International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Analysis of Wind Power Quality Disturbances Due To Mechanical Defects in Gearbox using Acoustic Sensor and Current Transformer

T. Rameshkumar, P. Chandrasekar

Abstract Power quality in wind turbines has become a major issue because of harmonic distortions, unbalance voltages, voltage fluctuations. Mainly harmonics occur in the wind mills if the rotor blades does not respond to the wind power. Moreover the gearbox in wind turbines does not respond to the rotor. Therefore the mechanical power from the rotor is not properly transferred to the generator. Here to analyse the power quality of the wind turbines, two methods are proposed. Using an acoustic sensor on the gear box we can acquire the sound signals from the gear box attached to the rotor. From the sound signals we can analyse the harmonics present. And by using a current transformer in the load we can acquire the power signals and analysing the harmonics present in the signal. Finally performing a correlation of the two signals we can reduce the harmonics. The simulation results provides a reproduction of the signal without harmonics. The simulation results are carried out using Matlab.

Key words: power Quality, Acoustic Sensors, Wind energy

I. INTRODUCTION

The technology of wind turbines has an increase in development continuously in nowadays. Wind turbines has become robust with new turbine designs having blade lengths larger that can acquire more wind and therefore produce more electricity.

Electricity is generated from the wind turbines by utilizing the wind's power. The energy from the wind causes the blades in the wind turbines to rotate and in turn the rotor also rotates. The rotor is connected to a low speed shaft and a gear box is connected to the low speed shaft the a high speed shaft connects the gear box and the generator. When the rotor rotates along with the blades, the gear box also rotates. The gear box transfers the wind's power directly to the generator when the blades of the wind turbines rotate. Wind Turbines has two types a) Wind Turbines with vertical axis b) Wind Turbines with horizontal axis. A wind turbine with horizontal axis is nothing but the axis of the rotation of the rotor is parallel to the wind's stream. A wind turbine with vertical axis is nothing but the axis of the rotation of rotor is perpendicular to the wind's stream.

Revised Manuscript Received on 30 May 2019.
***** Correspondence Author

T Rameshkumar*, Research Scholar, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technolgy, Chennai India.

Dr. P. Chandrasekar, HoD-EEE **&** Professor, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technolgy, Chennai India.

The kinetic energy of the wind is converted into mechanical energy by the blades of the wind turbines. The wind turbine has a shape like airfoil which triggers the forces of the wind to the low speed shaft.

This airfoil shape changes the streamline of the airflow and produce differences in pressure. A lift force is generated by the pressure differences on the blade which in turn generates a torque in the rotor. Drag forces also occurs which are other type of forces and they are resistant forces and should be eliminated. Based on the blade's shape, wind's speed, the angle of attack and the surface area, the lift and drag forces occur. No lift forces is produced by the symmetrical electrical foil, when the angle of attack is zero. There will be pressure difference between the two blades, when the angle of attack is more than zero and this creates a lift force.he mechanical power of the rotor is transferred to the generator using the gear box through the high speed shaft. The low speed shaft transfers the torque moments and the rotor's rotary motion to the gearbox.

The low-speed shaft is driven to the high-speed shaft by the gear box and the rotational speed of the rotor is increased. A wind turbine has a requirement of gear system depending on the type of the generator. In some wind turbines, there is no need of gear box and they are gearless type. Electrical generators require a high speed rotational input. But wind turbines rotor is rotating very low. So to increase the rotational speed of the rotor, the gear box is utilized.

The generator is the major part of the wind turbine that generates electricity. In the wind turbine's first generation, induction generators were used. Induction generators need a high rotational speed. Nowadays to increase the power production, new wind turbines models are designed for varying rotational speeds.

II. LITERATURE SURVEY

In charging of electrical transportation that involves electric vehicles and electrical buses, the power quality impacts the distribution systems. For electrical buses and electrical vehicles ,the random probabilistic distribution models of harmonics and for their scenarios of usage, these random probabilistic distribution models are created using the charging data measurement. A new method of power quality identification concerning the inabilities of charging of electric vehicles and electrical buses is suggested here using these models and their effects on distribution systems are discussed. In the advanced method to analyse the over current, low voltage, imbalances in voltage, overload of transformer, harmonics in current, voltage induced due to the random probabilistic distribution charging of electrical vehicles and electrical buses, Monte Carlo simulation is applied.[1] A solar photovoltaic conversion system that is single stage with a distribution grid that is three phase and four wire that has the capability of dual function that is standard power and at the point of interaction the improvement of power quality is proposed here. The photo voltaic energy conversion system is composed of a voltage source inverter and a solar voltaic array delivering standard power to the loads with single phase, loads with three phase and the distribution grid. In addition to the power transfer, the power quality at the point of interaction is enhanced by compensation of the reactive power and , attenuation of harmonics, correction of power factor and balancing of grid current. The voltage source inverter acts as an active power filter that is in shunt fashion overcoming power quality issues during night and finally the device utilisation factor is increased. A three phase magnitude-phase locked loop method is used to obtain and calculate basic term of load currents. An algorithm called incremental conductance algorithm is used for maximum tracking of power point. [2]

A methodology based on kalman filter developed through graphical processing units using parallel processing methods to minimise the time of execution is proposed to utilise the time domain power quality state estimation. The measurements for use are obtained from the simulation a per the state estimation algorithm. The waveforms for line currents with many sources of electromagnetic transients that are time variant in nature and voltages in the bus barare obtained by the Parallel Kalman Filter state estimation. By utilizing the Compute Unified Device Architecture and the Compute Unified Device Architecture Basic Linear Algebra Subprograms library, the Parallel Kalman Filter is evaluated and performed on GPU cards. Using the advanced parallel kalman filter-power quality state estimation method, the time of execution is reduced with the harmonics that is time varying in nature and load transient conditions, faults due to short circuit are reduced.[3] In the conventional modular multilevel converter, circulating current suppression will degrade the direct current-link voltage's power quality. Here to improve the direct current –link voltage's power quality and the circulating current suppression, a transformer with three winding and a direct current-alternating current circulating current suppression inverter is utilized. The mathematical models of the circulating current and the advanced modular multilevel converter and tare discussed further. For the three winding transformer the parameter setting is analysed and to make comparison, the parameter setting is set to have traditional modular multilevel converter's equivalent arm inductance. The results compared show that the advanced modular multilevel converter in the steady and dynamic conditions can deliver more performance. From the results, the significant direct current-link voltage does not present in the traditional modular multilevel converter. The mean-square-error values of direct current-link voltage have an improvement up to 90 percent in presence of steady and dynamic conditions [4]
The conventional electrical- vehicle on-board chargers that utilizes a front-end Power-Factor-Correction and an isolated direct current/direct current converter restricts the wall-to-battery efficiency to 94%. A new control methodology using variable switching frequency and variable phase shifts reduces the issues in power factor correction stage by eliminating the direct current link capacitor and thus increasing the system efficiency and power density. The main aim is to secure the zero-voltage-switching turn-on for every switches in the entire power range. Here a new variable switching frequency single dual phase shift control technique is suggested, that includes three control freedoms, i.e. two phase shifts and one variable switching frequency to secure zero voltage switching and achieve power factor correction concurrently. [5] To enhance the energy efficiency and power quality in radial distribution networks, the allocation and design method for open unified power quality conditioner with photovoltaic generation system. An unified power quality conditioner is a unique power device that contains inverters that are in shunt and series fashion that are incorporated in a network in various locations. A communication channel is present to with in these inverters to communicate the information to select the particular set point. Two methods are suggested (i) open unified power quality conditioner with battery and photovoltaic array and (ii)open unified power quality conditioner with only photovoltaic array . The main difference between open unified power quality conditioner with battery and photovoltaic array and open unified power quality conditioner with only photovoltaic array is that in the open unified power quality conditioner with battery and photovoltaic array that during its operation hour, the energy generated is stored to use it in the peak hour, but in open unified power quality conditioner with only photovoltaic array , the energy generated is injected directly to the network. The advanced methods are developed in the forward-backward sweep load flow to find the operational parameters such as bus voltage, To find the exact placement of open unified power quality conditioner with photovoltaic array in distribution networks, the optimisation problem is formulated and particle swarm optimisation as the technique for resolving the optimisation problem. [6]
Here using fuzzy-supervisory control, an additional compensation of active power of a micro grid to a grid that is weak is proposed. This reduces the high economic costs. The goals of this method are (a) during periods of over contract, grid support should be increased (b) to reduce the harmonic distortions and improve direct current-link voltage's dynamic stability (c) from the received power to enhance the toral harmonic distortions. The micro grid consists of a Li-ion battery energy storage system and wind energy conversion system. The power is fed into the point of common coupling during changes in wind speed and depends upon variations in the power of wind, direct current-link voltage and limitations in grid contract power and the battery's state of charge. The supervisory controller uses these variations to deliver extra support of power to the grid by the battery discharging. Using a fuzzy proportional derivative controller and int to eliminate distortions and enhance dynamic response of the received power, a fuzzy proportional derivative plus integral controller is used [7]
Here an advanced method for detecting the power quality disturbance automatically and to classify these power quality disturbances, the fuzzy logic with a based approach is proposed. The advanced method requires only a few numbers of features than approaches for detection of disturbances conventionally used.

A number of 17 types of disturbances in power quality with nine that are matching the real situations and eight general are taken for classification. The use of cross spectral analysis in the stage feature extraction reduces the uncorrelated noises. Experimental analysis is carried out in the laboratory under real operating conditions to the advanced method.[8]

The renewable energy resources in which the standalone power supplies utilizing it, has emerged as a main solution to discuss environmental limitations and energy consumption in particular locations. The standalone become weak low voltage networks due to unbalanced loads or heavy non linear loads, and adversely affect the quality of output voltage. Four-leg-voltage source inverters play a major role to provide full power with both balanced and unbalanced loads and output voltage. For compensation of harmonics under critical load conditions such as unbalanced non linear loads, a sliding mode control with a repetitive learning control is proposed. The repetitive learning control harmonic compensator regulates the input control signal of the SM controller smoothly in order to eliminate disturbing harmonics in presence of substantial disturbances.[9]

To identify and divide several classes of power system issues in a microgrid environment that is distribution generation based, a short-time modified Hilbert Transform and a multiscale morphological gradient filter is proposed. Using the proposed multiscale morphological gradient filter and short-time modified Hilbert Transform methods, near the target distribution generation, the power signal samples that are non stationary are processed. for multiclass event classification The fuzzy judgement tree structure is incorporated in which the event classification depends on the difficulty in the target attribute values in which overlapping occurs for variation disturbance patterns and for most of the classes, it is determined to be tough. Based on this, a vast simulation is carried out on a number of multiclass disturbances on the advanced microgrid models using MATLAB/simulink environment. [10]

A cascaded multilevel converter for flexible power conditioning in smart grid applications is discussed here. The main attribute of the advanced method is the utilization of independent direct current links that has minimum voltages that builds a unique solution for medium and high power applications with more capability. In every H-bridge cell, the independent direct current-link voltages are regulated by the developed control strategy. The developed control strategy also allows specific and flexible equalization of disturbance currents under various voltages. By the Conservative Power theory, the selective control strategies depends on the decompositions suggested results in several current components that are independent of each other. Based on this various compensation strategies can be defined and the selective one in reducing specific effects of disturbance loads. [11]

Harmonics have many effects on the power system. So the power quality of rectifiers should be enhanced. Here a new advanced rectifier that is single phase with capacitors parallel with diodes in one end of the rectifier. For the advanced methodology, a general analytical model is obtained. In selection of which leads to outstanding performance regarding the total harmonic distortion in input current, for the rectifier waveforms, the closed form expressions are utilized. Various rectifier topologies are estimated in terms of, waveform distortion in current , direct current voltage ripple in the output, input voltage and the output direct current voltage. From the advanced method, the total harmonic distortion is reduced from 145 percent ot 63 percent and keeping the dc bus ripple small. [12]

For more renewable energy sources share in electricity production worldwide standalone photovoltaic systems plays a significant role and the standalone PV system's power quality of play a major role in overcoming unstable power supply. To meet the specifications of power quality, a concrete design is proposed. In this way, a methodology has been developed in a way to specify the parameters values that enhances the quality of the power system. Here a vast sensitivity analysis is carried out concerning the impact of the specified parameters change on the power quality. From the sensitivity analysis results, the performance of the system under the system parameter variations is realised. [13]

A modern direct current/alternating current inverter called grid-connected inverter with hybrid-connection for photovoltaic active power generation with maintaining quality of power that contains a full wave bridge three direct current/alternating current inverter with three phase connection to the power grid with an inductive-capacitive filter that is thyristor controlled connected in series. The advanced hybrid connection grid connected inverter has different features of operational range wide and less direct current-link operational voltage rather than the traditional grid-connected inverter with inductive connection and grid connected inverter with capacitive connection. The hybrid connection grid connected inverter can transfer the standard power and equalize the power that is unbalanced, harmonic power and reactive power concurrently. Here the design of the parameter, hybrid connection grid connected inverter's control strategy and the structure analysis of the hybrid connection grid connected inverter are determined and demonstrated. [14]

The power quality disturbances are complicative in nature are frequently interrupted with the external noise. A new method for classification of power quality by classification and strong detection using classification and specific signal processing techniques. Here an identification tool as time frequency scale transform with high noise immunity is presented. The time-frequency-scale transform is the chirplet's transform modified form with a hann window for studying the quality of power and able to perform operations such as scaling and shifting. For performance assessment, the real disturbances of power quality are identified an under various noise levels, they are classified. The time-frequency-scale transform's performance depends on length of the window. So to analyse the window length's effect on precision of classification, three different classifiers are involved. Results of the advanced method are found to be acceptable. [15]

III. METHODOLOGY

The power quality from the windmills is affected due to the harmonic distortions. Hence to analyse the condition of power quality, a method is shown in block diagram as shown in fig 1.

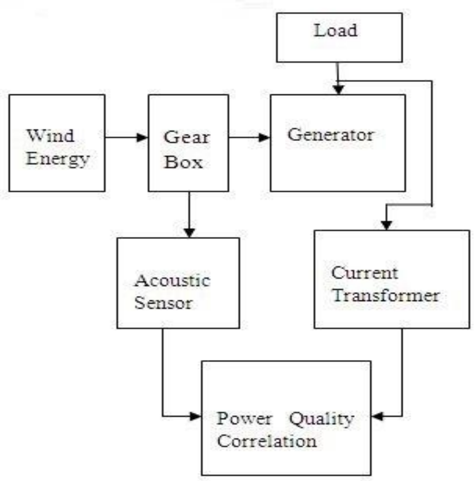

Fig 1. Power Quality Identification

The wind's kinetic energy is converted to mechanical energy by the wind turbines. The generator converts this mechanical energy to electrical energy. A gear box is connected to the wind turbine. Using the gear box, the power generated when the wind turbine rotates is transferred to the generator. When the wind turbine rotor rotates, the gear box also rotates, thus transferring the power to the generator. Here if the gearbox is not properly rotating along with the wind turbine rotor or if the wind turbine rotor is fault, harmonics will affect. This degrades the power quality of windmills. Here the power quality is identified by analysing the harmonics by acquiring the sound signals from wind turbines rotor and gearbox and by using a current transformer in the load connected to the generator.

The sound signals can acquired by using acoustic sensor. By placing the acoustic sensor on the gearbox, the sound signals can be captured by the sensor during the rotor movement and the movement of the gear in the gear box. From the sound signals captured, the presence of harmonics will be analysed.

Another technique of analysing harmonics in the power quality of wind turbines is by connecting a current transformer to the load. A current transformer is a category of transformer by which the alternating current is measured. It generates a current in the secondary corresponding to the primary. Current transformers are utilized in electricity generating stations, electricity substations and are used as current sensing units Here the power quality in presence of harmonics is analysed by connecting the load to the primary of the current transformer and acquiring the power signals at the secondary..

After analysing the harmonics by acquiring the signals from acoustic sensor and current transformer, the two techniques, correlation is done between the two signals and finally the harmonics can be reduced and power quality can be improved.

IV. RESULTS AND DISCUSSION

From the acoustic sensor and the current transformer, the original output signal is acquired. The original signal is shown in figure 2. As shown in figure the peak value is at 0.76 and 0.80. From the figure it is known that harmonics distortions are more in the original signal. From the values 0 to 0.6 in the horizontal scale, harmonics are present.

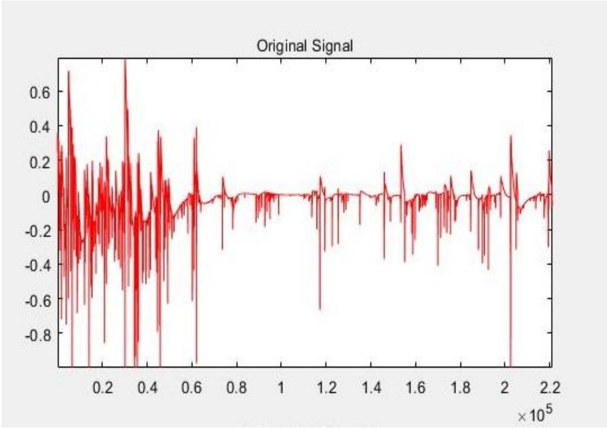

Fig 2. Original Signal

Fig 3. shows the coefficients of the original signal

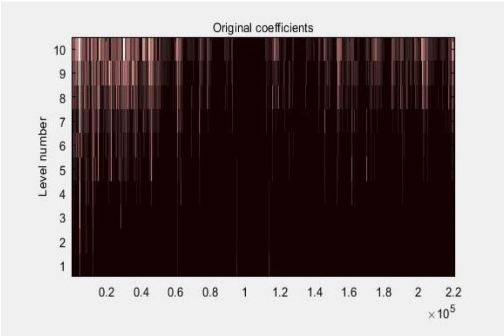

Fig 3. Original signal coefficients

Fig 4. shows the compressed signals. From the figure the retained energy is 68%. The global threshold is at 0.2

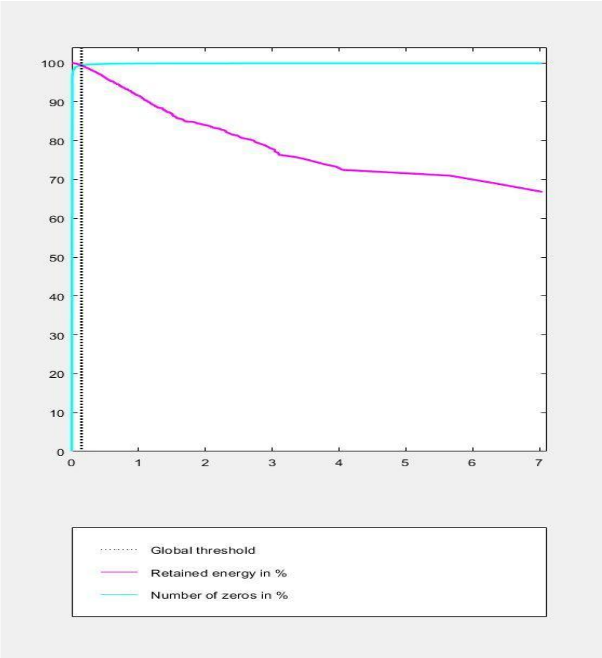

Fig 4. Compressed Signal

Fig 5 shows the denoised output of the signal. From the figure, the input signal is decomposed into 10 levels. In each level of decomposition, there are significant variations in the decomposed signal. For various coefficients of the original signals denoising is done by decomposing the original to 10 levels.

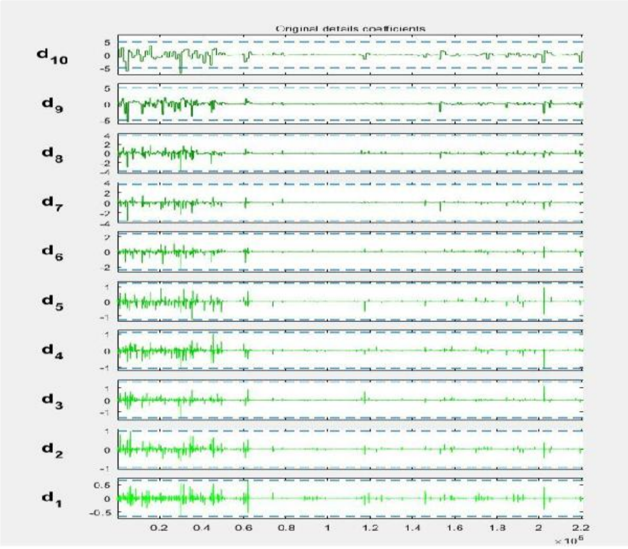

Fig 5. Denoised Output

Fig 6 shows the histogram of the original signal

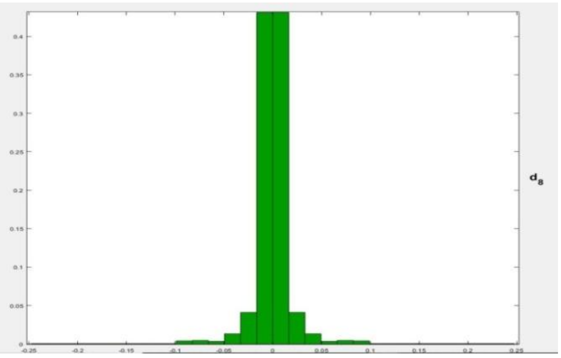

Fig 6. Histogram

From the figure the histogram of the signal has a peak value at 0.46 and minimum value at 0.2.

Fig 7 shows the histogram analysis of the signal .From the histogram analysis, the peak value is at 0.64

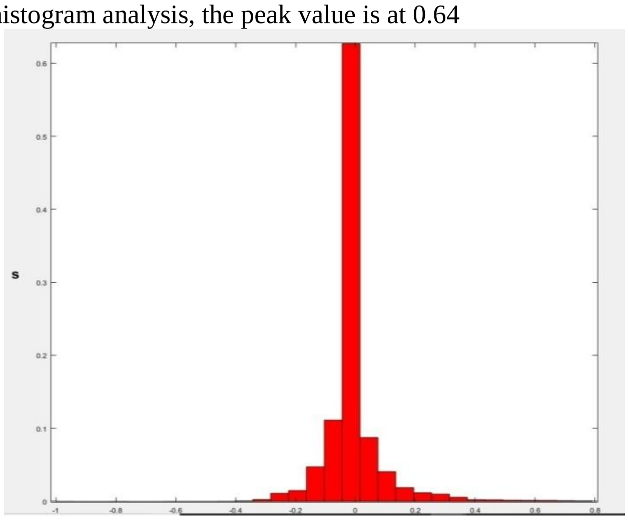

Fig 7. Histogram Analysis

Fig 8. shows the scroll view of the signal. From the figure shown the peak values are at 0.47 and 0.50. The scale of colors from min to max is shown in the details coefficients

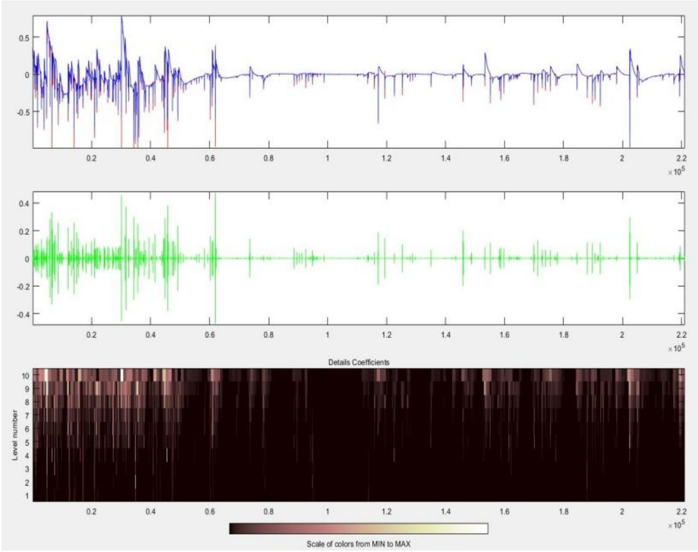

Fig 8. Scroll View

Fig 9. shows super impose mode of the signal.

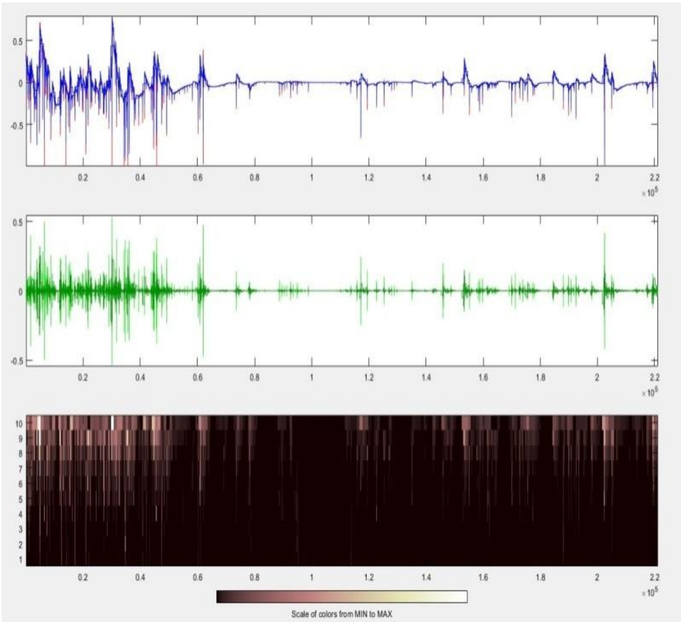

Fig 9. Super Impose Mode

Fig 10. shows the synthesis and approximations of the signal

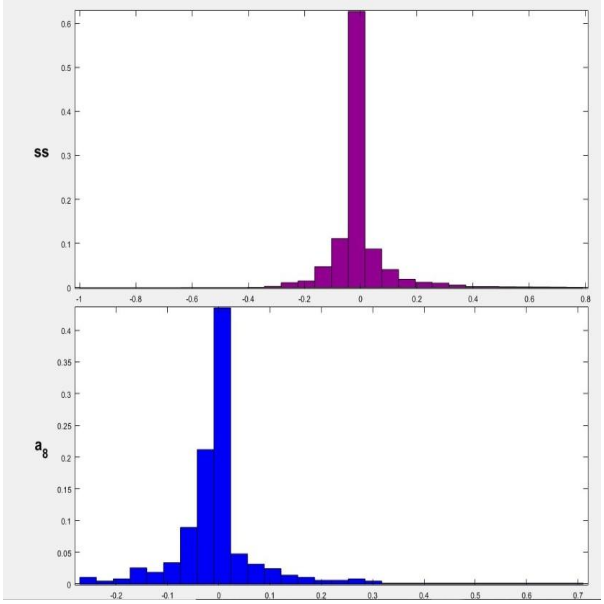

Fig 10. Synthesis and Approximation

From the figure shown the synthesised signal has the maximum value 0f 0.63 . The approximation of the signal has a peak value at 0.48.

The wavelet decomposition of the signal is shown in Fig 11.

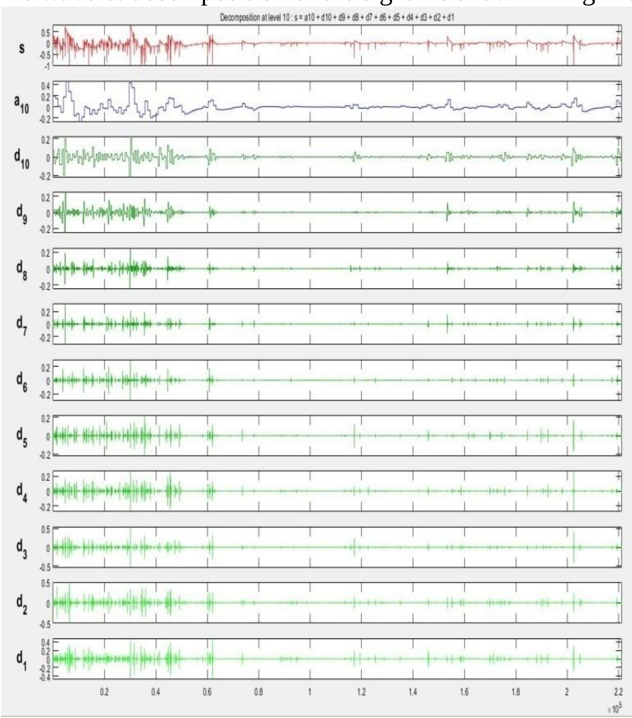

Fig 11. Wavelet Decomposition

From the figure the wavelet decomposition is done 10 levels and the decomposition at level 10 is the sum of the 10 levels as shown in figure

V. CONCLUSION

The use of the proposed method using acoustic sensor and current transformer gives a better outcome in the power quality enhancement. Using the proposed methods, a significant reduction harmonics that affects the power quality. The proposed method uses a series of signal computations in matlab simulation. From the results obtained the proposed methods of analysing the power quality in reliable and stable and can significantly overcome the limitations in power quality.

REFERENCE

1. R. Leou, J. Teng, H. Lu, B. Lan, H. Chen, and T. Hsieh, “Stochastic analysis of electric transportation charging impacts on power quality of distribution systems,” 2018.
2. R. K. Agarwal, I. Hussain, and B. Singh, “Dual-function PV-ECS integrated to 3P4W distribution grid using 3M-PLL control for active power transfer and power quality improvement,” 2018.
3. R. Cisneros-magaña, A. Medina, and S. Member, “Time-domain power quality state estimation based on Kalman filter using parallel computing on graphics processing units,” vol. XX, no. c, 2018.
4. K. Li, Y. Liao, H. Lin, R. Liu, and J. Zhang, “Circulating current suppression with improved DC-link power quality for modular multilevel converter,” vol. 3, no. 3, 2018.
5. Q. Tian and K. H. Bai, “Widen the Zero-Voltage-Switching Range and Secure Grid Power Quality for An EV Charger Using Variable-Switching-Frequency Single-Dual-Phase-Shift Control,” vol. 4, no. 1, pp. 11–19, 2018.
6. S. Lakshmi and S. Ganguly, “Modelling and allocation of open-UPQC- integrated PV generation system to improve the energy efficiency and power quality of radial distribution networks,” vol. 12, pp. 605–613, 2018.
7. C. Bhattacharjee and B. K. Roy, “Fuzzy-supervisory control of a hybrid system to improve contractual grid support with fuzzy proportional – derivative and integral control for power quality improvement,” 2018.
8. S. De and S. Debnath, “Real-time cross-correlation-based technique for detection and classification of power quality disturbances,” 2017.
9. A. Houari, A. Djerioui, A. Saim, M. Ait-ahmed, and M. Machmoum, “Improved control strategy for power quality enhancement in standalone systems based on four-leg voltage source inverters,” pp. 1–9, 2017.
10. T. Chakravorti, R. K. Patnaik, and P. K. Dash, “Detection and classification of islanding and power quality disturbances in microgrid using hybrid signal processing and data mining techniques,” 2017.
11. A. Mortezaei *et al.*, “Grid-Connected Symmetrical Cascaded Multilevel Converter for Power Quality Improvement,” vol. 9994, no. c, 2018.
12. S. Gupta, V. Nimesh, and V. John, “Diode Bridge Rectifier with Improved Power Quality Using Capacitive Network,” vol. 9994, no. c, pp. 1–10, 2017.
13. D. Voglitsis, S. Member, D. K. Baros, and S. Member, “Sensitivity Analysis for the Power Quality Indices of Standalone PV Systems,” pp. 25913–25922, 2017.
14. L. Wang, C. Lam, S. Member, M. Wong, and S. Member, “Analysis , Control and Design of Hybrid Grid-Connected Inverter for Renewable Energy Generation with Power Quality Conditioning,” vol. 8993, no. c, 2017.
15. U. Singh and S. N. Singh, “Detection and classification of power quality disturbances based on time – frequency-scale transform,” 2017.

AUTHORS PROFILE

T Rameshkumar, Research Scholar, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technolgy, Chennai India. Graduated Masters in Embedded System Technologies from Vel Tech Rangarajan Dr. Sakunthala R&D Institute of Science & Technology, Chennai, TamilNadu, India in 2011 and Bachelors in Electrical and Electronics Engineering from Anna University, Chennai.

Dr. P. Chandrasekar, HoD-EEE **&** Professor, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technolgy, Chennai India. Graduated PhD., Masters and Bachelors from Anna University, Chennai.