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Power Quality Study of Electrical Installation in Academic Institute – Case Study

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Abstract

In era of automation, the power quality disturbances are increasing day by day with use of electronics components or devices which are source of harmonics. Residential, commercial and industrial consumers are affected by deprived power quality. Levels of power quality disturbances depend upon type of loading in a system. Newly installed equipment or good quality equipment also get affected by other old equipments in electrical network. It happens due to shared infrastructure. Power quality monitoring and analysis of electrical network is important to maintain stability and reliability of power system. It also helps to reduce the heavy financial losses to customer and major breakdown of system equipment. The aim of this study is to identify and measures power quality disturbances like voltage, current imbalance, harmonics, quality of power factor and reactive power factor in educational institute campus. This paper present the results of study conducted on power quality analysis for military college of engineering Pune. Readings are taken with help of power quality analyzer. Readings are obtained in form of excel file in exponential format. Study and analysis of obtained readings is done for power quality parameters.

Keywords: Power Quality Analysis, Power Quality Issues, Harmonics, Power Quality Analyzer

INTRODUCTION

Power quality of electrical network depends upon wiring system and level of disturbances in electrical network. Power quality of electrical network is determined from magnitude and duration of electrical parameters. Magnitude of electrical parameter shows the level of power disturbances. From magnitude of electrical parameter we can determine sag, swell, flickers, harmonics, under voltage, overvoltage and time duration helps to determine the time of availability of grid or electrical system with load. Faults may be short term and long term. As per IEEE STD 1100-1 999, Power quality is defined as the concept of powering and grounding electronics equipment in manner that is suitable to the operation of equipment and compatible with the premises wiring system and connected load.

Power quality disturbances are defined as unwanted external and internal event affect the pure sinusoidal waveform or electrical parameters of the system which results distortion in magnitude and phase angle of voltage and current. Followings are the power quality disturbances in power system: Power frequency variation, voltage dips, voltage surges, voltage fluctuation, voltage imbalanced, current imbalanced, harmonics, poor power factor, Transient.

Power quality disturbances are occurred due to sudden switching ON /OFF of large loads, inductive loading, capacitor switching, internal and external faults, industrial arc furnaces and welding machines, use of non linear loads, use of electronics devices, rectifier circuit, unbalanced loading, lack of reactive power compensation, frequency drive. Some standard has given in IEEE and IEC which introduced about the control of power quality disturbances. IEEE 519 and IEC SC77A/WG1 are defined for harmonics control in power system. IEEE 1100 introduce powering and grounding of sensitive equipments.

These power quality disturbances create worst impact on both consumer end and supplier end. Impacts of power quality disturbances are unnecessary tripping of sensitive equipment like protective relaying system, stalling or tripping of motor due to voltage dips, equipment and equipment winding failure due to voltage surge, malfunction of equipment and capacitor failure due to harmonics, flickers of lighting due to voltage fluctuation in system, damage to computers, tripping of motor, unnecessary rebooting of electronics devices or digital equipments. Reliability and stability of power system is depends upon the disturbances in system. So it is very essential to mitigate or avoid these power quality disturbances in power system.

Due to worst power quality, equipment malfunction, equipment heating problems arises in electrical network and it leads to permanent failure of connected equipment. Now days in industries, residential and commercial sectors are work on automation so use of electronics devices are increased which are very sensitive to power fluctuation. Power quality study is

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very important to avoid interruption of power and maximize the efficiency of equipment, plants.

There are different types of mitigation techniques. Power disturbances are mitigated by using interrupting power supplies, use of power conditioner, ferroresonant control transformer, use of facts devices like D- STATCOM, DVR, and UPQC. Active and passive filters help to mitigate harmonics in system. Power factor or reactive power compensation can be done by using capacitor bank or power factor correction devices.

This paper presents the results of power quality analysis of transformer in educational institute campus. This study and analysis help us to understanding the behavior of power with educational institute building load.

LITERATURE REVIEW

M. Izhar, C. M. Hadzer, S. Masri [1], this paper gives results of power quality analysis of electrical and electronics engineering department building in university science, Malaysla. Data collection has been done with power quality instrument BMI over one week. This one week reading help to determine give higher accuracy of power quality analysis. In this paper, power quality parameters are considered such as total harmonics distortion, order harmonics, power factor, and Current, voltage distortion. These parameters are measured successfully. In this paper author observed that power consumption is more in ground and second floor of building as compared to other floor of building. Finding of this paper is higher neutral current in system due to unbalanced of three phase four wire system and higher total current distortion at neutral line.

P.Vasmi kumar Reddy, M. Rajesh, K. Palanisamy [2], this paper gives results of power quality analysis conducted in VIT, University at different load or feeders. The measurement of power quality parameters like total harmonics distortion, flicker, voltage and current imbalanced has been done by using PQ-Box-200. Author has found that power quality of educational institute or power quality events like voltage dip, voltage swell, flicker, and interruption, transient have increased and are degrading the entire system.

M. Rajesh, P. Vamsi Kumar, K Palanisamy [3], this paper present power quality analysis of academics & hostel building of educational institute. Readings has been taken with help of Win PQ mobil-200 power quality analyzer for 24 to 48 hrs. In this study and analysis of power quality parameters like voltage & current harmonics, voltage sag/swell, flickers are done. Collected data is analyzed power quality of academic and hostel building and results are used for to design of new power quality improvement device.

Christopher j. Melhorn, Mark F. McGranaghan [4], this papers discussed the power quality disturbances in power system. This paper also discussed the power quality measurement devices and data analysis techniques. Author said that power quality may be impact on end user facility but it may be consist of interaction between all levels of the system. Author also said that instrumentation should be able to process data during data analysis process and it is very important to be able to summarize variation in power quality with time.

Haroon Farooq, Chengke Zhou, Malcom Allan [5], this paper is present the power quality analysis of various non linear home appliances. Harmonics analysis is performed in Electrical Transient Analyzer Program (ETAP). This paper also discussed and analyzed the level of harmonics with their impact on system. In this research work, author found results from experimental, simulation process and it help to calculate the impact of various non-linear loads on power quality of system. Result has higher level of total harmonics levels which are beyond the acceptable standards values. Author also observed voltage and current at consumer's end is highly distorted which effect on equipment connected in system.

POWER QUALITY ANALYZER

In today's market numbers of power quality monitoring, power quality analysis kits are available. These kits are available with specifications, different function, and construction and also different manufactures. In this case study we have used Yokogawa company power quality analyzer kit. We have used current measuring clamp upto 500Amp.This device has main features as readings are automatically saved, easily monitor list of electrical parameters, Readings are available in form of graphs and waveforms.

Following power quality Analyzer available in market:

1. Yokogawa CW240 Clamp ON POWER METER
2. Fluke 1735 Three-Phase Power Logger
3. Fluke 435 Series II Power Quality Analyzers
4. Fluke 1750 Three-Phase Power Quality Recorder
5. Fluke 1760 Three-Phase Power Quality Recorder

We have used Yokogawa CW 240 clamp on power meter for this case study. It consists of three clamp meter and three cables for voltage measurement. We can change the rating of power quality analyzer by changing the current and voltage measurement cables or probes. Voltage rating of power quality analyzer is 1000 volt. It has memory card which can extend as per our requirement. Fig1 show introduction about power quality analyzer. We have used personal protective equipments like helmets, face shield, safety shoes, insulating gloves while working on high voltage power panels.

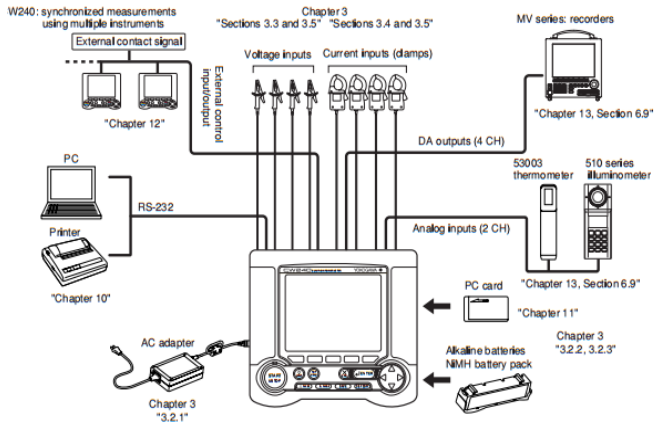

Fig 1

NEED OF POWER QUALITY STUDY

Manufacturing, production, processing, emergency services or industries are required continuous power supply. If there is any power interruption or component failure in facility, they lead to major breakdown in facility. Downtime and production cost of facility increases with higher breakdown time of facility. These all factors affects on growth and performance of industry or facility. So power quality study and analysis are important. In power quality study and analysis we can early detect fault and avoid system from major breakdown. It also helps to increase the performance of electrical system.

The objective of this study is to identification of power quality disturbances in electrical network of residential load and college building load in college campus area. We will also provide suggestion for facility against power disturbances or power quality issues.

POWER QUALITY DISTURBANCES

Power quality disturbances are defined as factor affect on performance of sinusoidal voltage and current waveforms. There are external and internal problem cause power disturbances in system. Lightening and faults on transmission and distribution network are external problem of power quality disturbances. Switching of heavy load, use of old appliances, use of non linear load are internal problem cause power disturbances in electrical system.

Following power quality disturbances are considered for this study.

1. Voltage or Current Unbalance
2. Power factor
3. Frequency deviation
4. Harmonics
5. Voltage Fluctuation

Power quality system consists of number of power disturbances. In this paper we will discussed about power quality of College of Military Engineering Pune. In this discussion is done on voltage asymmetry, current asymmetry, voltage fluctuation, flickers, and harmonics. For power quality analysis of college campus we have taken reading at transformers output side of three areas.

Firstly we discuss about power quality disturbances. Power quality disturbances means factors, parameters which are hazardous to power system or power system equipments. Due to power quality disturbances performance of system will decreases. Disturbances are arises in system due to external and internal conditions. Lightening, earth quake, heavy rain, short circuit occurs due to birds, trees. Internal conditions are use of old appliances, switching of large load.

VOLTAGE UNBALANCE & CURRENT UNBALANCE

Voltage and current unbalance means magnitude and phase shift of voltage and current waveform are not identical. That means three phases are not symmetrical. In this unbalance conditions generator or motor draws more current than its normal operation which result increase temperature of generator. There is chance of major fault with generator due to temperature rise. Generators are more expensive so protection against this type faults are important to avoid major breakdowns of generators. The main reason of unbalance voltage and current is asymmetrical loading and loose connection in one of the phase. Voltage unbalanced may be acceptable limit for few second to few minute.

POWER FACTOR

Current drawn by load is different for resistive load, capacitive and inductive. Current and voltage both are start with same instant in resistive load.. So power dissipation is higher in case of pure resistive load. Current drawn by inductive and capacitive load is lag to voltage and lead to voltage respectively. As per definition of power, Power is product of voltage and current. Current lag, lead affect on performance of power. In case of inductive and capacitive load average value of power is zero. Only in pure resistive circuit has average value of power. If pure resistive load is present then value of power factor is 1. For R-L circuit and R-C circuit value of power factor is 0 to 1 Lag and 0 to 1Lead resp. For pure Inductor, Capacitor is Zero.

FREQUENCY DEVIATION

Frequency of ac power system is defined as number of cycles per second. It also defines as it is inverse of time where time is calculated in second. Unit of frequency is hertz. In India frequency is 50 Hz. Frequency deviations is critical issue for some of components of power system. Like induction generator, motor, transformer. Speed of induction generator and motor depends upon frequency of ac system. In transformer induced voltage is depends upon the frequency of ac system. Frequency deviation is allowed to system from 49.1 to 50.3 HZ. It is considered in case of power stability of power grid. Because all power grid components are designed as per supply frequency. While power quality monitoring and

analysis of any power system or facility frequency is important parameter.

HARMONICS

Harmonics means distortion in sinusoidal voltage and current waveform. Harmonics arises in system due to change in impedance of load. When sinusoidal voltage applied across the variable impedance of load then resulting waveform creates another sinusoidal waveform. Uses of nonlinear loads are the main reason of harmonics. The power system connected with non-linear load draws current are not fallows the voltage waveform which also effect on sinusoidal voltage waveform. That means current waveform distortion lead to voltage waveform distortion. Sheared infrastructure is one of the problems of power quality problem .In sheared infrastructure; harmonics in current enters from one facility to other facility. But now day all industries are works on automation and also use of electronics devices are increased. So chance of harmonics generation is increased. Nonlinear load are Arc Furnace, Computers, printers,

High load machineries, induction motor and generator, electronic components, programmed logic controllers, welding machines, variable frequency drives, switching mode power supplies.. Harmonics are stated as 3^{rd}, 5^{th}, 7^{th} etc. This numbers are denotes a level of harmonics or frequency as a multiples of their fundamental frequency. Harmonics are very harmful for system or system components. Effect of harmonics on power system is malfunctions of system components some time permanent damage of system components, interferences between telephonic communications, losses in motor increases with increases level of harmonics components because hysteresis and eddy current losses of electrical motor are directly proportional to frequency. So it is important to mitigate the harmonics contents from power system. It will be help to increase the performance of the system

VOLTAGE FLUCTUATION

Voltage fluctuations are defined as continuously or cyclic, regular or irregular voltage changes in time. These are produced from continuously start or stop of heavy load machineries. Examples are Welding machines, rolling machines, arc furnaces.

The flicker is main problem of this effect. A permissible voltage change in magnitude is allowed upto +/- 10%.

CASE STUDY

In this power quality assessment, we have done power quality analysis of College of Military Engineering campus where power is given to different load, residential and college building through transformer. We have taken reading of power quality parameters with help of power quality analyzer. Power quality parameters are voltage unbalance, current unbalance, reactive power, power factor, harmonics and voltage fluctuation. These power quality parameters are consider in power quality analysis of electrical network of college of military engineering. All the power quality problems are recorded at interval of 1 min. As per definition of sag, swell requires time duration in millisecond and microsecond. Data related to sag and swell are not recorded in this power quality assessment or analysis due to selection of 1 min. time interval. In this assessment we have done power quality analysis on one transformer output.

Site and Location Information: Military College of Engineering Pune

Date and Time: 02 /03/2017 16:42:00

Nominal Frequency: 50Hz

Power Type: Three phase

Nominal Voltage 480 Volts

With help of power quality analyzer reading are taken. Readings are presented in form waveforms. In this case study all readings are taken for 10 minute time period. Fig 2 presents three phase voltage U1, U2, U3. Graph plotted between time interval of one minute and three phase voltage. From fig 2 we observed that all three phase voltages are in phase. There is no deviation in three phases. For Voltage waveform Voltage parameter are summarized.

Max Voltage: 449.2 volt observed at phase U1. Time: 16:44:00

Min Voltage: 426.1 Volt observed at phase U2. Time: 16:43:00

Average Voltage: 358.37 volt

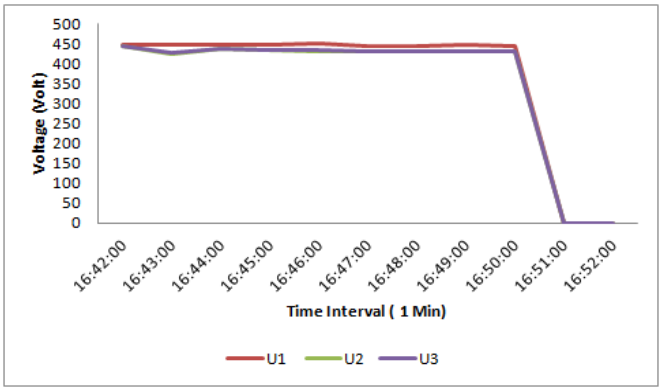

Figure 2. Three Phase Voltage Waveform

Fig 3 shows the current waveform, it consist of three phase current. Current I1, Current I2 and Current I3.here also readings are taken for 10 minutes with time interval of 1 minute. From fig we observed that current taken by phase 1 is higher than other two phase.

Max Current: 54.9 Amp At phase I1. Time: 16:50:00

Min Current: 16.9 Amp At phase I3. Time: 16:49:00

Average Current: 27.78 Amps

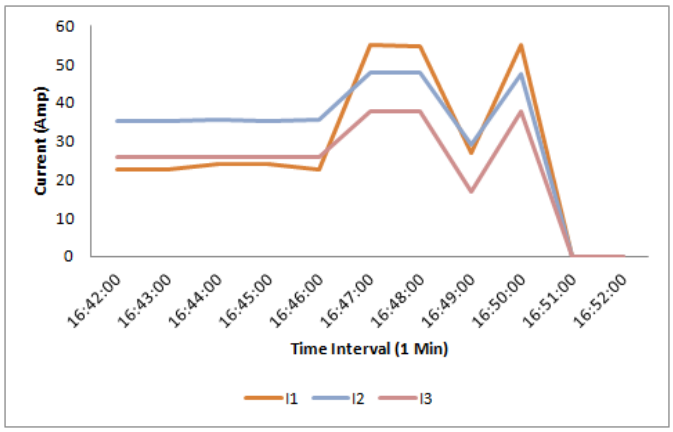

Figure 3. Three phase current waveform

Fig 4 shows power waveform, graph is plotted between time and power. Active, reactive and apparent power is three power curves on waveform. These readings are taken for 10 minutes with an interval of 1 minute.

Max active power: 32600 W
Max Reactive Power: -20000 Var

Min active Power: 3700 W
Min Reactive power: -12200 Var

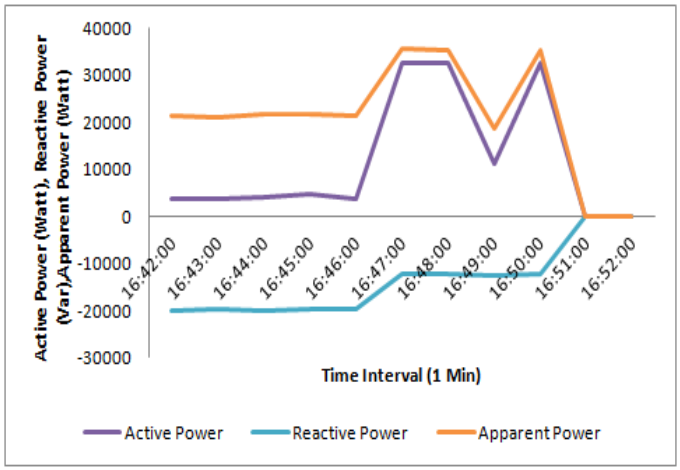

Figure 4. Three Phase Power Waveform

From fig 4 we can observe that level of reactive power is very low. It has minimum value is around -20000 Var. Reactive power is plays important role to maintain voltage stability of system. The system voltage decreases with higher load and increase with lower loads. So power transfer from sending end to receiving end requires stable value of voltage which can transfer it easily without power loss in distribution system. System voltage can be changed by injecting and supplying reactive power to distribution network. From graph, we can conclude reactive power for system is not nominal value. There is need of reactive power compensation devices.

Reactive power Compensation can be done by adding or supplying reactive power to distribution circuit. It can be done with help of Shunt capacitors (fixed / Switchable), Synchronous Condenser, Synchronous Generator, Static Var Compensator. If system has already reactive power compensation arrangements then there is need to check capacitor values (weak or strong), check any facility expansion or load added in facility after design of compensator. If there is found any abnormalities then there is need to replace faulty capacitor with new one.

Following Table shown power factor, frequency of electrical network of facility.

In table no.1 we have given power factor for different time with different load conditions. When load is pure inductive that means there are zero real power and more reactive power. Power factor should lie between 0 to 1 and 1 is better value of power factor. At unity power factor power system will give better performance. Below table has recorded readings of college of military engineering. Power factor is not unity that means load is not pure resistive. It is combination of resistor and inductor. The worst power factor is found -0.16 at 16:42 to 16:46.

Table 1

TIME	PF_INST_1	PA_INST(deg)_1	F_INST(Hz)
16:42:00	-0.17	-80.1	50.1
16:43:00	-0.18	-79.7	50.11
16:44:00	-0.19	-78.9	50.15
16:45:00	-0.22	-77.3	50.12
16:46:00	-0.18	-79.9	50.1
16:47:00	-0.92	-23.5	50.03
16:48:00	-0.92	-23.5	50.05
16:49:00	-0.6	-52.9	50
16:50:00	-0.92	-23.3	50
16:51:00	----	----	OR
16:52:00	----	----	OR
16:52:00			

Graphs for TDH in voltages U1, U2, U3 & in currents I1, I2, I3:

Following fig and graphs are present data related harmonics in U1, U2 and U3 phase & harmonics in I1, I2, I3 phase. The graphs are plotted between voltage and total harmonics distortion in % for voltage. The waveforms are plotted between current and total harmonics distortion in % for current.

Waveforms are shown the harmonics components in current. Current drawn by the load or delivered by source should have fundamental frequency. Current can delivered maximum power to load. Current with distortion waveforms or contains harmonics frequency can't deliver active power to load. Total

harmonics distortion is ratio of harmonics components in I rms current to fundamental current. It is calculated in percentage.

Effect of current harmonics on distribution system or components:

Impedance of transformer is directly proportional to frequency. Higher level of harmonics distortion creates higher heat loss in transformer.

Effect of voltage harmonics on distribution system or components:

Negative sequence harmonics present in induction motor due to voltage distortion. They are very harmful for motor and produce negative torque in motor and rotate in reverse direction with reduced rotation. Sometime temperature of motor increases and fails.

Other effect like failure, malfunction of equipment occurs in system due to harmonics distortion. From the waveforms we conclude the level of current harmonics distortion is more. It might be serious to system components.

Total Harmonics Distortion in Voltage Waveform:

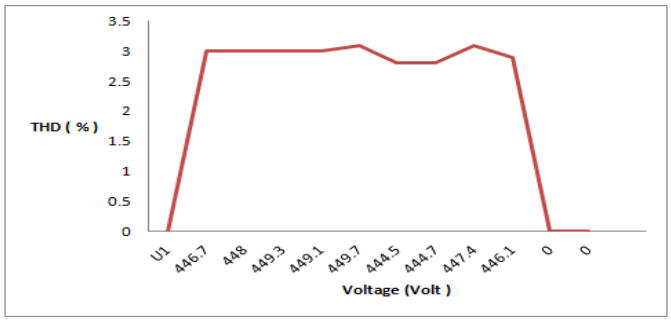

Figure 5. Total Harmonics Distortion in R Phase Voltage

Maximum THD: 3.1% Minimum THD: 2.8%

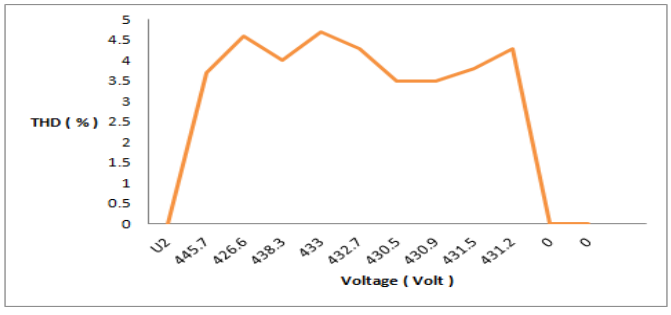

Figure 6. Total Harmonics Distortion in Y Phase Voltage

Maximum THD: 4.7% Minimum THD: 3.5%

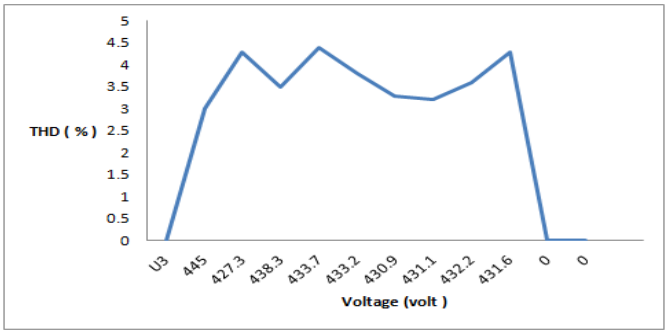

Figure 7. Total Harmonics Distortion in B Phase Voltage

Maximum THD: 4.4% Minimum THD: 3%

Fig 5, 6, 7 shows the voltage distortion in electrical network of college of military engineering campus. From fig we observed that it is permissible harmonics contents. TDH value is recorded for voltage in phase Y or U2 is more i.e. 4.7%. 5th and 7th harmonics level is more in phase U2 and U3 and 5th harmonics level found more in phase U1 for voltage distortion.

Total harmonics Distortion in Current Waveform:

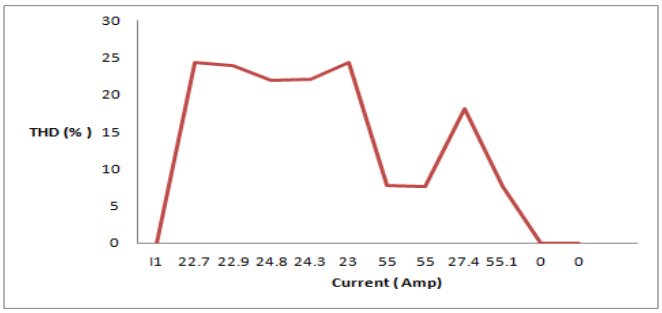

Figure 8. Total Harmonics Distortion in R Phase Current

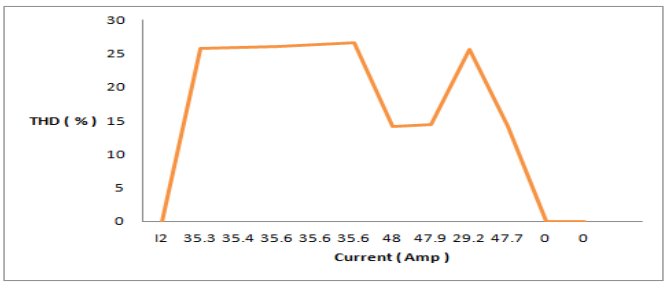

Figure 9. Total Harmonics Distortion in Y Phase Current

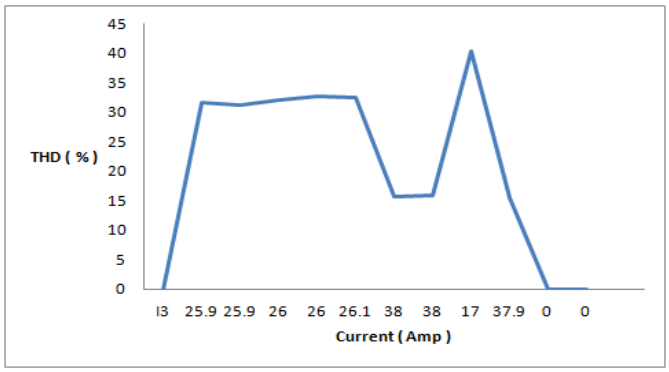

Figure 10. Total Harmonics Distortion in B Phase Current

Fig 8, 9, 10 are showing Total harmonics distortion in current phase I1, I2 and I3 resp.

The current waveform distortion is occurred in all three phase waveform. Fig 8 shows the total distortion in phase R. We observed that maximum THD value at 24.3% and minimum THD value is 7.7%. There is more current distortion in waveform due to 7^{th} and 11^{th} order of harmonics.

Fig 9 shows the harmonics components in phase Y. Current distortion is found more in phase Y due to 5^{th} and 7^{th} order harmonics. Maximum

Total harmonics distortion is 26.6% and minimum harmonics distortion is 14.1%.

Fig 10 shows the total harmonics distortion in phase B. Maximum harmonics distortion is observed 40.3% in phase B. Minimum value is observed 15.4%.%. 7^{th} order harmonics are more in phase B. All harmonics data collected for voltage and current harmonics distortion over an interval of 1 min.

Figure 11. Connection of power quality analyzer

Fig 11 is snap of connection of power quality analyzer with three phase bus system. This connection is done without shutdown of system. So PPEs are used while connection of power quality analyzer.

LIMITATION

Small duration readings cause reduces accuracy of power quality study and analysis. This power quality studies are only applicable to determine electrical performance of system like voltage, current imbalanced, harmonics, and quality of electrical parameters. But it is unable to determine mechanical performance of system like torque, speed, power and overall efficiency of machinery.

CONCLUSION

This paper discussed power quality disturbances in electrical network of college of military engineering campus. In this power quality assessment, we have identified power quality disturbances. In case study I, We observed that total harmonics distortion in current was higher with presence of 7^{th} order of harmonic. Also observed that reactive power and power factor was very poor. The perfect balance value of reactive power should be required to maintain voltage stability of electrical system. But in this case study we got very lower value of reactive power. Power factor also very poor and it was in negative. That means load supply power back to source which happens due to use of energy storage devices s load. So this facility requires power factor correction devices or arrangements.

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