



International Journal of Advance Engineering and Research Development

Volume 4, Issue 1, January -2017

Monitoring of Power Quality using PLC

Divyang Modi¹, Prof.Nimesh Smart²

¹Scholar BE, Vidhyadeep Institute of Engineering & Technology, Surat,

²Asst. Professor, Vidhyadeep Institute of Engineering & Technology, Surat.

Abstract—Modern innovation makes the life easier and safe by utilizing the technology which relies on the application of power electronics it turnabout power quality. Problem related to quality of power has been turned out to be increasingly concern with electricity consumers in last few decades. It has become an important issue in monitoring, controlling and managing of power quality. Sensitive equipment's and power electronics based load or non-linear load are ordinarily used as a part of industrial, commercial and household environment. Control operation with automation like Programmable Logic Controller (PLC) and Supervisory Control & Data Acquisition (SCADA) is mandatorily smooth in industry. The sensitive equipment and power electronics based load or non-linear load generates disturbances in power supply, which affect the other equipment and likewise equipment generates the distorting harmonics. The principal aim of this paper is to investigate the most common power quality problems, effect of harmonics on the power quality, the ways of evaluating the amount of harmonic distortion present in a power system which lead to isolate the cause of the problem and finally device a solution for a good power quality.

Keywords- Power quality, Energy audit, Monitoring, Harmonics, Mitigation techniques

I. INTRODUCTION

Electricity is not anymore luxury article like few decades ago, but it has become a necessity and a part of our everyday life. With the development of science and technology, people's demand for electricity increasing. Since late 1980s, the word power quality becomes most prolific for power industry. The changing face of the electric power system is due to latest power apparatus, the proliferation of customer owned resources and smart devices. The proliferation of highly sensitive equipment places increasingly more demands on the quality of electric power supplied to the customer. Not only the power be supplied without interruption, but voltage and current waveforms must maintain nearly sinusoidal shape, constant frequency, and amplitude at all times to ensure continuous equipment operation.

Power quality is one of the main signs of power industry development. Improving power quality is important in ensuring the operation of safety and the economy in power grid, ensuring the normal quality of industrial products and the scientific experiments, reducing energy consumption and so on. Advance electronic technology, sophisticated equipment, complex control systems and processes are widely used in modern industry, science, and technology, which make more and more high request in power quality. Therefore, power quality has been directly related to the overall benefit of the national economy.

Understanding power quality can be confusing at best. There have been numerous articles and books concerning power quality. There are two terms known in power systems about the quality of power: Good power quality and Poor power quality. In good power quality, the voltage and frequency tolerances is within limits and has a pure noise-free sinusoidal wave shape to all equipment. In poor power quality, the voltage get distorted and affecting other equipment's. Sensitive power disturbances resulting in reduced performance and it will cause equipment miss operation or premature failure. Power quality is an important point in relationship between suppliers and consumers.

II. POWER QUALITY

Many industrial and commercial customers have equipment that is sensitive to power disturbances. Therefore, it is more important to understand quality of power being supplied in a power system, faults, dynamic operations, or nonlinear loads often cause various kinds of power quality disturbances such as voltage sags, voltage swells, switching transients, impulses, notches, flickers, harmonics, etc. Power quality is defined in the IEEE 100 Authoritative Dictionary of IEEE Standard Terms as the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment utilities may

want to define power quality as reliability. Power Quality may also be defined as “a set of electrical boundaries that allows equipment to function in its intended manner without significant loss of performance or life expectancy.”

2.1. Importance of Power Quality

1. Proliferation of highly sensitive computerized equipment places more stringent demands on power quality
 - Semiconductor industry
 - Computers and computer-related businesses
 - Variable-speed drives or robots
 - Programmable logic controllers
2. Electronic equipment results in more power quality problems
3. Deregulation of power industry creates more competitive market
4. Impact
 - One cycle interruption makes a silicon device worthless
 - Five minutes shutdown causes delay from a day to week
 - One second of power outage makes e-commerce sites lose millions of dollars' worth of business

2.2. How to measure Power Quality?

To solve a power problem for a single unit of equipment, the monitor should be placed as close to the load as possible. For a power quality problem, need that voltage signal is monitored and finally to find the cause, accurate measurement of power quality issues requires that the monitor accurately measure the voltage and current waveforms. To identify equipment problems, it is key to analyze data in a systematic manner. First, look for power events that occurred during intervals of equipment malfunction. Second, identify power events that exceed performance parameters for the affected equipment. Third, review power monitor data to identify unusual or severe events. Finally, correlate problems found during the physical inspection with equipment symptoms.

III. ISSUES OF POWER QUALITY

3.1. Causes of Power Quality

Voltage Fluctuations: It is mainly caused by arc furnaces, frequent start/stop of electric motors (for elevators), oscillating loads, etc. and its consequences are under voltages, flickering of lighting and screens etc.

Voltage Surges/Spikes: Voltage rise that may be nearly instantaneous (Spike) or takes place over a longer duration (Surge). A voltage surge takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off.

Voltage Dips and Under voltage: Short duration under-voltages are called “Voltage Sags” or “Voltage Dips”. Voltage sag is a reduction in the supply voltage magnitude followed by a voltage recovery after a short period of time. The major cause of voltage dips are fault in the system, starting of large loads.

High Voltage Spikes: High voltage spikes occur when there is a sudden voltage peak up of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on electronic systems can include loss of data and burned circuit boards.

Frequency Variations: A frequency variation involves a change in frequency from the normally stable utility frequency of 50 or 60 Hz, depending on geographic location. This may cause by erratic operation of emergency generators or unstable frequency power sources. For Sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shutdown.

Electrical Line Noise: Electrical line noise is defined as Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) and causes equipment to lock-up, and data error or loss. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms.

Brownouts: A brownout is a steady lower voltage state causes data loss and equipment failure. An example of a brownout is what happens during peak electrical demand in the summer, when utilities can't always meet the requirements and must lower the voltage to limit maximum power.

Blackouts: A power failure or blackout is a zero-voltage condition that lasts for more than two cycles. It may be caused by tripping a circuit breaker, power distribution failure or utility power failure. A blackout can cause data loss or corruption and equipment damage.

Very Short Interruption: Total interruption of electrical supply for duration from few milliseconds to one or two seconds' causes ripping of protection devices, loss of information and malfunction of data processing equipment. Mainly due to the opening and automatic reclose of protection devices to decommission a faulty section of the network.

Long Interruption: Long interruption of electrical supply for duration greater than 1 to 2 seconds causes stoppage of all equipment. The main fault causes are Equipment failure in the power system network, storms and objects (trees, cars, etc.) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

Voltage Swell: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds. The main causes are Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours). And the consequences are data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

Harmonic Distortion: Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency (50Hz). Harmonics are created by non-linear loads that draw current in abrupt pulses rather than in a smooth sinusoidal manner, (a) Normal fundamental 50Hz Waveform (b) Waveform containing the fundamental plus third and fifth harmonics.

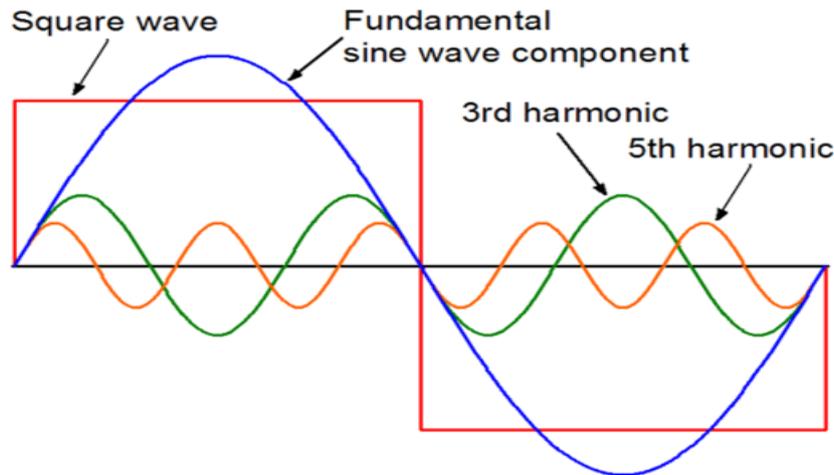


Figure 1. Various Harmonics in Supply Signals

Power system voltage and currents are sinusoidal waves. Harmonics are sinusoidal components of a periodic wave that are integral multiples of the fundamental frequency. Superposition of harmonics with fundamental will distort the original waveform.

Noise: Superimposing of high frequency signals on the waveform of the power-system frequency caused by microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment, improper grounding etc. Consequences are disturbances on sensitive electronic equipment, usually not destructive, data loss and data processing errors.

Voltage Unbalance: A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal. Causes are large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault). Unbalancing results in negative sequence that is harmful to all three phase loads, particularly most affected loads are three-phase induction machines.

3.2. How to minimize the issues of power quality?

3.2.1. Supply system quality problem:

For the voltage disturbances, such as momentary outage, sags and swells and transient voltages, the most convenient solutions to improve the performance of a sensitive equipment is to install a protective device between the power source and sensitive equipment. Voltage regulators are installed between the power source and sensitive equipment to control the incoming voltage in order to sustain a constant output voltage, it protects the equipment against overvoltage's and under voltages.

3.2.2. Harmonic problem:

Harmonic currents are fact of life and cannot be eliminated unless nonlinear loads are avoided. Active harmonic filters inject an exactly complimentary harmonic current into the supply to cancel that produced by the non-linear loads. Filters types include line-reactors, passive harmonic filters, active harmonic filters, electronic feedback filters and special transformers that use out of phase windings to accomplish harmonic reduction. While these units are effective at reducing the harmonic current as seen by the utility.

Take account of harmonic generating loads when planning the installation.

- Reduce the number of socket outlets on each circuit and increase the number of circuits.
- Carefully distribute these circuits among the phases to reduce out of balance currents.
- Increase the cross-sectional area of feeders, neutral feeders and distribution panels.
- Uses of 5 core copper cable- one core for each phase and two for the neutral.
- Maintain records of cable layout and usage.
- Maintain and upgrade the system carefully.
- Routinely monitor neutral and phase currents.
- Check for excessive heating in transformers, motors and distribution boards.

3.2.3. Earth leakage problems:

The primary purpose of grounding electrical systems is to protect human and property if a fault occurs. The second purpose of a grounding system is to provide a controlled, a low impedance path for lightning induced currents to flow to the earth harmlessly. Problems can be avoided if it is recognized that the grounding system in electrical installations is no longer designed for fault conditions.

3.2.4. Mitigation Equipment

1. **Thyristor based static switch:** The static switch is a versatile device for switching. To correct quickly for voltage spikes, sags, or interruptions, the static switch can be used to switch capacitor, filter, alternate power line or energy storage system.
2. **Energy storage systems:** Storage systems can be used to protect sensitive production equipment from shutdowns caused by voltage sags or momentary interruptions. These are usually dc storage systems, such as UPS, batteries, superconducting magnet energy storage, storage capacitors, etc.
3. **Filters:** Filters are categorized into noise filters, harmonic filters (active and passive filters) etc. Noise filters are used to avoid unwanted frequency current or voltage signals from reaching sensitive equipment. This can be accomplished by using a combination of capacitors and inductances that creates a low impedance path to the fundamental frequency and high impedance to higher frequencies, that is, a low-pass filter. Harmonic filters are used to reduce undesirable harmonics. Passive filters consist in a low impedance path to the frequencies of the harmonics to be attenuated using passive components (resistors, inductors and capacitors).
4. **Isolation Transformer:** Isolation transformers are used to isolate sensitive loads from transients and noise deriving from the mains. The particularity of isolation transformers is a grounded shield made of nonmagnetic foil located between the primary and secondary. Any noise or transient that come from the source in transmitted through the capacitance between primary and the shield and on to the ground and does not reach the load. Isolation transformers reduce normal and common mode noises.
5. **Static Var Compensators (SVC):** This is a shunt-connected assembly of capacitors, and reactors, which provides reactive power to a network during disturbances to minimize them. It is normally applied to transmission networks to counter voltage dips/surges during faults and enhance power transmission capacity on long transmission circuits.

IV. PROPOSED SYSTEM

For the given research paper, here we represent the block diagram of proposed system. The System have four different stages, Transducer Kit, PLC, SCADA and different types of Load; which is shown in below block diagram,

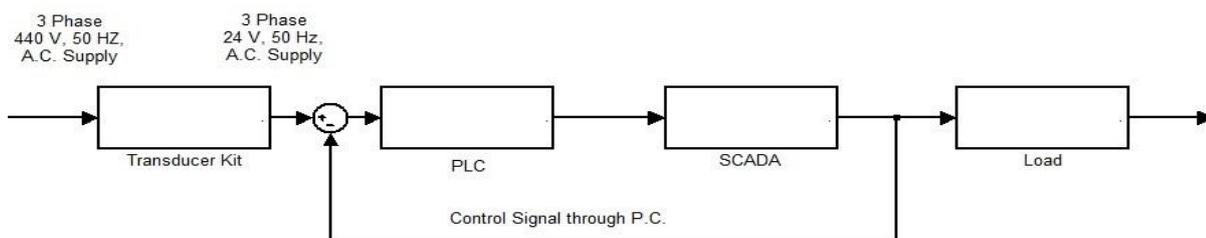


Figure 2. Block diagram of Proposed System

1. **Transducer Kit:** A transducer is an electronic device that converts energy from one form to another form. In the transducer kit, there is a step-down transformer which has two sides. One is primary side, where 3-phase, 440 volts, 50 Hz A.C. supply is given. And on secondary side, tapping are provided as per requirement.

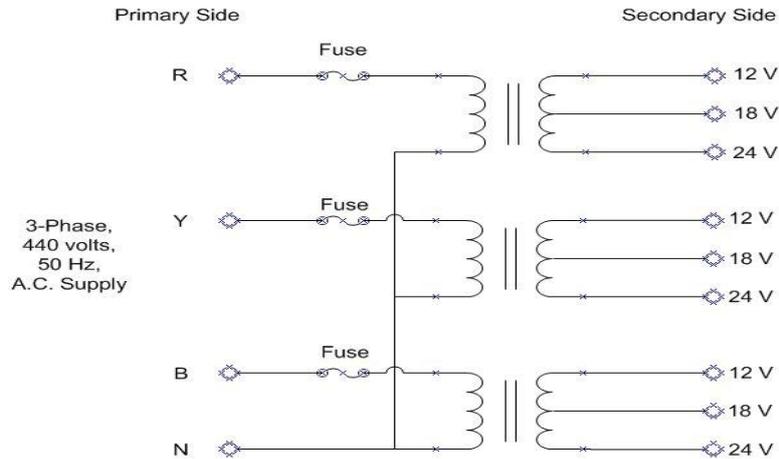


Figure 3. Connection diagram of Transducer Kit

The output of the transducer kit is 12 volts, 18 volts or 24 volts as per Programmable Logic Controller (PLC) specification. And the output of the transducer kit is directly given to the input of PLC.

2. **PLC:** PLC stands for Programmable Logic Controller. Making products under the control of programmable controllers is known as PLC. It is the delegation of human control functions to technical equipment for increasing productivity, better quality, increasing safety in working conditions reducing manpower and cost. PLC works as follows.
 1. Testing input status
 2. Programming Execution
 3. Checking and correction of output status
3. **SCADA:** SCADA stands for Supervisory Control And Data Acquisition. As the name indicates, it is not a full control system, but focuses on the supervisory level. It is used to monitor and control plant or equipment. The control may be automatic or indicated by operator commands. SCADA runs on a PC and is generally connected to various PLCs and other peripheral devices. It enables you to generate applications for the most demanding requirements of plant engineers, operators, supervisors and managers tailored precisely the needs of each plant. SCADA constantly gathers data from the plant. In real-time, stores and processes it in the database, evaluates and generates alarms, displays information to plant operators, supervisors and managers and can issue instructions to PLCs on the plant floor. SCADA has some features like, dynamic process graphic, real time and historical trend, alarms, recipe management, security, device connectivity, database connectivity etc.
4. **Load:** The electrical loads are mainly divided in 3 parts.
 - a) **Resistive Load:** Resistive load resist current flow linearly and it causes in terms of heat and light. For example, Incandescent lamp, etc.
 - b) **Inductive Load:** Resist changes in current and as such, when you measure the current, it lags (is behind) the voltage. Electromagnetic fields are the key to inductive loads, and as such all motors (fans, pumps, etc.), solenoids, and relays are inductive in nature.
 - c) **Capacitive Load:** Capacitive load resist changes in voltage, and as you'd expect, the voltage lags the current (or more commonly said "current leads voltage").

V. IMPLEMENTATION

5.1. PLC

Programmable logic Controller, All the input and output elements are correlates with the operational parameters to the process arrangement through the user and monitors the system during normal operation. **Wiring diagrams** shows the circuit wiring and its associated devices (relays, timers, motor relays, switches, etc.) in their relative physical location. This type of diagram assists locating components and shows how a circuit is actually wired, it does not show how a circuit is actually wired, it does not show the circuit in its simplest form. To simplify understanding of how a circuit works, and show the electrical relationship of the components, a ladder diagram is used. **Ladder diagram** also referred as schematic or elementary diagram is used by the engineers to speed their understanding of how a circuit works.



Figure 4. Ladder diagram of the system

As per the above ladder diagram, here we give step by step description of all the functions;

- **M1002** is “ON” during the first scan when PLC starts to Run and remains “OFF” afterward.
- **D1120** get the value above communication protocol and move in to the H97 in hexadecimal value. When the SET instruction is driven, the device is to be “ON” which will keep “ON” whether the SET instruction is still driven. You can use RST instruction to set the device “OFF”.
- Set **M1143** instruction is set the data of Modbus address in ASCII or RTU mode this instruction is used with MODRD/MODRW/MODWR.
- Set **M1161** is “ON” when it is in 8-bit mode.
- **D1129** in this time out setting after 500 micro-seconds in communication.
- **D1121** is an address that save PLC communication address, it is latched.
- **M1013** gives 1s clock pulse it means on for 0.5 s and off for 0.5s but it is operating in only positive clock pulse and Set **M1122** is sending request to the drive for getting data from the Modbus.

5.2. SCADA

A SCADA system mainly performs 4 functions.

1. **Sensors:** Sensors (either digital or analogue) and control relays that directly interface with the managed system.
2. **Remote Telemetry Units (RTUs):** These are small computerized units deployed in the field at specific sites and locations. RTUs serve as local collection points for gathering reports from sensors and delivering commands to control relays.
3. **SCADA Master Units:** These are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.
4. **Communications Network:** The communications network that connects the SCADA master unit to the RTUs in the field. SCADA systems report to human operators over a master station, HMI (Human-Machine Interface) or HCI (Human-Computer Interface). SCADA master station has several different functions:
 - Continuously monitors all sensors and alerts the operator when there is an “alarm”
 - Presents a comprehensive view of the entire managed system,
 - Presents more detail in response to user requests
 - Performs data processing on information gathered from sensors
 - Maintains report logs and summarizes historical trends.

VI. RESULT

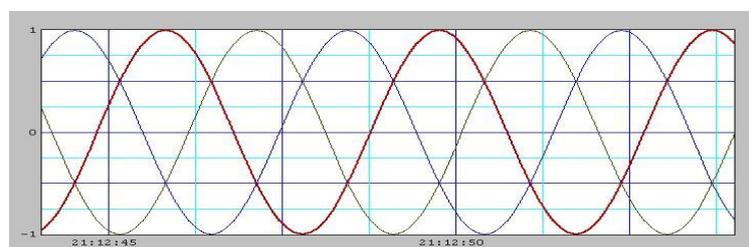


Figure 5. Waveform of the Proposed System

Sr. No.	Phase R	Phase Y	Phase B	Hz R	Hz Y	Hz B	3 rd HR	3 rd HY	3 rd HB	7 th R	7 th Y	7 th B
1.	24.8387	77.7017	-42.264	49.0696	49.069	49.0695	29.2767	12.8787	13.56	0.9925	0.7518	0.859
2.	49.8363	102.6753	-17.2706	49.0717	49.072	49.0715	29.1045	12.7977	13.707	0.9702	0.6779	0.897
3.	75.711	128.4475	8.5688	49.0668	49.067	49.0668	29.3317	12.7182	14.16	1.0305	0.7626	0.9036
4.	99.5066	152.2678	32.3324	49.0666	49.067	49.0668	29.3923	12.7437	14.109	1.0285	0.6695	0.8047
5.	123.4883	176.2212	56.3417	49.0664	49.067	49.0666	29.0932	13.1238	14.052	0.9324	0.838	0.8644
6.	147.307	200.0842	80.177	49.0639	49.064	49.064	29.2416	13.3733	14.136	1.0081	0.6826	0.8826
7.	170.7012	223.4768	103.585	49.0607	49.061	49.0606	29.688	13.2706	13.949	1.07	0.8001	0.8862
8.	192.3393	245.0785	125.202	49.0571	49.057	49.0571	30.0223	13.1869	13.833	0.9697	0.7821	0.7846
9.	212.9632	-94.3148	145.79	49.0558	49.056	49.0559	30.0706	13.2277	13.903	1.0871	0.818	0.9648
10.	232.9901	-74.2096	165.837	49.0493	49.049	49.0493	30.2611	13.2843	14.197	1.0699	0.9338	0.8382

Table 1. Results from the Proposed System

VII. CONCLUSION

The availability of electric power with high quality is crucial for the running of the modern society. If some factors are satisfied with the quality of the power provided by utilities, some other will demand more. The present paper gives an assessment of power quality. Various issues and factors concerning power quality have been discussed. Also, discussed about the measurement strategies used to monitor the power quality. Due to the technology, monitoring and control is highly effective means to detect and solve. Before monitoring, a design step is needed and should take into account the electrical environment and define how the electrical installation must meet the needs of the business.

VIII. REFERENCES

- [1] IEEE 100, The Authoritative Dictionary of IEEE Standard Terms, seventh edition, 2000, p. 234.
- [2] Anurag Agarwal, Sanjiv Kumar, Sajid Ali, “A research review of power quality problems in electrical power system”, MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2, No. 2, Aug. 2012, pp. (88-93).
- [3] Zhiqiang Gao, Ke Zhang, Xuesong Zhou, Youjie Ma, “The Discussion on Power Quality Technology”, Proceedings of 2016 IEEE International Conference on Mechatronics and Automation, August 7-10, Harbin, China.
- [4] P. V. Chopade Member IEEE, V. A. Bugade LMISTE, D.G. Bharadwaj, “Ensuring Power Quality and Reliability- A step towards securing energy for the future”, For NPSC-2006, National Conference @ IIT Roorkee.
- [5] Shilpa.R, P.S.Puttaswamy, “A Review on Power Quality Issues in Power Systems”, International Journal of Industrial Electronics and Electrical Engineering, ISSN: 2347-6982, Volume-2, Issue-10, Oct-2014.
- [6] Pulkit Gupta, “Controlling of Electrical Power System Network by Using SCADA”, Emerging Trends in Engineering and management for Sustainable Development 2016, International Conference, Feb-2016.
- [7] Angamma AM CJ, Seyon K, Tennakoon SMK (Miss), Weerasekara JMCA, “Project on Power Quality”
- [8] Michal Regula, Alena Otcenasova, Marek Roch, RoamnBodnar, Michal Repak, “SCADA system with power quality monitoring in Smart Grid Model”
- [9] MehebabAlam, Mandela Gain, “Power Quality Problems and Solutions: An Overview”, International Journal of Science and Research (IJSR), ISSN (online): 2319-7064, Impact Factor (2012): 3.358
- [10] Ramya L.N, M.A.Famina, “Energy Auditing- A Walk-Through Survey”, Vol.3, Special Issue 2, April 2014.