

Effects of Non Linear Loading on Power Quality

Prashant Kedarnath Magadum¹ and Dr. Sangmesh G. Sakri²

¹Research Scholar, VTU, Belagavi and Assistant Professor, Electrical Engineering Department, Brahmddevdada Mane Institute of Technology, Solapur
Email: magadumpk@gmail.com

²Associate Professor, Electrical Engineering Department, Poojya Dodappa Appa College of Engineering Kalburgi
Email: sakripda@gmail.com

Abstract—Recent advances in power electronics has made it easier to control the consumer electronics appliances efficiently. Also there is a growing need of highly reliable and cost efficient products to cater a wide range of the society needs. The electronic front end of such products contributes to be a nonlinear load. The most common device is a simple rectifier with capacitive filter which converts AC into DC that in turn powers a wide range of household appliances like LED lighting, mobile charger etc. Such a nonlinear load causes power quality to degrade. Many of the modern days power sources acts as a non-linear load over the grid which contain power electronic switching devices. These devices do not conduct current for entire cycle of the supply voltage, and hence harmonics are introduced in the power system. If the power quality of the supply system is in accordance with regulatory standards, then efficient and satisfactory operation of load can be ensured. But if the power quality of the supply system is not in accordance with standards, then there exists chances of load failure and reduced lifetime hence leading to the inefficient operation of the overall installation. This paper describes brief review on the impact of nonlinear loads on power quality in terms of harmonics. Also, case study for study of harmonics profile of various types of non linear loads is presented with MATLAB simulations.

Index Terms— Non linear load, power quality, harmonics, reactive power.

I. INTRODUCTION

The electric supply voltage in ideal power distribution system is sinusoidal in nature with constant frequency and amplitude. The supplier of electricity is responsible for assuring good quality of power supply [1]. However, the electrical loads connected in the system can affect the amplitude of voltage thus making it a distorted sinusoidal waveform. Electrical loads are classified as linear load and nonlinear load. For Linear loads, voltage and current waveforms are sinusoidal in natural and the instantaneous current is proportional to the voltage e.g. resistor, motor, transformer, capacitor etc. On the other hand for Non linear loads the voltage and current waveforms may not be sinusoidal in nature. They draw pulsating current from the source which results in generation of harmonics which can affect the distribution system as well as the connected load. In short it creates power quality problems [2, 3]. The power quality of a distribution system is measured through power factor, harmonic distortion, voltage fluctuation, crest factor and K factor. The power quality disturbances are categorized into four parts as: amplitude, phase, frequency and waveform. The amplitude disturbance is observed when the amplitude of current or voltage waveform deviates from its normal working range as shown in figure 1. The frequency disturbance is observed when the frequency of supply deviates from its normal working limits as shown in figure

2. The phase disturbances are observed when the phase angle relationship between the waveforms deviates from their normal working limits as shown in figure 3. The waveform disturbances are observed when the waveform deviates from its normal shape as shown in figure 4.

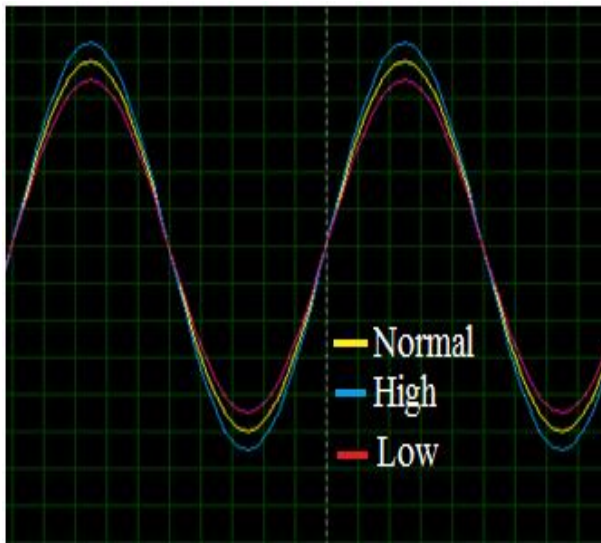


Figure 1: Amplitude Disturbances

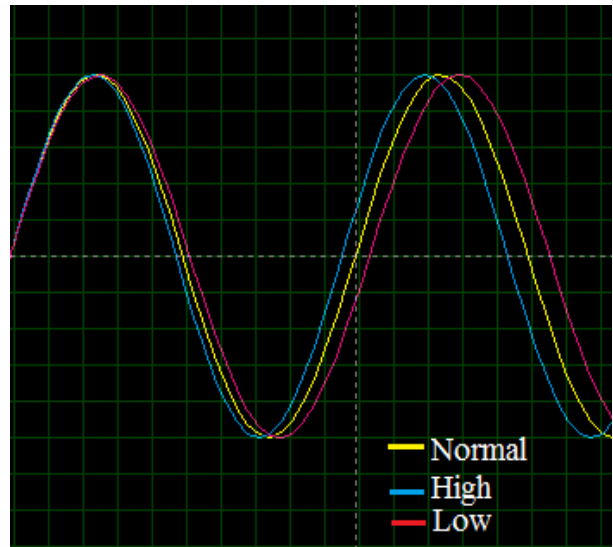


Figure 2: Frequency Disturbances

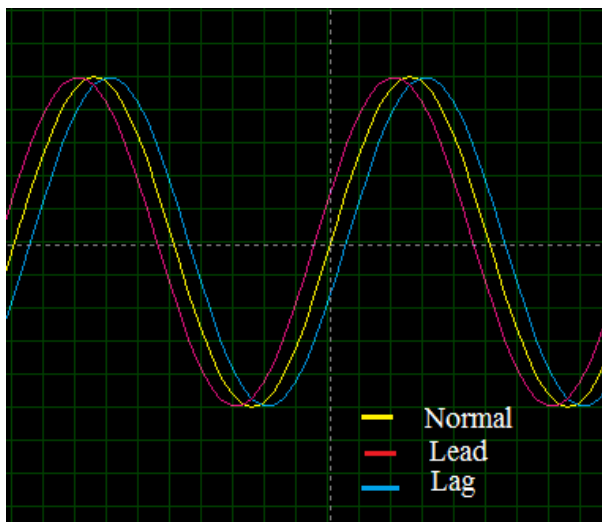


Figure 3: Phase Disturbances

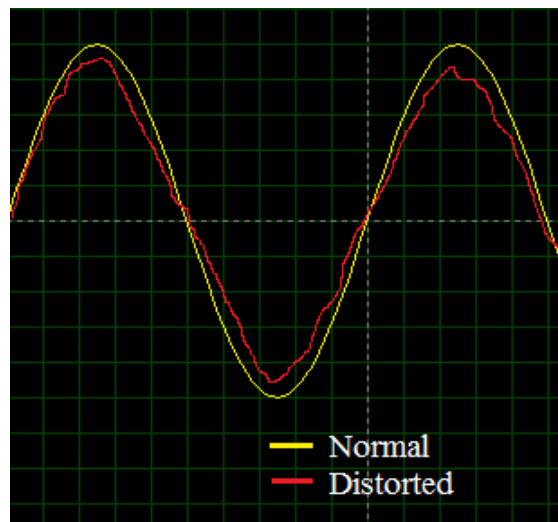


Figure 4: Waveform Disturbances

Problems with power quality might arise from the supply system, the user's load, or a neighboring load. Overheating of components, insulation breakdown, flashing of lights, malfunctioning of equipment, or even system failure might occur as a result of these disturbances [4].

The power quality is most important aspect of the power system. The power quality standards are defined for various power quality parameters like voltage distortion, sag & swell, flicker, transient, unbalance, interruptions, harmonics, power factor etc. by IEEE and many standardizing authorities [5, 6]. It is to be noted that the power quality parameters shall be within 5% [7].

II. NON LINEAR LOAD

A non linear load is one where the current characteristics are not the same as the fundamental shape of applied voltage waveform. A voltage and current harmonic analysis is used to investigate this scenario technically. Some of the commonly encountered and troublesome non linear loads include power electronics switching devices like phase controlled thyristor bridges, motor control drives, etc [8].

III. EFFECTS OF NON LINEAR LOAD ON POWER QUALITY

The power quality effect of consumer electronic devices and applications like computers, television set, laptop and fluorescent lamps is investigated in [9 - 12]. A summary of harmonics produced by residential load equipments like mobile charger, LED lamps, CFL lamps, desktop computers, laptop and printers is presented in [13]. It is seen that the current harmonic distortion is dominant in such devices. The harmonics measurement results of various loads like uninterruptable power source, CNC machines, ventilation systems, fluorescent lamps and motor driving is presented in [14]. Harmonics also contributes for low power factor. Harmonics within acceptable limits can be tolerated by a power plant.

Along with nonlinear loads some external factors also contributes for power quality deterioration. Method of assessment for identifying distortion sources with application of passive filter is discussed in [15]. It can be noted that the decrease in the value of passive filter resistance increases the accuracy of harmony current estimation of non linear load.

The THD analysis of nonlinear loads for various orders of harmonics has been investigated by many researchers through practical measurements with Power Quality Analyzers, simulation work and case studies of domestic and industrial loads. High levels of harmonic distortion can cause several effects such as increased transformer, capacitor, motor or generator heating, false operation of electronic equipment especially relying on voltage zero crossing detection or is sensitive to wave shape, incorrect readings on meters, false operation of protective relays, interference with telephone circuits, etc.

In power system, it is very necessary to monitor THD value. Majority of electrical components and devices in grid are designed for sinusoidal-wave currents and voltages in a certain rated frequency. Currents and voltages in different higher order frequency can harm components and shorten the life time. Another influence of harmonics is that they can cause overheating of devices, such as transformers, which results in more losses being brought up. Given these negative impacts of harmonics in power system, researchers have been working on the analysis and solutions for harmonics. Many devices like passive filter, active filters, hybrid filters have been devised [16, 19] and the modified configurations of FACT devices like series and shunt compensation devices are being worked on.

Considering future demands of electric vehicles which are growing at exponential rate more EV infrastructure like charging stations, battery swapping stations are being proposed which will in turn contribute to increased non linear load. Hence a MATLAB simulation is performed for analyzing the ill effects of such load which is based on AC to DC converters.

IV. MATLAB SIMULATIONS OF NON LINEAR LOAD

MATLAB simulation of three phase non linear load is performed to analyse the percentage of harmonics introduced in the system. A three phase rectifier feeding RL load as shown in figure 5 is taken for case study. Figure 6 shown harmonics profile of the load. It is seen that such load causes 31% harmonic distortion.

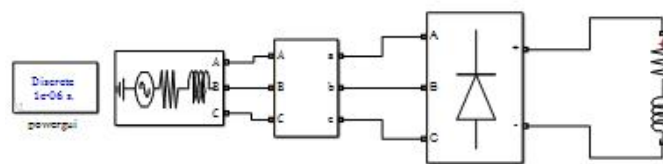


Figure 5: Grid connected rectifier feeding RL load

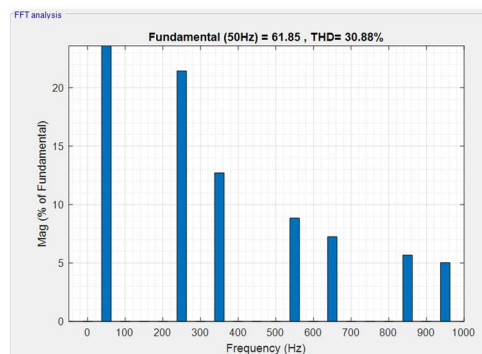


Figure 6: harmonics contents

Another case study of three phase battery charging load is shown in figure 7 and figure 8 respectively indicating the MATLAB model and FFT analysis for harmonics. For battery charging load, harmonics are seen to be 38%.

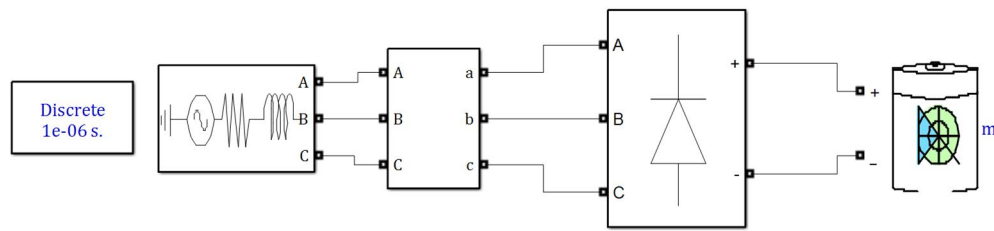


Figure 7: three phase rectifier fed battery charging load

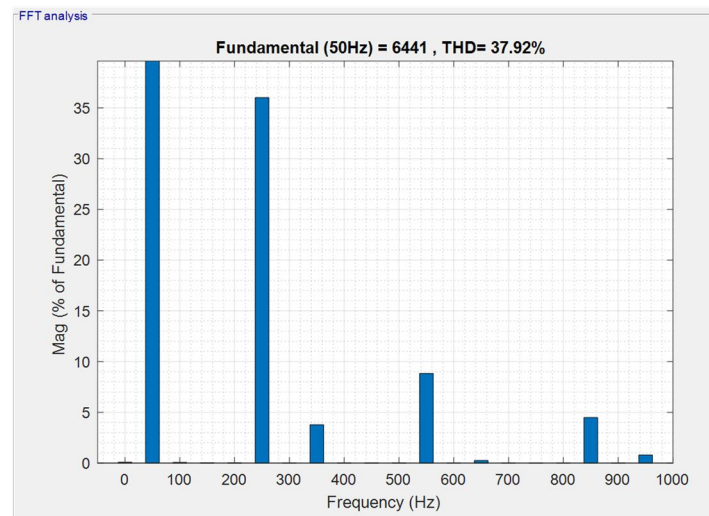


Figure 8: harmonics contents of battery charging load

V. CONCLUSION

The non linear load causes power quality pollution particularly in terms of increased reactive power demand, waveform distortions and harmonics. In spite of the problems created, the non linear loads have become an essential thing in day today life. Considering the need of non linear load to the society and power quality standards recommended by the governing bodies, a technical and methodical approach is required to be devised to tackle power quality problems created by non linear load. Passive filter, active filter and hybrid filters are conventionally deployed for harmonics mitigation. The role of renewable energy powered STATCOM may further be explored in this area.

REFERENCES

- [1] de Almeida, Aníbal & Moreira, L & Delgado, Joaquim, "Power Quality Problems and New Solutions", Renewable Energy and Power Quality Journal, 2003
- [2] Kevin Olikara, "Power Quality Issues, Impacts, and Mitigation for Industrial Customers", Rockwell Automation, 2015
- [3] Pradeep Kumar, "A Review of Power Quality Problems, Standards and Solutions", International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 01 | Jan -2017
- [4] Qiu Hongbo, Yi Ran, Li Weili, and Jin Nan (2015) Influence of Rectifiers on High-Speed Permanent Magnet Generator Electromagnetic and Temperature Fields in Distributed Power Generation Systems. *IEEE Transactions on Energy Conversion*, Vol. 30, No. 2
- [5] R. C. Sermon, "An Overview of Power Quality Standards and Guidelines from the End-User's Point-of-View", IEEE Rural Electric Power Conference, San Antonio, TX, May - 2005
- [6] Galzina, "Grid integration of distributed energy sources regarding power quality," IEEE International Energy Conf. (ENERGYCON), 2014 pp. 1320-1324.
- [7] IEEE Standard for "Interconnecting Distributed Resources with Electric Power Systems," IEEE Std 1547-2003, pp.1-16

- [8] "Non Linear Loads", Application Guidance Notes: Technical Information from Cummins Generator Technologies, AGN 025 ISSUE B/3/9.
- [9] T. A. Abdul-Hameed, M. F. Akorede, Y. Abdulrahman and O. M. Tijani, "An Investigation of the Harmonic Effects of Nonlinear Loads on Power Distribution Network", *Nigerian Journal of Technology*, Vol. 38, No. 2, April 2019, pp. 401 – 405.
- [10] A.Priyadharshini, N.Devarajan, AR.Uma saranya, R.Anitt, "Survey of Harmonics in Non Linear Loads", *International Journal of Recent Technology and Engineering (IJRTE)*, Volume-1 Issue-1, April 2012
- [11] Karuna Nikum, Rakesh Saxena and Abhay Wagh, "Effect on Power Quality by Large Penetration of Household Non Linear Load", *IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)*
- [12] Vicky T. Kullarkar and Vinod K. Chandrakar, "Power Quality Analysis in Power System with Non Linear Load", *International Journal of Electrical Engineering*. ISSN 0974-2158 Volume 10, Number 1 (2017), pp. 33-45
- [13] Bhagyashri S. Patil, V.S. Pawar, "Power Quality Effects on Nonlinear Loads", *International Research Journal of Engineering and Technology (IRJET)*, Vol.4, issue 6, 2017, pp. 3244 – 3247
- [14] Samira Reda Nassar, Ayman A. Eisa, A. A. Saleh, M.A. Farahat and Amal F. Abdel-Gawad, "Evaluating the Impact of Connected Non Linear Loads on Power Quality- a Nuclear Reactor case study", *Journal of Radiation Research and Applied Sciences*, Taylor & Francis, 2020, VOL. 13, NO. 1, 688–697.
- [15] Aleksandr Skamyin, Aleksey Belsky, Vasiliy Dobush and Ilya Gurevich, "Computation of Nonlinear Load Harmonic Currents in the Presence of External Distortions", *MDPI Journal of Computation*, Vol. 10 issue 22, 2022
- [16] Suad Ibrahim Shahl, "Simulation and Analysis Effects of Non-Linear Loads in the Distribution Systems", *International Journal of Scientific & Engineering Research* Volume 10, Issue 7, July-2019, pp. 888 – 892
- [17] "Harmonic Solution Guide", MTE Corporation, USA, 2016
- [18] Viveksheel Verma, Ved Prakash Verma, Harkamaldeep Singh, "THD Analysis of Non-Linear Loads", *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, Vol. 7, Issue 7, July 2019
- [19] Muhamad Hafiz Ab Aziz, Muhammad Mokhzaini Azizan, Zaliman Sauli and Mohd Wafiuddin Yahya, "A Review on Harmonic Mitigation Method for Non-Linear Load in Electrical Power System", *AIP Conference Proceedings* 2339, 020022, (2021)