Artificial intelligence-based approaches to control the neutral current compensator and implementation of power quality conditioner for power quality enhancement

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Abstract - Power electronic components and electronic converters gave birth to numerous new applications, offering unmatched comfort, flexibility and efficiency to the customers. Owing to the improvement in technologies, large number of harmonics are introduced and they degrade the performance of the three-phase four-wire distribution system. These effects of distortion also affect the point of common coupling where other loads are connected to the system. A lot of measures and mitigating techniques have been presented in the literature but each has its own drawbacks like circuit complexity, lack of reducing lower order harmonics, occurrence of resonance problems with line impedance, etc. To overcome these defects, the thesis proposes two techniques to improve the power quality of the system. The first method aims at designing a Neutral Current Compensator and the second method involves designing of Unified Power Quality Conditioner. The neutral conductor of three-phase four-wire distribution systems have been widely employed to deliver electric power to single-phase or three-phase loads. The neutral conductor usually carries the zero-sequence current due to the unbalanced loading among phase conductors. As more and more electronic equipment such as computers, copy machines and adjustable speed drives are being used, the harmonic currents drawn by their rectifier front ends also become significant. Especially, the zero-sequence triple (3rd, 9th, etc) harmonics accumulate in the neutral conductor, resulting in overloading of the neutral conductor and the distribution transformer. Survey results in United States have indicated that 22.6% of the sites have neutral current exceeding the phase currents. In order to alleviate the effects of neutral current, the thesis proposes a new technique based on neutral current compensator. The neutral current compensator is a series active filter which is connected in series with the neutral conductor. The main objective of this compensator is to eliminate the harmonic component present in the neutral conductor there by overloading and overheating in the neutral conductor can be eliminated. By eliminating the harmonic distortion in the neutral, the phase current distortion is also reduced to a considerable extent. Rotating unit vector-based hysteresis controller is used to extract the harmonic component in the neutral conductor. The proposed method implements back propagated artificial neural network, fuzzy logic controller techniques and fuzzy solar PV based hysteresis controllers. The MATLAB simulation software is used to model and simulate the circuits. The hardware model is also implemented for the compensation of the neutral current harmonics to validate the simulation results. The effects of nonlinear loads also have a high impact on the load voltage distortion and load current distortion. Consequently, the current drawn by the loads has a high harmonic distortion level. If this level continues, then it affects the performance of the system by causing over heating of the conductors and degrades the efficiency. The thesis prescribes a model of Unified Power Quality Conditioner to overcome these potential problems. Synchronous Reference Frame controller is used to extract the reference signals for the series and shunt inverter of unified power quality conditioner. The conventional Proportional Integral (PI) controllers, genetic algorithm-based tuning of PI controllers and particle swarm optimization-based tuning of PI controllers are implemented for maintaining constant voltage across the input of inverter circuit. Hysteresis current and voltage controllers are used to generate the switching signals for the series and shunt inverters. Fuzzy logic controller is implemented to control the upper and lower band of the hysteresis controller. Among the various techniques stipulated, the PSO tuned PI controller with fuzzy hysteresis controller provides good dynamic response by reducing the harmonic distortion in the load current and load voltage, thereby balancing the unbalanced loads.

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1. OBJECTIVE OF THE PAPER

In power transmission and distribution system, maintaining the quality and reliability of the supply is the first concern. The harmonic currents generated by the power converters flow through the electrical utility system and cause various power quality problems such as neutral current harmonics, load current harmonics and load voltage harmonics. So, these harmful harmonics should be reduced in order to protect the loads connected to the line. The proposed method has two objectives: the first one is to design the Neutral Current Compensator (NCC) i.e., an active filter connected in series with neutral conductor in order to aims at these functions: To eliminate the harmonic content in the neutral conductor of three-phase four-wire distribution system during unbalance and non-linear load condition. To extract the harmonic component in the neutral conductor by designing the proposed Rotating Unit Vector (RUV) based hysteresis controller. To attain the objective by implementing Artificial Intelligence (AI) controllers like, Neural Network (NN), Fuzzy Logic (FL) and solar PV based fuzzy controllers. 21 The second objective of the thesis is to design a unified power quality conditioner and it intends, to enhance the power quality in 3P4W distribution system by eliminating load voltage distortion, load current distortion, neutral current distortion and balancing an unbalanced loading condition. The proposed work implements Synchronous Reference Frame (SRF) theory for extracting harmonic current and voltage components. Fuzzy Hysteresis Controller (FHC) is used for generating gating pulses to the inverter of UPQC with PI, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) based PI tuning for DC charging capacitor. The RUV theory and SRF theory are used to extract the reference signals for NCC and UPQC respectively. This work also makes an attempt to illustrate the electric utility and effectiveness of the artificial intelligence approaches. This is achieved by indulging in modelling and control over harmonics at that utility. This soft computing research with converters is concerned with the integration of artificial intelligent tools like fuzzy logic and back propagated neural network. It also exploits some of the optimization techniques like GA, PSO to solve the major problems caused by harmonics. The MATLAB/Simulink model version 10.0 is used for the simulation

2. PROBLEM STATEMENT

(a) Electric power industry shapes and contributes to the welfare, progress, and technological advances of every nation and humanity. The growth of electric energy consumption in the world has been phenomenal. Electric energy sales have been grown well in the period between the turn of the century and the early 2020s. This growth rate was several hundred times 4 as much as the growth rate in all other energy forms used during the same period.

(b) At the same time, it is very crucial to provide quality and reliable power supply to the consumers. But due to this development, maintaining the power quality within its standard becomes a very difficult task.

(c) With the development in the computer products, a lot of sensitive components are connected to the 3P4W systems which lead to the injection of harmonics in the distribution system. The harmonic current flowing through lines distorts the bus voltage and creates problem on sensitive loads operating on the same bus. So, these harmful harmonics should be completely reduced or it can be limited within some safe guard limit to protect the loads connected in the line.

The paper deals with two important problems which occur due to harmonics.

1. The first problem relates to the effect of harmonics on the neutral conductor of 3P4W distribution system. Most of the loads connected to the distribution systems are connected between any one of the phase conductors and the neutral. It leads to an unbalance condition and the flow of current in the neutral conductor. The commercial buildings which have thousands of computers are connected in such a manner, which injects the harmonic components in the neutral conductor along with the fundamental due to unbalance loads.The survey shows that current in the neutral is more than 160% of the phase conductor due to harmonics. Its results in the following harmful effects on the neutral conductor: Wiring failure due to improper sizing of neutral conductor. Overheating of transformer due to harmonic currents and insulation damage and failure. 5 Excessive neutral to ground voltage due to voltage drop caused by the neutral conductor results in malfunction of sensitive electronic components. Due to these harmonic currents, other loads connected to the PCC also get affected. De-rating of the distribution transformer which affects the three-phase sources and the phase conductors too. The neutral current is predominant in the zero sequence components i.e., third order harmonics. This effect of harmonics on the neutral conductor should be eliminated in order to enhance the power quality in the distribution system.
2. The second problem is concerned with the influence of harmonics on the load current, load voltage and unbalance system. The nonlinear loads such as arc furnaces, power converters and diode rectifiers are commonly used in power systems. These switching devices have the properties of injecting harmonics which lead to the distortions in the load current and load voltage waveform. The following problems are identified in the 3P4W system due to non-ideal relation between the voltage and current. Load current harmonics - impact of non-linear loads causes this distortion which affects the phase conductor waveforms.

Load voltage harmonics - due to load current distortion, the voltage across the load is affected and distorted. Consequently, other linear and sensitive load connected to PCC also gets distorted. 6 Unbalance load currents - if the loads connected to distribution are not equal i.e., the loads connected to all the three phases are not same, then the problem of unbalance on the load side occurs.

3. LITERATURE REVIEW

3.1 Harmonic Intrusions in Distribution System

Harmonic Intrusions in Distribution System number of investigations have been carried out for the improvement of power quality in the distribution system. The main objective of the power engineer and the electric utility is to provide reliable supply to their consumers. This objective becomes more complicated due to the effects of harmonics in the distribution system. On account of the growing use of the non-linear load equipment and new technologies, harmonic currents generated in distribution systems pose a new problem for electrical engineers. The problem becomes serious when power quality is a prime concern. The effect is due to some non-linear loads showing different current waveforms when supplied by a distorted voltage. These high neutral currents are accounted by three main components, namely fundamental phase current unbalance, third-harmonic current caused by saturation of ballasts and more third-harmonic current caused by third harmonic voltage waveform distortion in the supply. Ming -Yin Chan et al (2007) conducted another case study in an office building with a large number of computers which are analysed as a major source of harmonics. The study focused on the characteristics and effects of harmonic distortion of load current and voltages on distribution systems. It also suggested that proper planning and designing could minimize the harmonic-related problems in electrical systems. Po-Tai Cheng et al (2001) proposed a method of new harmonics suppression scheme for the neutral current in 3P4W distribution system. In this method, a series active filter was connected in series with the neutral conductor which reduced the effect of harmonics on the neutral conductor without over loading the distribution transformer. Peng et al (2001) published an article about the characteristics of the harmonics due to non-linear loads. The non-linear loads are characterized into two types of harmonic sources, namely current source non-linear loads and voltage source non-linear loads. These two types of harmonic sources are completely distinctive and exhibit dual properties and characteristics. Based on their properties and characteristics, the current-source nonlinear loads and voltage-source nonlinear loads have their own suitable filter configurations. The personal computers draw non-sinusoidal current with odd harmonics more significantly. Power quality of distribution networks is severely affected due to the flow of these generated harmonics during the operation of electronic loads.Jabbar Khan & Akmal (2008) discussed the mathematical modelling of odd order harmonics in current like 3rd, 5th, 7th and 9th which influence the power quality. Venkatesh et al (2008) suggested a method for optimal location of filters for harmonic analysis in the distribution system. The nonlinear loads used in domestic and small-scale industrial distribution systems are also modelled and simulated.

3.2 Passive and Active Power Filters

Review on Passive and Active Power Filters with Intelligent Controllers The solutions to the harmonic problems can be found by using the filtering techniques. The filters are used to remove the ripples or harmonics in the voltage and current waveform in order to maintain the utility system within the safe limit. In the early 1 providing the solution to the harmonic problems. A passive filter consists of a series combination of an inductance and capacitance, which are connected in parallel with the load. Peng et al (1999) proposed a passive system configuration for power quality improvement. The method traditionally consisted of 5th and 7th tuned LC series resonant and high-pass circuitry which are connected in parallel to nonlinear load. The effectiveness of the parallel LC filter for both harmonic current and voltage source type of nonlinear loads are explored. General compensation characteristics and comparison of parallel LC filters and series LC filters are given analytically. The effectiveness of series LC filters is demonstrated experimentally. Ji Yanchao& Fei Wang (1998) suggested a novel passive filter for single phase diode bridge rectifier. The single-phase diode rectifiers which are used in Switched Mode Power Supply (SMPS), personal computers are the main sources of generating zero sequence harmonics in the distribution system. The novel topology maintains high input power factor, high quality input current waveforms and low rectifier current stress. The operating principle of topology is analyzed in detail under steady state condition and then theoretical results have been verified on an experimental model. 9 Prasad et al (1990) designed a passive filter for wave shaping of current and voltage harmonic waveforms which are generated due to diode rectifier load. This method lowers the Volt-Ampere (VA) rating of the associated reactive components as compared to the standard diode rectifier. Relevant input and output current waveforms, component ratings, and power factor values are derived. Different modes of operation of passive filters are also discussed for obtaining high performance. Hamadi et al (2010) devised a hybrid filter configuration for harmonic compensation in the distribution system. The topologies have three phase Hybrid Passive Filter (HPF) for reactive power and harmonic compensation. The HPF consists of a series passive filter and a thyristor-controlled reactor. A mutual-inductance design concept is used to reduce the series passive filter inductance rating. The special features of the stipulated HPF system include insensitivity to source impedance variations, fast dynamic response and significant size reduction. Chou et al (2000) preferred an optimal planning of a large passive harmonic filter for high voltage applications. It is based on multi-type and multi-set of filters, from which the types, set numbers, capacities and the important parameters of filters are determined to satisfy the requirements of harmonic filtering and power factor.

4. INTRODUCTION

Electricity is by all means one of the most basic needs in today's world. As a matter of fact, many social and economic activities depend on the quality of electrical power and efficiency. Providing reliable and efficient power supply to the consumers has become one of the difficult tasks of the power engineers. Due to the advancement in power electronic converters and information technologies, a large number of computer products and nonlinear loads have been connected to power distribution systems. The properties of nonlinear loads affect the performance of power supply and reduce the life and efficiency of the modern-day equipment. The other linear loads which are connected to the Point of Common Coupling (PCC) also are affected and degrade the overall performance of power system. Electric power is distributed through a Three-Phase Four-Wire (3P4W) system in many industrial and commercial sectors. These 3P4W distribution systems can be realized by providing the neutral conductor along with three power lines from the generating station or by utilizing a delta-star transformer in the distribution system. Most of the loads in commercial buildings are connected to any one of the phases of 3P4W distribution system. The loads connected to the distribution systems may not be equal, and they lead to unbalanced load conditions. Due to this unbalance load, some part of current flows in the neutral conductor. If the loads connected to the 2 distribution systems are non-linear, then harmonic component of current flows along with the fundamental component in the neutral conductor. These effects of the neutral current lead to an over burden and over sizing of the neutral conductor and affect the performance of the distribution transformer. As a result, load currents and load voltages are also distorted and the overall performance of the power system gets degraded. To prevent these effects, a lot of methods have been proposed in the past decades. It is not an easy task to prevent these effects completely, but they can be reduced to some extent. In order to protect the equipment from damages, some international standards like IEEE 519-1992, IEC 61000-3-2, IEEE 1159 are proposed. These standards set the limits for the variation of voltage and current distortion, below which the equipment can function without any malfunction. This safety margin of standards provides the good power quality and thereby safeguards the equipment from malfunction. The limits given by the standard IEEE 519-1992 for current harmonic distortion and voltage harmonic distortion are depicted in Table 1.1 and Table 1.2 respectively. Thus, for ensuring good power quality requires, good initial design, effective correction equipment and co-operation with the supplier of electricity, frequent monitoring and good maintenance. The limits of IEEE 519 are intended to assure that an electric utility can deliver relatively clean power to all of its customers. ensure that an electric utility can protect its electrical equipment from overheating and loss of life from excessive harmonic current and harmonic voltage. The current distortion limits are 5% and voltage distortion limits are 3% for individual harmonics set by international standards. ISC is the short 3 circuit current at PCC, IL is the fundamental component of maximum demand load current at PCC and TDD is the Total Demand Distortion.

5. POWER QUALITY TERMS AND DESIGN OF PROPOSED NEUTRAL CURRENT COMPENSATOR USING RUV BASED HYSTERESIS CONTROLLER

The development of technology in all its areas is progressing at a faster rate. The various effects of harmonics and diode bridge rectifier are discussed in this chapter. The series active filter which is connected in series with the neutral conductor called as neutral current compensator is designed to enhance the power quality. The switching pulses to the inverter of NCC are obtained by implementing hysteresis controller which uses PWM techniques. The performances of the distribution system without compensation and with RUV based hysteresis controller are simulated using MATLAB/Simulink and the results are analysed.

6. IMPORTANCE OF POWER QUALITY

Electric Power Quality (EPQ) is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without any significant loss of performance or life expectancy. Good power quality can be specified as follows:

- The supply voltage should be within guaranteed tolerance i.e.10% in voltage variations and ± 2% of frequency deviation.
- The waveform should be pure sine wave within allowable limits for distortion.
- Voltage should be balanced in all the three phases.
- The earthing system should serve its purpose properly.

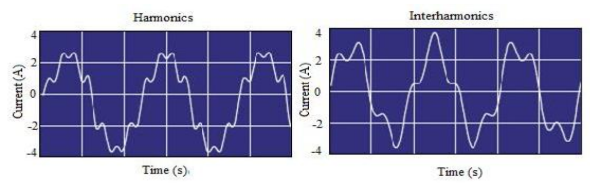
7. POWER QUALITY TERMS AND DEFINITIONS WAVEFORM

Any periodic signal (voltage or current) which changes its magnitude and polarity with respect to time is said to be a waveform (Dugan 2004). The analysis of waveform using Fourier series is given by,

$$u(t) = U_{dc} + \sum_{n=1}^{\infty} (U_{(n)s} \sin(n\,\omega t) + U_{(n)s} \cos(n$$

Inter harmonic component

The frequency component of an alternating electric power supply which is not aninteger multiple of the fundamental frequency is called interharmonics. It creates new problems such as sub-synchronous oscillations, voltage fluctuations, etc. The difference between the harmonicand interharmonic wave form



is depicted in Figure.

Figure 1: Wave form of harmonics and interharmonics

Point of Common Coupling

The PCC is apointinan electrical system where multiple customers or multiple electrical loads may be connected. According to IEEE-519, this should be a point which is accessible to both the utility and the customer for direct measurement.

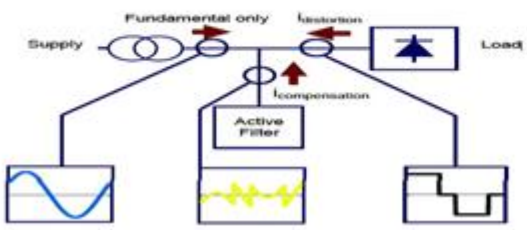


Figure 2: Harmonic compensationusing active filter

Notching

A switching disturbance of the normal power voltage wave form that lasts for aperiod less than 0.5 cycles is said to be not ching. It is initially in opposite polarity and is thus subtracted from the normal waveform in terms of the peak value of the distortion voltage. This includes complete loss of voltage upto 0.5 cycles.

Voltage Swell

Voltage swell is an increase in rms value of electric supply voltage or current from 1.1 to 1.9 puofitsrated value and its durations will be from 0.5 cycles to 1 min.

Voltage Sag

Voltage sag is the decrease in rms value of electric supply voltage or current between 0.1 to 0.9 puofitsrated value and its duration will be from 0.5 cycles to 1 min.

Flicker

The impression of unsteadiness of visual sensation induced by alight stimulus whose luminance or spectral distribution fluctuates with respect to time is known as flicker. The heavy loads can greatly change the load currents in an electrical distribution system. Voltage flicker occurs when heavy loads are periodically turned ON and OFF in a weak distribution system.

Transients

Transients may generate in the system itself or may come from the other system. It is nothing but the sudden rise of an electrical signal. The phenomena with the duration of less than one cycle (of the power-system frequency of 50 Hz) are generally referred to as transients. There are mainly two types of transients i.e., Impulsivetransient and Oscillatorytransient.

ImpulsiveTransients

Animpulsivetransientis as udden change in the steady state condition of voltage, current or both which is unidirectional in polarity (primarily either positive or negative). Impulsive transients are normally characterized by their rise and decay times.

Oscillatory Transients

Oscillatory transients show a damped oscillation with a frequency ranging from a few hundred Hertzto several mega hertz. These types of transients are the naturaltransients in electric power systems. Atypical example of an oscillatory transientis created by energizing a capacitor bank.

Total Harmonic Distortion

Total Harmonic Distortion (THD) is an important figure of meritused to quantify the level of harmonics in voltage or current waveforms. Thetotal harmonic currentdistortionis defined as the squarerootof the sum ofthe squares of the current harmonic components to its fundamental currentcomponents.

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$$

THD_I = total current harmonic distortion, I_n = Order of currentharmonics (3rd,5th,andso on), I_1=Fundamentalcurrentcomponent(50Hz).

The total harmonic voltage distortionis defined as the square rootof sum of the squares of the voltage harmonic components to its fundamental voltage components.

$$THD_V = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1}$$

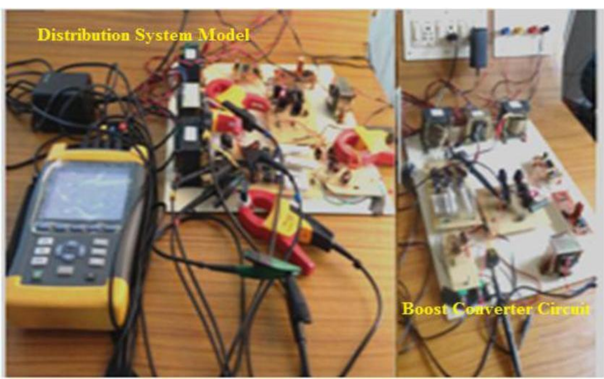
THD_V = total voltage harmonic distortion, V_n= Order of voltage harmonics (3^{rd},5^{th},etc.), V_1=fundamental voltage component (50Hz).

Hardware implementation

7. SOURCES OF HARMONICS

Electrical power system harmonic problems are mainly due to the substantial increase of nonlinear loads such as the use of power electronic circuits and devices. These kinds of equipment createload-generated harmonics through out the system. Ingeneral, the sources of harmonics are due to

- Power Electronic Converters.
- Devices which include semi-conductor elements.
- Lightening equipment working by gas discharge principle.
- Personal Computers.
- Electronic ballasts.
- Uninterrupted power supplies.
- Switching power supplies.
- Welding machines and arcfurnaces used in industries.
- Control circuits used by switching devices.
- Frequency converters.
- Static VAR compensators.



- HVDC transmission systems.
- Industrial Process Control.

8. MONITORING AND SOLUTIONS TO POWER QUALITY PROBLEMS

Power quality monitoring is the process of gathering, analyzing andinterpreting raw measurement data into useful information. The process ofgathering data is usually carried out by continuous measurement of voltageand current over an extended period. Hence in the last decade many utilitycompanies have implemented extensive power quality monitoring programs. Several common objectives of power quality monitoring are,

a. Monitoring to characterize the system perform

b. Monitoring to characterize the specific problems

c. Monitoring as part of an enhanced power quality service

d. Monitoring as part of predictive or just-in-time maintenance.

8.1 Effects of diode bridge rectifier

Most of the house holding equipment's and other sensitive components uses diode bridge rectifier for the rectification processes whichare the main causes of the harmonics. The single-phase diode rectifier has become a popular power source for these appliances because of its reduced cost and relatively low sensitivity to supply voltage variations. The thesismainly concentrates on these devices because all the circuits considered for the simulation consists of diode bridge rectifier whichis taken asthe source of the harmonics for the analysis. The effect of diode bridge rectifier with smoothening capacitor is very harmful to the load current as shown infigure 2.6.The harmonic spectrum implies that the load current is affecteddue to 3^{rd} order harmonics of 72%, 5^{th} of 60%, 7^{th} of 40%, 9^{th} of 22.6% and soon. To illustrate the cumulative effect of this type of diode bridge rectifierload, the following case study is analyzed

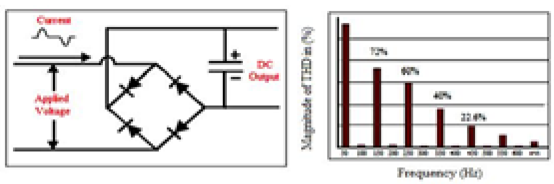


Figure 3: Effects of diode bridge rectifier

8.2 System Parameter sand MATLAB Model of Diode Bridge Rectifier in 3P4W Distribution System

The analysis on the effect of harmonic sowing to diodebride rectifier as a nonlinear load is simulated using MATLAB. The system parameters are given in Table and MATLAB model of system is shown in Figure 3

System Parameters	Values
Line to neutral voltage, Frequency	240 V/120V,50 Hz
Leakage reactance of the distribution transformer	0.35mH
Filte rinductance, capacitance	0.2mH, 1μF
DC link capacitance	2500μF
Load Values of Resistance and DC Capacitance at rectifier side	RA B=15Ω RC =25Ω R =50Ω $C_A=C_B=C_C=1000\mu F$

The system voltage is taken as 240 V/120 V, 50 Hz. In order to create an unbalance system, the different values of resistances are connected in each phase of the 3P4W distribution system.

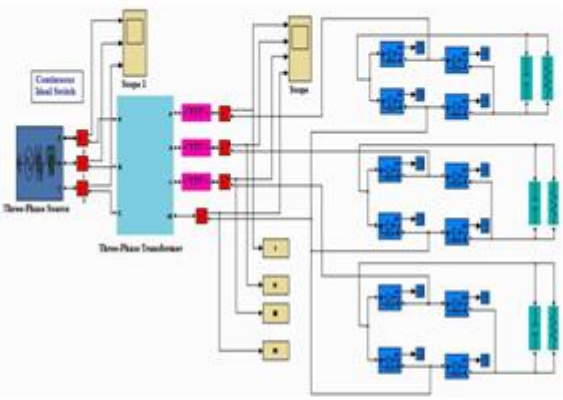
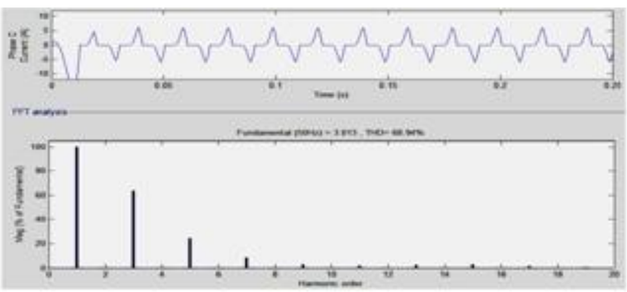


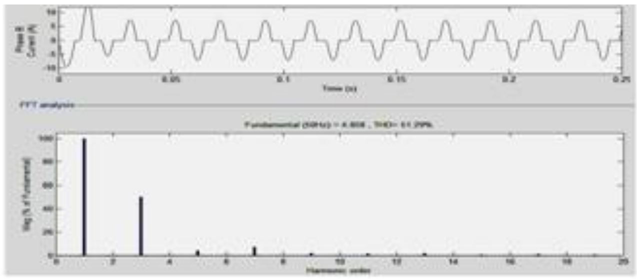
Figure 4: MATLAB model of diodebridge rectifier with 3P4W system

To realize the 3P4W distribution system, three single phase diodebridge rectifiers with different values of load resistance is connected to thesystem. The capacitance in the rectifier side isused to remove th eDCripples.

Result-1



Result-2



9. CONCLUSION

The areas of power quality issues and remedial measures have received considerable attention from the power utilities, power consumers andpower equipment manufacturers over the last decade. The large-scale use of bulk powerthyristor converters and industrial electronic equipment resulted in wave form pollution at all levels in the power systems from mid-eightiesonwards.

The problem became more serious with the proliferation of nonlinear loads (rectifiers, arc furnaces, variable speed drives, UPS, computer load, printers and domestic electronic equipment) in the industrial, commercial and residential sectors in the past decade.

These loads draw nonsinusoidal currents from the supply and lead to voltage distortion and related system problems. With the widespread use of power electronics at all levels, the polluting loads spread out system wide. Power quality improvement measures concentrated on a few bulk power points and they turned out to be insufficient in mitigating system wide problems.

The paper concentrated on two important effects of power quality.The first one is neutral current harmonics which flow due to nonlinear andunbalanced system of the loads in the 3P4W distribution system. The effects of neutral current were realized by modeling a 120V, 50Hz distribution system using MATLAB simulink and the mitigation of these neutral current harmonics has already been discussed in the literature. The seexisting methods have draw backs like circuit complexity, lack of lower order harmonic reduction and they use complex zigzag transformer connections.

To overcome these difficulties, neutral current compensator was designed using rotating unit vector-based hysteresis controller, back propagated artificial neural network controller, rotating unit vector with fuzzy logic hysteresis controller and solar PV based fuzzy logichysteresis controllers were proposed. RUV controller was used to extract the harmonic components present in the neutral conductor. The second one is the load voltage harmonics, load current harmonics and unbalanced load which occurs due to non-linearity and unbalanced load present in the distribution system. These effects of load voltage and load current harmonics affect the overall performance of the

3P4W distribution system. It also affects the voltage across the point of common coupling. Due to this, other linear loads connected to the point of common coupling also get degraded. The various filtering techniques like passive filters, seriesactive filters, shunt active filters, hybrid filters and FACTS controllers were implemented and discussed in the literature as well.

Although the existing methods provide the distortionlevels with in the good standards achieving balanced load currents from the unbalanced system was a difficult task which leads to the flow of neutral current.

Also, the existing controllers were not able to maintain the constant voltage across the inverter input dc-link capacitor voltage. The proposed method uses unified powerquality conditioner, which compensated both voltage and current harmonic distortion in the distribution system and also proved to be capable of balancing a nun balanced system. The proposed method used synchronous reference frame controller for extracting reference signal for voltage and current compensation along with modified phase locked loop. Fuzzy hysteresis voltage and current controllers were used to generate the switching signals for UPQC inverter circuits. The implementation of fuzzy logic controller in the proposed method was used to optimize the upper and lower bands of the hysteresis controller.

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