = \begin{cases} v_{ij}^{k+1} & if\ rand < CR \\ x_{ij}^{k} & Otherwise \end{cases} \quad (14)$$

D. Selection Operator

If the offspring u_{ij}^{k+1} is feasible, its fitness is evaluated and compared with the fitness value of the parent vector x_i^k . If the fitness of offspring u_{ij}^{k+1} is higher than that of parent's fitness value, then offspring u_{ij}^{k+1} replaces the parent (Step 7). That is

$$x_i^{k+1} = \begin{cases} u_i^{k+1} & if\ fitness(u_i^{k+1}) < fitness(x_i^k) \\ x_i^k & Otherwise \end{cases} \quad (15)$$

V. Simulation Results and Discussions

The performance of the adapted DE algorithm was investigated and its performance was compared with standard genetic algorithm and greedy algorithm [xxiv]. All the algorithms were programmed using C++ and executed on computers with Intel *i*7 processor, 8 GB RAM and Microsoft Windows 10 platform.

As per other studies a standard approach of data generation was adopted. The set of tasks to be scheduled were generated as DAGs using the TGFF utility [xxiv]. The number of tasks in a DAG was selected randomly between 10 and 300. The workload were generated for the tasks within the interval of [10, 4500] as used in a previous study [iv]. The tasks were also assigned deadlines using the technique suggested in [xxv]. The volume of data exchanged between tasks was randomly generated and was in the range 50 - 1500. The total number of accessibleVM was 50. Different set of values were assigned randomly for cost and speed of the virtual machine as given in [iv, xvi, xxvi]. The transmission costs/unit data between the VM were also generated in the range 1 - 5.

The greedy algorithm for each input combination was executed once. However the genetic algorithm and the DE algorithms were run for 30 times for each input combination. This is a standard practice for analyzing the performance of iterative heuristics. The parameters used for GA and DE are given in Table I.These parameters were selected after performing parameter sensitivity analysis for both GA and DE for DAGs having 5, 10 and 15 tasks each.

TABLE I
Parameter Settings for GA and DE

Algorithm	Parameter Setting
Genetic Algorithm	Population size: 40 Parent selection: Roulette-wheel Crossover rate: 0.8 Mutation rate: 0.05
Differential Evolution	Population size: 30 Mutation factor: 0.5 Crossover rate: 0.8

Table II give value of the cost function obtained by each algorithm. For DE and GA, the average cost for 30 independent run is reported. The results show that performance of the greedy algorithm is the worst as compared to GA and DE for all the test cases. It can also be observed that DE outperforms both the greedy as well as GA algorithm in terms of quality of the solution. The Wilcox on matched pair test indicates that solution quality of DE algorithms is statistically significant. In addition, the results also showed that DE's performance is more stable among different independent runs as is evident from with a low standard deviation value as compared to that of GA. The percentage improvement of DE over greedy and GA is shown in Table III. The results indicate that the improvements achieved by DE over the greedy algorithm were extensively high 16.65% to 45.87%. The percentage improvements of DE over GA were in the range of over 5.17% to almost 15.99%. The results indicated that all improvements achieved by DE were statistically significant.

TABLE II.
Comparison of Costs of Greedy, GA, and DE Algorithms

No. of Tasks	Greedy	GA	DE
10	41.28	30.52	28.30
20	94.13	79.35	75.45
40	210.24	162.71	149.26
80	438.82	345.60	316.27
100	480.91	405.35	349.47
200	689.62	632.15	591.20
300	1015.36	892.72	834.75

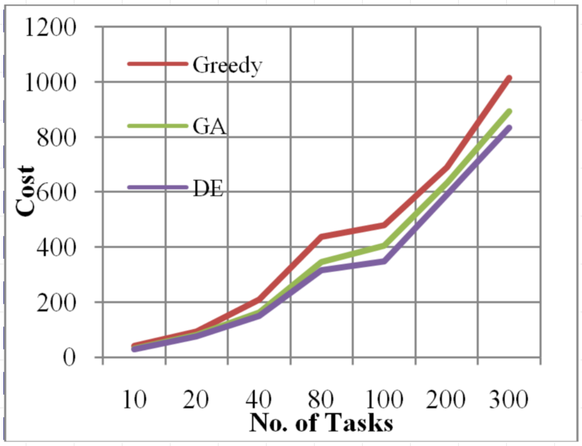

Fig. 4. Graph plotted using No. of Tasks and Cost of Algorithms

TABLE III
PERCENTAGE IMPROVEMENT OBTAINED BY DE OVER GREEDY, AND GA

Tasks	DE vs. Greedy	DE vs. GA
10	45.87	7.84
20	24.76	5.17
40	40.85	9.01
80	38.75	9.27
100	37.61	15.99
200	16.65	6.93
300	21.64	6.94

V. CONCLUSION AND FUTURE WORK

Task allocation and scheduling on virtual machines in a cloud computing environment is a well-known NP-hard problem. This paper presented the differential evolution algorithm customized for solving the task allocation and scheduling problem. The solution encoding scheme and various operators of DE are presented. The experimental results show the performance of DE is significantly better than the performances of the greedy as well as GA algorithms in terms of solution quality. As a future work, we intend to test the performance of the DE algorithm with other population based algorithms. Developing hyper heuristics can also be another future direction.

REFERENCES

[i] J. Z. Luo, J. H. Jin, A. B. Song, and F. Dong, "Cloud Computing: Architecture and Key Technologies", Journal of China Institute of Communications, Vol. 32, No. 7, pp.3-21, 2011.

[ii] M. Abdullahi, M. Ngadi, "Hybrid Symbiotic Organisms Search Optimization Algorithm for Scheduling of Tasks on Cloud Computing Environment", PLoSone, Vol. 11, pp. 6-26, 2016

[iii] M. Armbrust, A. Fox, R. Griffith, A. Joseph, R. Katz, A. Konwinski, M. Zaharia, "A view of cloud computing", Communications of the ACM, Vol. 53, No. 4,pp. 50-58, 2010.

[iv] K. Kumar, J. Feng, Y. Nimmagadda, Y. H. Lu, "Resource allocation for real-time tasks using cloud computing", Proceedings of IEEE 20th International Conference on Computer Communications and Networks (ICCCN), Maui, HI, USA, pp. 1–7, 2011.

[v] A. I. Awad, N. A. El-Hefnawy, H. M. Abdelkader, "Enhanced Particle Swarm Optimization for Task Scheduling in Cloud Computing Environments", Procedia Computer Science, Vol. 65, pp. 920-929, 2015.

[vi] N. J. Navimipour, L. M. Khanli, "The LGR method for task scheduling in computational grid", Proceedings of International Conference on Advanced Computer Theory and Engineering, Phuket, Thailand, pp. 20-22 pp. 1062–1066, 2008.

[vii] H. Chen, X. Zhu, H. Guo, J. Zhu, X. Qin, J. Wu, "Towards energy-efficient scheduling for real-time tasks under uncertain cloud computing environment", Journal of Systems and Software, Vol. 99, 20–35, 2015.

[viii] X. Wu, M. Deng, R. Zhang, B. Zeng, S. Zhou, "A task scheduling algorithm based on QoS-driven in cloud computing", Procedia Comput. Sci. Vol. 17, pp. 1162–1169, 2013.

[ix] Y. C. Lee, C. Wang, A. Y. Zomaya, B. B. Zhou, "Profit-driven scheduling for cloud services with data access awareness", Journal of Parallel and Distributed Computing , Vol. 72, No. 4, pp. 591-602, 2012.

[x] S. K. Panda, I. Gupta, P. K. Jana, "Allocation-aware Task Scheduling for Heterogeneous Multi-cloud Systems", Procedia Computer Science, Vol. 50, pp. 176-184, 2015.

[xi] A. Sangwan, G. Kumar, S. Gupta, "To Convalesce Task Scheduling in a Decentralized Cloud Computing Environment, Review of Computer Engineering Research,Vol. 3, No. 1, pp. 25-34, 2016

[xii] S. Jang, T. Kim, J. Kim, J. Lee, "The study of genetic algorithm-based task scheduling for cloud computing", International Journal of Control and Automation, Vol. 5, No. 4, pp. 157-162, 2012.

[xiii] A. Razaque, N. Vennapusa, N. Soni, G. Janapati, "Task scheduling in Cloud computing", Proceedings of IEEE Long Island Systems, Applications and Technology Conference (LISAT), Farmingdale, NY, USA, pp.1-5, 2016.

[xiv] S. Sindhu, "Task scheduling in cloud computing", International Journal of Advanced Research in Computer Engineering & Technology, 2015, Vol. 4, pp. 3019–3023, 2015.

[xv] J. Li, M. Qiu, Z. Ming, G. Quan, X. Qin, Z. Gu, "Online optimization for scheduling preemptable tasks on IaaS cloud systems", Journal of Parallel and Distributed Computing, Vol. 72, No. 5, pp. 666-677, 2012.

[xvi] J. T. Tsai, J. C. Fang, J. H. Chou, "Optimized task scheduling and resource allocation on cloud computing environment using improved differential evolution algorithm", Computers & Operations Research, Vol. 40, No. 12, pp. 3045-3055, 2013

[xvii] S. Pandey, L. Wu, S. Guru, R. Buyya, "A particle swarm optimization-based heuristic for scheduling workflow applications in cloud computing environments", Proceedings of 24th IEEE International Conference on Advanced

Information Networking and Applications (AINA), Perth, Australia, pp. 400–407, 2010.

[xviii] N. Navimipour, f. Milani, "Task scheduling in the cloud computing based on the cuckoo search algorithm", International Journal of Modeling and Optimization 5, Vol. 5, no. 1, pp. 44, 2015

[xix] S. Raghavan, P. Sarwesh, C. Marimuthu, K. Chandrasekaran, "Bat algorithm for scheduling workflow applications in cloud", Proceedings of International Conference on Electronic Design, Computer Networks & Automated Verification (EDCAV), Shillong, India, pp. 139-144, 2015.

[xx] R. A. Bahlool, "Optimized Real-time Tasks Allocation in Cloud Computing Environment", MSc Thesis, University of Bahrain, 2016

[xxi] S. Liu, g. Quan, s. Ren, "On-line scheduling of real-time services with profit and penalty" Proceedings of ACM Symposium on Applied Computing, Taichung, Taiwan, pp. 1476-1481, 2011.

[xxii] S. Deniziak, L. Ciopinski, G. Pawinski, K. Wieczorek, S. Bak, "Cost optimization of real-time cloud applications using developmental genetic programming", Proceedings of IEEE/ACM 7th International Conference on Utility and Cloud Computing (UCC), London, UK, pp.774-779, 2014.

[xxiii] K. V. Price, R. M. Storn, J. A. Lampinen,."The differential evolution algorithm", Differential evolution: a practical approach to global optimization, pp.37-134, 2005.

[xxiv] A. Mahmood, S. A. Khan, (2017),"Hard Real-Time Task Scheduling in Cloud Computing Using an Adaptive Genetic Algorithm", Computers, Vol. 6, No. 2, pp.15, 2017.

[xxv] R. P. Dick, D. L. Rhodes, W. Wolf, "TGFF: Task graphs for free" Proceedings of 6th International Workshop on Hardware/software Codesign, Seattle, WA, USA, pp.97-101, 1998.

[xxvi] C. W. Tsai, W. C. Huang, M. H. Chiang, M. C. Chiang, C. S. Yang, "A hyper-heuristic scheduling algorithm for cloud", IEEE Transactions on Cloud Comput. Vol. 2, pp. 236-250, 2014

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A Security Model for IoT based Systems

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Abstract-Internet of things is novelemerging Internet based system for the exchange of information to provide efficient services regardless of time and place. IoT technology is playing a vital role in the current environment due to its wide spread applications in every domain of life like industrial, social, health care and domestic applications. IoT directly affects the security and privacy of all its involved entities as reported in the literature. Therefore, this study aims to propose a Security Enabled Model to provide secure end to end communication in IoT environment. Intensive literature review has been conducted to identify and investigate various security and privacy challenges encountered by the IoT environment. Proposed model ensures security at each layer of IoT. These layers includes I) perception layer which provides authentication process for the identification of fake objects ii) network layer that emphasis on data security process through cloud platform and iii) application layer which provides authentication for the end users. Results show that small sensing devices need to be highly focused in order to make them more secure and lightweight encryption techniques need to be developed. Furthermore, sensing devices are required to be more secure and protected from unauthorized access.

***Keywords-*:** IoT, Object Identification, Authentication, Security Enabled Model

I. Introduction

Internet of Things (IoT) include Smart devices, sensor networks and wearable devices with the purpose of exchanging information and services whereas sensor networks are the key for creating smart environments [i-v]. IoT systems are growing rapidly due to the rapid increment of wireless networks and enhanced range of sensing devices. IoT technology deals with millions and billions of sensing objects, machines and virtual entities that interact with each other. IoT technology is rapidly gaining attention by the practitioners and it is expected to have more than 100 billion interconnected IoT devices by 2020 [vi-ix]. In IoT data is collected from sensing objects that contain bulk data of structured or un-structured format that is managed through cloud platform services [x]. Collected data is transferred from objects to server for the storage and processing so that data would be available for visualization. IoT data resort towards cloud for the outsourced processing, storage that has brought a series of emerging challenging of security and privacy [ii, xi-xiii].

IoT is heterogeneous in nature (as shown in Figure 1) that increases complexity of security and privacy mechanisms so enhanced security protocols and crypto system are required [xiv] in order to ensure the secure interaction between the objects. Therefore, security is one of the key challenges that must be inhibited in order to drive IoT in real world. Moreover, security incidences that are resulted from bugs are software vulnerability that can cause huge damage to the whole networks. Vulnerability leads to a lot of more backdoor issues and let hackers attack on the network. Security challenges of IoT technology include object identification for fake objects, authentication, trust management, data confidentiality, network security and access control [i, ii, vi, xi, xv-xxxi]. The first malware issue in IoT was reported in 2013 [xxx] which highlighted the need to create a secure environment for small IoT objects to protect them from malicious attacks. Traditional symmetric and asymmetric encryption key distribution schemes cannot be applied to billions of IoT devices. Hence, a novel reliable and scalable key management scheme is required that leads to seamless interoperability between different networks and is vital for IoT system integration of big-data in cloud environment [xxiv, xxxii-xxxiv]. Therefore, this study focused on the identification and analysis of security challenges encountered by each layer of IoT architecture. Furthermore, this study contributes to fashion by proposing a novel model in order to cope with the end to end security challenges confronted by the IoT technologies through identification of each object.

This study is alienated as section 2 provides literature review of current security and privacy work in IoT, section 3 discusses identified challenges and Section 4 delineates the proposed model. Whereas Section 5 elaborates future work and Section 6 concludes the paper.

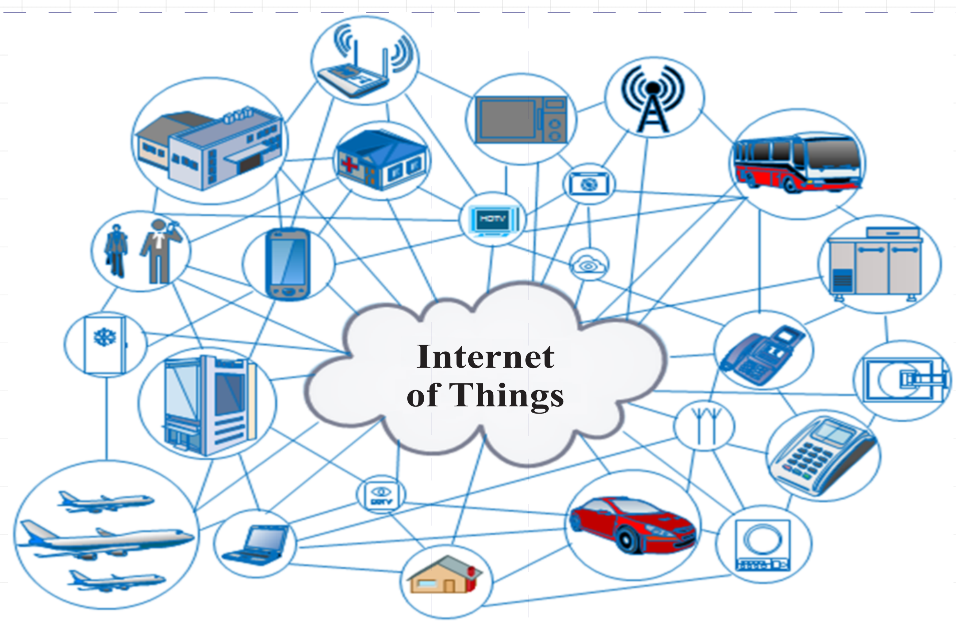

Fig. 1. Fundamental elements of IoT

II. Literature Review

The term IoT was coined by Kevin Ashton [ii, xii, xxxv-xxxvii] in late nineties. According to another definition [v] IoT is"A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these 'smart objects' over the Internet, query their state and any information associated with them, taking into account security and privacy issues". To Extend IoT include various technologies and sensors by which it facilitates exchange of things, such as goods, information and services between machines and human beings in more reliable and secure way. IoT sensor objects have simple structure, processors and high heterogeneity. IoT system collects real time data from Radio Frequency Identification Devices (RFID), public security, Laser Printer and Scanners, Global positioning Systems (GPS), logistics, intelligent building, healthcare including sensors such as body sensors, infrared sensors, Smart Meter, environmental monitoring and other embedded sensing devices etc. [ii, viii, xv, xvii, xxvii, xxxi, xxxviii-xl]. Then collected data is processed for identification, control of objects and management. IoT technology must have three characteristics that include reliable transmission of data over the network, intelligently processing the data before storing in data centers and comprehensive perception of store data from everywhere [xxxi].The cost of sensor objects effect all the working, if cost is too low it reduce the performance of overall network and make it less secure. High cost sensor objects improve the performance as well as increase cost of network maintenance. Fog computing is a new emerging trend which aims to reduce persuading service through moving the cloud services towards edge of the network. In recent years fog computing vision and key qualities have been outlined by many researchers. Fog computing is a stage to convey a rich portfolio of new applications and services at the edge of the system [xlii, xliii]. Generally, IoT structure is separated in three type of layers that include Application, Network or Transmission and Perception layer [xxxi]. Perception Layer intends to acquire, collect, process and store data from different wired or wireless objects [xli]. Data is collected from physical world that include different sensing devices, networks, RFID tags, wearable devices etc. Moreover, these devices monitor state of the physical environment and store it continuously [xii]. Perception layer is the initial source of IoT system that includes different technologies for the collection of data including short range radio technologies, device identity, signal detection, and connection with devices. The collected data is transferred through the network/transmission layer using Bluetooth, 2G, 3G and other technologies. Data is transferred from one place to another based on traditional communication networks for the integration of perception and communication networks [xli]. Network/transmission layer transfer data to the application layer that intends to process data and management of services [xli]. Application layer provide various services to all kinds of its users.

Requirement of privacy and security in IoT technology is most important concern for its stakeholders. IoT structure must support its characteristics for protecting data from unauthorized access. Each layer of IoT structure face challenges for providing security and privacy. These issues of IoT are directly related to its wide spread systems and applications. Fulfillment of these requirements is quite difficult and requires different technologies to meet security and privacy goals. The challenges that IoT structure is facing at each layer have been identified and depicted in Fig. 2. Identified issues/challenges must be resolved for providing a secure and protected IoT system.

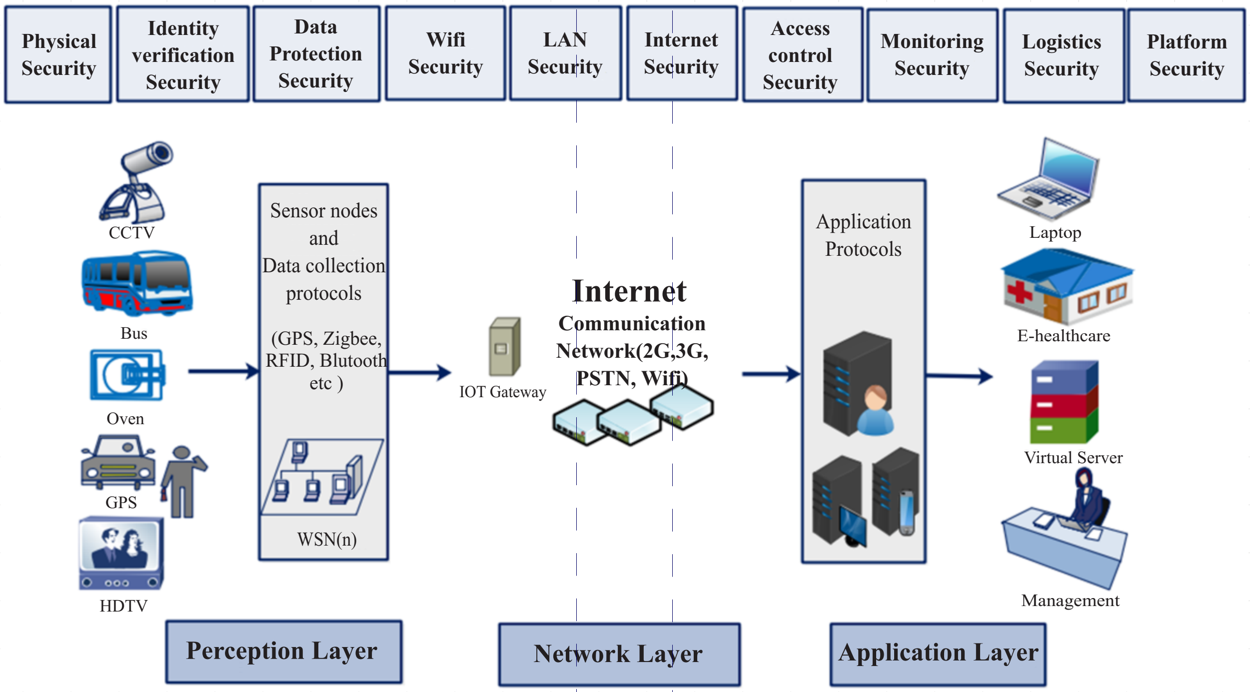

Fig. 2. IoT Architecture concerning Security and privacy

Many researches have proposed Architecture of this masive foundation of fog computing and storage and it also manage administration of the Fog objects. It is predicted that in coming years Internet of Everything (IoE) gadgets will be furnished. IoE will have wireless network interface cards for each heterogeneous device that include remote system interface cards through which energy efficient transport protocols will be designed[xliii].

TABLE I
COMPARISON OF IoT SECURITY ALGORITHMS

Algorithm	Function	Reference
AES	Confidentiality	[i, ii]
ECC	Digital signatures	[i]
RSA	Digital signatures	[i]
DH	Key agreement	[i]
SHA	Integrality	[i]

So far there is a notable and generally trusted suite of cryptographic algorithm connected to web security conventions as shown in Table I. Advance Encyption Standard (AES) has been used to maintain the confidentiality. Rivestshamiradelman (RSA) and Elliptic curve cryptography (ECC) algorithm has also been used to encrypt data by using digital signature and key transport in the network. Diffie Hellman (DH) and Secure Hash Algorithm (SHA-1/SHA-256) are used to maintain the integrity in the network. The importance of security and privacy related requirements have been addressed [xxix, xliv] for enterprises which have adopted IoT technologies. Furthermore, technologies for enhancing privacy, legal courses of action and state law scenarios have also been discussed. An other effort has been made[xxiii] in furnishing diverse levels of IoT security. Whereas a model for the perception layer have been placed forward for attacks. Later on [xxxi] a description was provided about IoT security architectures with their features and state problems related to diverse layers of IoT. Moreover, eachIoT layers' security measures have been discussed to provide better mechanism for security. Afterward each IoT layer security problems with solution have been outlined [xx]while security architecture was proposed and various security issues of IoT at various platforms were addressed [xxx]. A concise description of major challenges was proposed for full expansion of IoT devices and access control mechanisms for distributed devices werealso proposed for capable distributed devices [vi]. Subsequently, [xv] literature highlighted diverse aspects of IoT including existing security issues and open research challenges were included. Later on, [xiv] research provides an impetus for designing and developing security techniques for IoT Computer-Aided Design through highlighting different physical IoT devices challenges and opportunities. Additionally, privacy and trust relationship have been analyzed [xviii] while a formal model was proposed to link privacy with trust and it maps their relationship to maintain privacy relation in IoT systems. A confined solution to the security challenges of IoT had been proposed [xxvii] which focuses industries only. On the other hand, [xxvi] researchers proposed a trust management system considering the unsolved IoT security challenges. An efficient and scalable encryption protocol and protection techniques for heterogeneous devices was also proposed [xvi]. Whereas social aspect of implication of IoT in society was addressed including confidentiality and authentication etc. [xxii]. However, issues associated with secure packet forwarding includes privacy protection, authentication, cloud-based IoT cell phone technologies, their architectures and their requirement for security and privacy were also identified [xi]. Various challenges and solution of security, privacy, trust and robustness in location based devices have also been tackled [xvii] further it emphasized a wide range of policy regulations, privacy features in localization base devices for providing more secure and robust services.

Current literatures have only discussed the security and privacy challenges being faced by the diverse layers of IoT environment. Different security and privacy challenges of IoT system have only been discussed. Moreover, the existing models are confined to highlight the challenges without providing any mechanism to solve them. To the best of review and knowledge, there is no such security model that cover each layer's challenges [xxiii]. Therefore, the model proposed in this study ensures security at the diverse layers of IoT that has never been done before.

A. Security

Current research in IoT does not properly investigate security and privacy requirements for maintaining users trust. The main focus was to outline the challenges encountered by research community but no significant mechanism was devised to deal with problem [xx, xxvi, xlv, xlvi]. Existing IoT environment devices have no prior knowledge about one another so it is a big challenge to identify fake objects. Hackers and intruders have bad intensions for accessing devices data and changing information and software in IoT that can affect operational behavior of connected devices. Another challenge was to avoid user's privacy misuse [xxvi, xliv]. According to the review, Smart phones were sensor based devices that contain GPS, embedded sensors, proximity sensor, and gyroscope that are prone to security flaws. These devises lack data security and privacy in many cases [xvi, xli]. The critical areas of IoT include providing users personal data security, its availability, and query privacy, providing security at the vast collection of data and then protecting against legitimates is the critical challenge of IoT. Since IoT formed by the smart objects with autonomous facility in real time and spread the services all over the world, it required suitable solutions for ensuring the security goals of confidentiality, integrity and availability [xiv]. To ensure the availability to right people, strong access control and authentication systems with footprint supported by smart devices was highly required.

B. Privacy

Privacy includes personal information about identifiable participants. In IoT, increasing amount of participants, data, and communicating devices led to the need of privacy preservation mechanisms. Providing privacy of data were critical topics in sensing devices [x, xiv, xxvi, xlvii]. Technical approaches were required for the protection of participants' data. Next, in IoT main challenge was to provide application data protection, identity and access management, firewall, data encryption, privacy enhancing interaction, Radio Frequency Identifiers (RFIDs), Global Positioning System (GPS) and Near Field Communicators (NFC) which contain important characteristics associated with participants location[xxi, xxvi, xlviii-l]. Sometimes participants want to hide their personal information regarding location etc., but In IoT environment it becomes difficult to hide location on participants demand. So, as per the researcher, a trustable system was one that has analyzed all the risks and whose security and privacy issues had been settled [xxvi, li]. Trust look upon to the users 'faith', 'expectation', 'anticipation', 'confidence' and belief on the consistency and reliability of all the services provided by service providers. A trustable system must insure its users that their data would be with authorized service provider [xviii, lii].New Privacy Enhancing technologies (PET) had been developed for achieving these goals such as Virtual Private Networks (VPN) that is established by groups business partners, Transport Layer Security (TLS) TLS connection was required for providing confidentiality and integrity, DNS Security Extensions (DNSSEC) use shared public and private keys for providing integrity and authentication, onion routing encrypts data in multiple layers and wrapped it with covers of encrypted data and Private Information Retrieval (PIR).But providing security to all objects had become difficult in IoT environment[xxix, liii].

Hence, a novel reliable and scalable security model is required to authenticate each and every object that become a part of IoT environment that leads to seamless interoperability between different networks. Therefore, this study focused on the identification and analysis of security challenges encountered by each layer of IoT architecture. Furthermore, this study contributes in such a manner that proposes a Security Enabled Model in order to deal with the security challenges confronted by the IoT system through identification of each object. Proposed model includes security at each layer.

III. IDENTIFIED SECURITY AND PRIVACY CHALLENGES

Currently billions of people daily use internet but there are only few people who have knowledge of its working. Internet of things (IoT) connects various heterogeneous devices through internet that capacitate IoT devices with new capabilities. The amount of these heterogeneous devices is increasing every day that lead towards less reliability, adaptability, security and trust [xi, xxii, liii].Traditionally, the security mechanisms can't be devised to IoT technologies, because of its diverse communication standards and protocols. So these devices may not be protected under these mechanisms. These devices can be attacked and analyzed to reveal personal information. Security and privacy of users data needs to be ensured to stop access of illegitimate users along with access control, integrity, validation and verification mechanisms. Security challenges include object identification, authentication, authorization, privacy, security protocols, software vulnerability, privacy, malware in IoT etc. To provide most secure and reliable networks at a low cost there are many more challenges to overcome. Mostly security and privacy challenges are categorized on the basis of their need, to overcome as quickly as possible. The most important challenges are as follows:

A. *Object Identification*

Objects are the building blocks of IoT that need to be identified physically or in the network [liv-lvi]. Sensor networks cover a huge area so adversaries can monitor the transmission between objects and gain access to the overall network. Without data integrity the overall naming structure of objects is insecure [xxx]. DNS cache positioning attacks can harm the overall working of the network. Object identification is important so each object can be uniquely identified. Fake objects should be identified as soon as possible as each object signifies potential spot of attack. The network must be protected from physical or logical attacks on devices and their data. **Identity Management:** The complex relation between interconnecting things possess security challenge to identify objects uniquely [xxviii, xxx].A proper object identification method is required to identify objects as well as reflecting all the important properties of the object. For these interconnecting objects identification of fake objects is most important. Many IoT devices don't have suitable user interfaces for communication to connect with each other [xxvii]. Therefore, a new device is needed with appropriate user interfaces for providing suitable communication between entities.

B. *Authentication and Authorization*

How to achieve authentication and authorization of objects? For unique identification of objects authentication and authorization can be achieved through ID passwords, cryptography and database based access control [xxx, xxxi, lvi, lvii]. Authentication can be achieved by cryptography algorithm. To provide secure communication between objects the interconnected devices need to verify themselves through trustable services. Many open research issues have been discussed for IoT objects' secure identification but a deeper research and analysis is necessity of the time. To uniquely identify all the "things" in IoTa more secure identity management is required.

C. *Privacy*

Due to the heterogeneity nature of the interconnected devices it has become difficult to accomplish user's privacy requirements [xxi, xxxi, xlviii, xlix]. Privacy is absolute human right which includes the control over personal information as well as what can be done with this information. It depends on the stakeholder to whom they want to share their personal information or not want to share at all. In IoT privacy is one of the most dominant challenges [xv]. Privacy Enhancing Technologies (PET) including VPN that provide better data integrity and confidentiality are new technologies for IoT devices [xxii, xxviii, xxx]. The privacy requirements for cloud coverage with IoT devices should also be considered. **Input privacy:** The input that users put should be kept private from everyone even from authorized receivers. The user data should be protected from the adversaries and attackers [xi]. **Output privacy:** The authorized receivers should be the only one that deciphered computation output and it should only give access to its authorized user. **Function privacy:** The underlying functions should be private and protected from attacker and unauthorized users. **Location Privacy:** Location privacy is the most critical as if it is disclosed it will disclose all the information of the user including user's personal living habits [xi, xvii, xviii]. The Pseudonyms technique is adopted here to hide user's location. However the location is not directly protected. The adversary can physically search most visited places of the user and can get access to information[xvii].

D. Network Security

Network security of interconnected things split into object confidentiality, object authenticity, object integrity, and object availability [xxviii, l, lviii]. Object confidentiality must be provided as it prevents sensitive information leakage on internet. Providing security to each layer increases complexity. Therefore, new Privacy Enhancing technologies (PET) have been developed for achieving these goals such as Virtual Private Networks (VPN), IPSec and Transport Layer Security (TLS). TLS connection is required for providing confidentiality and integrity. Authenticity provides proof of validity that claimed entity is the one that it claims to be. It provides secure connection with an authenticated entity. Integrity ensures that no data is lost or modified.

E. Identity Privacy

The fact of being the real user or claimed users refer to the identity privacy that should be well protected from public/attackers [xvii, xviii]. Sometimes, in emergency cases when some dispute occurs the privacy of information can also effect the scenario [xi]. Pseudonyms technique has been adopted to overcome this problem. The periodic updating of pseudonyms leads towards unbearable computational cost for IoT.

F. Trust

Trust is another crucial requirement of IoT due to its distributed nature. Maintaining trust in IoT is very important for its users. IoT must ensure sensing device's trust, entity trust, and data trust [xviii, xxx, xxxi]. Maintaining trust in the system for secure interaction between objects is important. IoT structure is facing challenges for providing trustable system to its users. IoT system must have decentralized models, implementation of new trust mechanisms and new applications maintaining trust for its users [xv]. Reputation management mechanisms will help to maintain the trust of objects in the network.

G. Removing or Adding Layers

To maximize rewarded credits sometimes social groups of IoT users remove the layers connecting them for forwarding this help them to reduce transmitters that are sharing the reward is called removing layer [xi]. To increase credits sometimes IoT users maliciously bypass the path of forwarding packets between them by increasing total obtainable utility and it is called adding layer [xi]. These attacks are dangerous for networks and can lead towards huge loss of the private information. We need better way of dealing with these attacks and provide quick solutions if something bad happen.

H. Forward and Backward Security

Another challenge is to provide forward and backward security in the network. The heterogeneous nature of IoT make it necessary to provide security and privacy for social formulated groups of users [xi]. It is necessary to provide backward and forward security for these users. The newly joined users must not have access to the mails before they join the network. Same goes for the users who left the network must not have access to the mails.

I. Lightweight Devices

Lightweight devices are another challenge as sensing objects are very small and contain lightweight processors that decrease the performance of network. Lightweight symmetric and asymmetric key management systems need to provide trustable services to the user [xv, lix]. Lightweight encryption and decryption algorithms should be used to provide security authentication [vi]. Designing lightweight security algorithms, protocols and their implementation is the key to tackle uncontrolled surrounding conditions of IoT network.

J. Object Compromise

Object compromise attack occur when some adversary attack the sensing device and extracts all the necessary and private information of the user as well as secret key [xi, xxxiv]. By gaining all the information they can reprogram or replace sensing IoT devices with malicious one that are under control of adversary. The adversary can select any object to attack and can damage the whole network.

IV. Proposed Model

Numerous sensors contribute from various hardware platforms for the exchange of information. IoT sensors engage people and communities in collecting data but managing data security and privacy with traditional techniques is a hard job. Current IoT devices are protected using traditional techniques that are prone to error. Many industries are using small sensing devices that are vulnerable to security theft and misuse of private data. Large scale implementation of sensing systems increases new challenges of privacy and security. Upon intensive review, it has been found that there is lack of any such model which can provide finest security system for small sensing devices of IoT. In this section, a model has been proposed (as shown in Fig. 3) namely Security Enabled Model (SEM) to overcome security and privacy challenges in IoT systems. Our proposed model detailed how small sensing devices can improve their applicability in real world scenario and eradicate the limitation of power consumption factor.

To illustrate the performance of the proposed model, it is assumed when the sensing devices generate data from diverse places then that data has to be visualized by end users. Hereafter, many end users request to view reports at the same time from server. These objects are concerned about three aspects of data: 1) Security and privacy mechanism 2) quick response and 3) data quality. The proposed model is comprised of three layers where each layer aims to provide security and privacy solutions and it also illustrates the sensing objects authentication and principles that IoT system should support.

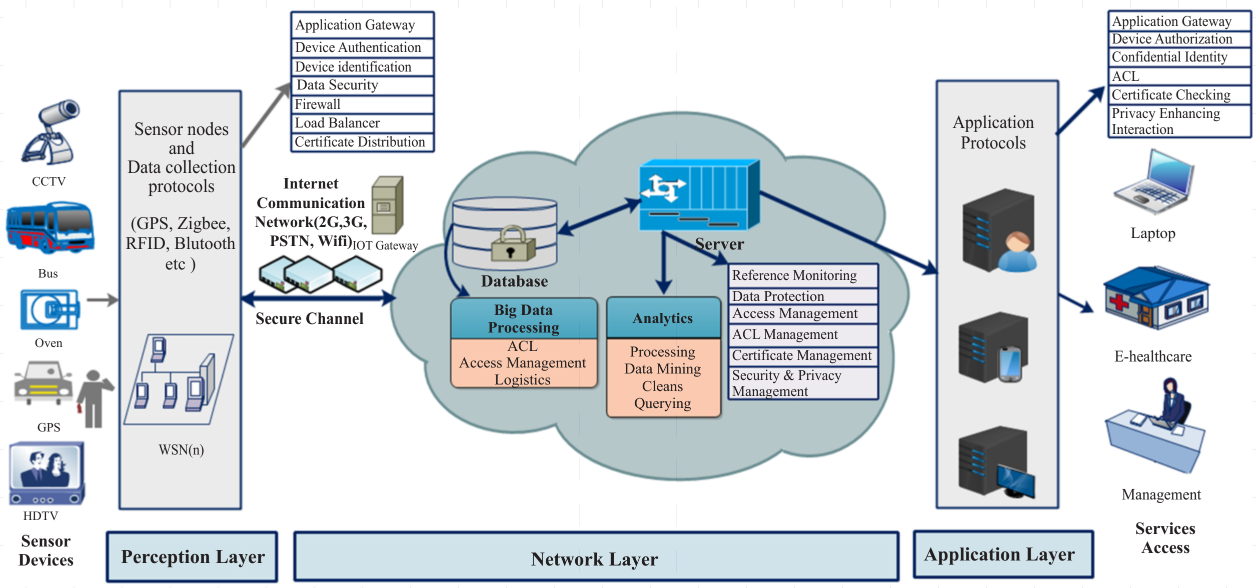

Fig. 3. Proposed Security Enabled Model (SEM) for IoT System

A. Perception Layer

Sensing devices collect data that is transmitted by using protocols e.g. Zigb towards the server system. The signals that carry data travel through public places so we need effective protection of data from being monitored and intercepted. Most sensing devices are installed in places where it can be easily accessed and monitored. The attacker can easily gain access to the equipment and can physically harm these devices. Currently, the most important security challenges of perception layer includes securing objects from being captured by unauthorized user, being secure from fake objects, protection from Denial of Service (DoS) attacks, protection from routing threats, timing and replay attack [xli]. We propose an authentication process through which sensing devices must be identified to make part of the network. Authentication process includes application Gateway for the checking of data sending sensors. Identification of fake object will become easy through checking the contents of sensing devices which they are sending. Firewall provides secure packet filtering that will enhance protection of data from internal and external networks. Load balancer and certificate distribution will enhance security as each device must have the certificate of being authorize and becoming part of the network. Through proposed authentication process the small sensors will be secure from unauthorized access to the device information. Further, this model will enhance the power of small sensing devices in order to make them more secure and smart.

B. Network Layer

When large number of objects sends data at the same time including fake objects, it can lead towards DoS attack in the network. Network layer security challenges include: reducing compatibility problems by providing data integrity and confidentiality, protecting privacy of user's, protection against DoS and Man in The Middle Attacks etc. [xxxi]. Existing internet security architecture is appropriate for the humans but IoT environment includes machines and humans so a new way of securing these devices is highly required. A new way of identifying objects is necessary as current IP technology cannot be applied on IoT. IoT system is facing challenges in the transmission of data that can be retrieved later. The data can be attacked during its transmission and at the time of retrieval. In this model, network layer transfers data to the cloud servers to process data where data is transferred by establishing secure channel to follow proposed authentication process through which each object is identified and their data contents are checked within the network. Furthermore, this layer includes cloud gateway that provides data driven Application Programming Interface (API) for collecting data from objects and route data to the servers for analysis. Cloud gateway safely transmits data from objects to servers for storage and data analytics that includes Access Control List (ACL) management. Server is the processing data center that will provide secure analytic services and server is also responsible for managing and evaluating reports, visualization, and querying data. Server maintains data and manages the ACL of each object's previous contributions. New analytical techniques support querying of data according to user requirements. Server maintains the status of each object and check the ACL for granting services to the users. Servers perform data mining techniques for knowledge discovery and real time analytics [xxxiv]. Data collected from diverse sources may be structured, unstructured or semi structured. We suggest a process for authentic access of database so that data may be accessed by authorized administrator and users only. For prevention of fraud in databases data mining techniques are implemented for fraud recognition. Preprocessing techniques of data are used for fraud recognition, validation, error modification and access control. Logistic regression is performed for managing the concurrency in the database. Managing data integrity constraints is the main challenge for specifying the uniqueness of data in database and it is well tackled in this proposed model.

C. Application Layer

Visualization is requested from end users to view reports of analysis and to get response of their queries. Data is managed from the start their will be no issue regarding processing of data. By using data delivery techniques and principles end users can visualize data that is authentic, secure, protected and according to the users standard. Data delivery techniques minimize latency, increase throughput of the system and provide faster retrieval of the data. The proposed model provides ACL for managing the access rights of each user. Only those who have certificate including the access list for interaction can gain access to services. Different applications have many complex security issues e.g giving reports to unauthorized person. In IoT environment it has become difficult to capture fake objects consequently new technologies are required for overcoming these situations. Application Layer Security challenges include authentication and restricting data access, dealing with large amount of data, providing data recovery and identity authentication. Sensing devices are sending data continuously so it becomes difficult to store massive amount of data. Therefore, protection of this massive amount of data is difficult. By following this process each object can have better privacy enhancing interaction and can gain services in a more secure way.

V. FUTURE DIRECTION\

As security and privacy issues are very serious concern that should be considered immediately. Since IoT technology deals with vast amount of personal and private data with the power of insure abilities to control its physical environment so significant solution for the security issues are required. The proposed model will protect physical and logical environment from any kind of theft and attacks. The smart devices that have embedded sensors will be identified for secure communication. However, new security technologies for the identification and data protection will be helpful in this regard. Designing new interfaces and security protocols for lightweight sensor devices in IoT network would be favorable and beneficial. Participants should also have knowledge and security privileges of the system. Future work also includes the deployment of proposed model in IoT based smart university and new security mechanism for lightweight IoT devices will also be targeted.

VI. CONCLUSION

IoT vision allows humans and machines to be connected with anything, anyone, anywhere and anytime. IoT devices can be part of any wireless sensor networks or wired networks simultaneously. Anyhow main concern of IoT is to create smart spaces like smart home, smart grid, smart transportation, smart traffic, smart cities and smart health for users. IoT concept is increasing speedily while facing different challenges; such as assuring availability and reliability, creating business models for interconnection of devices, security and privacy challenges for providing secure communication between devices. Intensive literature review has been conducted to identify and investigate various security and privacy challenges encountered by the IoT environment. Hence, security architecture has been designed to elaborate the current security and privacy challenges faced by IoT technology. Different challenges being faced by IoT layers have been identified in the current investigation. Moreover important security and privacy challenges were outlined like object identification, authentication, authorization, privacy, network security etc. Identification is the most important challenge as verifying fake objects for secure communication. This study proposed a Security Enabled Model (SEM) to cope with the outlined challenges and make IoT environment more secure and efficient. SEM ensures security at each layer of IoT moreover perception layer includes authentication process for the secure communication between sensors and Application Programming Interfaces (APIs). A part of authentication process is identification of objects and managing ACL for access rights, further it will provide better protection from malicious objects and manipulation of confidential data. Network layer that emphasis on data security so that data will be transferred from authentic objects through secure channel, moreover it will become easy for server to maintain security. Server also includes security process to manage unauthorized access through reference monitor. At the end application layer includes visualization of data to provide services to its intended users. To sum up, it was identified that data will be collected from secure objects which lead towards a secure network communication by using firewall and load balancer. Transferring data from secure objects towards server that includes secure database for the storage and analytics is another feature of this model. Server manages reference monitors and certifies authorities. Eventually, passing from secure server towards end users, data will be protected by implementing this model. Besides, in order to create most secure IoT environment we need more encryption algorithms and their implementation. Only authorized users can get the desired services through the proposed model.

REFERENCES

[i] H. Chan and A. Perrig, "Security and Privacy in Sensors Networks". Computers, 36(10): p. 103-105. 2003.

[ii] J. B. Gubbi, R. Marusic, S. Palaniswami and Marimuthu, "*Internet of Things (IoT): A vision, architectural elements, and future directions.*" Future generation computer systems, 2013. 29(7): p. 1645-1660.

[iii] R. Roman, J. Zhou and J. Lopez, "*On the features and challenges of security and privacy in distributed internet of things.*" Computer Networks, 2013. 57(10): p. 2266-2279.

[iv] R. Roman, P. Najera and J. Lopez, "*Securing the internet of things.*" Computer, 2011. 44(9): p. 51-58.

[v] S. Haller, S. Karnouskos and C. Schroth, "*The internet of things in an enterprise context.*" Future Internet Symposium. 2008. Springer.

[vi] A. F. Skarmeta, J. L. H. Ramos and M. V. Moreno, "*A decentralized approach for security and privacy challenges in the internet of things.*" Internet of Things (WF-IoT), 2014 IEEE World Forum on. 2014. IEEE.

[vii] F. Tao, Y. Zuo, L. D. Xu and L. Zhang, "*IoT-based intelligent perception and access of manufacturing resource toward cloud manufacturing.*" IEEE Transactions on Industrial Informatics, 2014. 10(2): p. 1547-1557.

[viii] S. D. T. Kelly, N.K. Suryadevara and S. C. Mukhopadhyay, "*Towards the implementation of IoT for environmental condition monitoring in homes.*" IEEE Sensors Journal, 2013. 13(10): p. 3846-3853.

[ix] K. D. Chang, C. Y. Chang, H. M. Liao, J. L. Chen and H. C. Chao, "*A Framework for IoT objects management based on future internet IoT-IMS communication platform.*" Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2013. IEEE.

[x] M. Aazam, I. Khan, A. A. Alsaffar and E. N. Hu,"*Cloud of Things: Integrating Internet of Things and cloud computing and the issues involved.*" 11th International Bhurban Conference on Applied Sciences and Technology (IBCAST), 2014. 2014. IEEE.

[xi] J. Zhou, Z. Cao, X. Dong and A. V. Vasilakos, "*Security and privacy for cloud-based IoT: challenges.*" IEEE Communications Magazine, 2017. 55(1): p. 26-33.

[xii] D. Bandyopadhyay, and J. Sen, "*Internet of things: Applications and challenges in technology and standardization.*" Wireless Personal Communications, 2011.58(1): p. 49-69.

[xiii] B. Dorsemaine, J. P. Gaulier, J. P. Wary, N. Khier and P. Urien,"*Internet of Things: a definition & taxonomy.*"9th International Conference on Next Generation Mobile Applications, Services and Technologies, 2015. 2015. IEEE.

[xiv] T. Xu, J. B. Wendtand M. Potkonjak,"*Security of IoT systems: Design challenges and opportunities.*" Proceedings of the 2014 IEEE/ACM International Conference on Computer-Aided Design. 2014. IEEE Press.

[xv] M. Abomhara, and G. M. Køien, "*Security and privacy in the Internet of Things: Current status and open issues.*" International Conference on Privacy and Security in Mobile Systems (PRISMS), 2014. 2014. IEEE.

[xvi] E. Bertino, "*Data Security and Privacy in the IoT.*" EDBT. 2016.

[xvii] L. Chen, S. Thombre, K. Jarvinen, E. S. Lohan, A. A. Savikko, H. Leppakoski, M. Z. H. Bhuiyan, S. B. Pasha, G. N. Ferrara, S. Honkala, J. Lindqvist, L. Ruotsalainen, P. Korpisaari and H. Kuusniemi, "Robustness, Security and Privacy in Location-Based Services for Future IoT: A Survey". IEEE Access, 2017.

[xviii] J. Daubert, A. Wiesmaier and P. Kikiras, "*A view on privacy & trust in IoT.*"IEEE International Conference on Communication Workshop (ICCW), 2015. 2015. IEEE.

[xix] J. P. Hubaux, S. Capkun and J. Luo, "*The security and privacy of smart vehicles.*" IEEE Security & Privacy, 2004. 2(3): p. 49-55.

[xx] Q. Jing, A. V. Vasilakos, J. Wan, J. Lu and D. Qiu, "*Security of the internet of things: Perspectives and challenges.*" Wireless Networks, 2014. 20(8): p. 2481-2501.

[xxi] P. McDaniel, and S. McLaughlin, "*Security and privacy challenges in the smart grid.*" IEEE Security & Privacy, 2009. 7(3).

[xxii] S. Nath, and S. Som, "*Security and Privacy Challenges: Internet of Things.*" Indian Journal of Science and Technology, 2017. 10(3).

[xxiii] C. C. Niu, K. C. Zou, Y. L. O. Yang, G. J. Tang and Y. Zou,"*Security and Privacy Issues of the*

Internet of Things." Applied Mechanics and Materials. 2013. Trans Tech Publ.

[xxiv] H. K. Patil, and R. Seshadri, "*Big data security and privacy issues in healthcare*." Big Data (BigData Congress), 2014 IEEE International Congress on. 2014. IEEE.

[xxv] H. C. Pöhls, V. Angelakis, S. Suppan, K. Fischer, G. Oikonomou, E. Z. Tragos, R. D. Rodriguez, and T. Mouroutis,"*RERUM: Building a reliable IoT upon privacy-and security-enabled smart objects*." IEEE. Wireless Communications and Networking Conference Workshops (WCNCW), IEEE. 2014.

[xxvi] K. A. Rafidha Rehiman and D. S.Veni, "*Security, Privacy and Trust for Smart Mobile devicesin Internet of Things – A Literature Study*." International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)2015. 4.

[xxvii]A. R. Sadeghi, C. Wachsmann, and M. Waidner, "*Security and privacy challenges in industrial internet of things*." Design Automation Conference (DAC), 2015 52nd ACM/EDAC/IEEE. 2015. IEEE.

[xxviii]E. Vasilomanolakis, J. Daubert, M. Luthra, V. Gazis, A. Wiesmaier and P. Kikiras,"*On the Security and Privacy of Internet of Things Architectures and Systems*." *International Workshop onSecure Internet of Things (SIoT)*, 2015. IEEE.

[xxix] R. H. Weber, "*Internet of Things–New security and privacy challenges*." Computer law & security review, 2010. 26(1): p. 23-30.

[xxx] Z. K. Zhang, M. C. Y. Cho, C. W. Wang, C. W. Hsu, C. K. Chen and S. Shieh,"*IoT security: ongoing challenges and research opportunities*." IEEE 7th International Conference on Service-Oriented Computing and Applications (SOCA), 2014. IEEE.

[xxxi] K. Zhao and L. Ge, "*A survey on the internet of things security*." *International Conference on Computational Intelligence and Security (CIS), 2013 9th*. 2013. IEEE.

[xxxii]M. Dabbagh, and A. Rayes, "*Internet of Things Security and Privacy.* Internet of Things From Hype to Reality. 2017, Springer. p. 195-223.

[xxxiii]L. Tan, and N. Wang, "*Future internet: The internet of things*."3rd International Conference *on*Advanced Computer Theory and Engineering (ICACTE). 2010. IEEE.

[xxxiv]A. Karim, A. Siddiqa, Z. Safdar, M. Razzaq, S. A. Gillani, H. Tahir, S. Kiran, E. Ahmad and M. Imran, "*Big data management in participatory sensing: Issues, trends and future directions*." Future Generation Computer Systems, 2017.

[xxxv]F. Xia, L. T. Yang, L. Wang and A. Vinel, "*Internet of things*." International Journal of Communication Systems, 2012. 25(9): p. 1101.

[xxxvi]H. Kopetz, "*Internet of things*, in *Real-time systems*."2011, Springer. p. 307-323.

[xxxvii]F. Wortmann and K. Flüchter, "*Internet of things*." Business & Information Systems Engineering, 2015. 57(3): p. 221-224.

[xxxviii]L. Atzori, A. Iera, and G. Morabito, "*The internet of things: A survey*."Computer networks, 2010. 54(15): p. 2787-2805.

[xxxix]S. H. Yang, "*Internet of things*."Wireless Sensor Networks". 2014, Springer. p. 247-261.

[xl] G. M. Lee, N. Crespi, J. K. Choi and M. Boussard, "*Internet of things*." Evolution of Telecommunication Services. 2013, Springer. p. 257-282.

[xli] Q. Zhu, R. Wang, Q. Chen, Y. Liu and W. Qin,"*Iot gateway: Bridging Wireless sensor networks into internet of things*."2010 IEEE/IFIP 8th International Conference onEmbedded and Ubiquitous Computing (EUC), 2010. IEEE.

[xlii] F. Bonomi, R. Milito, J. Zhu, S. Addepalli"*Fog computing and its role in the internet of things*." Proceedings of the first edition of the MCC workshop on Mobile cloud computing. 2012. ACM.

[xliii] E. Baccarelli, P. G. V. Naranjo, M. Scarpiniti, M. Shojafar and J. H. Abawajy,"*Fog of Everything: Energy-efficient Networked Computing Architectures, Research Challenges, and a Case Study*."IEEE Access, 2017.

[xliv] H. Suo, J. Wan, C. Zou and J. Liu"*Security in the internet of things: a review*." International Conference onComputer Science and Electronics Engineering (ICCSEE), 2012. IEEE.

[xlv] D. Miorandi, S. Sicari, F. D. Pellegrini and I. Chlamtac, "*Internet of things: Vision, applications and research challenges*."Ad Hoc Networks, 2012. 10(7): p. 1497-1516.

[xlvi] Y. K. Chen, "*Challenges and opportunities of internet of things*."17th Asia and South Pacific, Design Automation Conference (ASP-DAC), 2012 2012. IEEE.

[xlvii] J. Schrammel, C. Hochleitner and M. Tscheligi, "*Privacy, trust and interaction in the internet of things*." *International Joint Conference on Ambient Intelligence*. 2011. Springer.

[xlviii]A. S. Ukil, S. Bandyopadhyay and A. Pal, "*Iot-privacy: To be private or not to be private*."IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 2014. IEEE.

[xlix] C. Perera, R. Ranjan, L. Wang, S. U. Khan and A. Y. Zomaya, "*Privacy of big data in the internet of things era*." IEEE IT Special Issue Internet of Anything, 2015. 6.

[l] C. M. Medaglia, and A. Serbanati, "*An overview of privacy and security issues in the internet of things*."The Internet of Things. 2010, Springer.

p. 389-395.

[li] J. H. Ziegeldorf, O. G. Morchon and K. Wehrle, "*Privacy in the Internet of Things: threats and challenges*." Security and Communication Networks, 2014. 7(12): p. 2728-2742.

[lii] F. T. Commission, "*Internet of Things: Privacy & security in a connected world*." Washington, DC: Federal Trade Commission, 2015.

[liii] P. Porambage, C. Schmitt, P. Kumar, A. Gurtov, M. Ylianttila and A. Vasilakos, "*The quest for privacy in the internet of things*." IEEE Cloud Computing, 2016. 3(2): p. 36-45.

[liv] D. Uckelmann, M. Harrison and F. Michahelles, "*An architectural approach towards the future internet of things*." Architecting the internet of things. 2011, Springer. p. 1-24.

[lv] M. Kranz, P. Holleis and A. Schmidt, "*Embedded interaction: Interacting with the internet of things*." IEEE internet computing, 2010. 14(2): p. 46-53.

[lvi] X. Jia, Q. Feng, T. Fan and Q. Lei,"*RFID technology and its applications in Internet of Things (IoT)*." 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet), 2012. IEEE.

[lvii] J. Liu, Y. Xiao and C.P. Chen, "*Authentication and access control in the internet of things*."32nd International Conference on Distributed Computing Systems Workshops (ICDCSW), 2012. IEEE.

[lviii] L. Atzori, A. Iera, G. Morabito and M. nitti, "*The social internet of things (siot)–when social networks meet the internet of things: Concept, architecture and network characterization*." Computer networks, 2012. 56(16): p. 3594-3608.

[lix] J. Y. Lee, W.C. Lin, and Y. H. Huang, "*A lightweight authentication protocol for internet of things*." International Symposium on Next-Generation Electronics (ISNE), 2014. 2014. IEEE.

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