

Harmonic Improvement of Electrical Power Quality in Atbara Cement Mill Company, Sudan

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ABSTRACT

Nonlinear electrical loads are a major source of harmonic distortion in modern power systems, leading to deterioration of electrical power quality, increased losses, overheating of equipment, and malfunction of protection devices. Industrial facilities that rely heavily on three-phase induction motors, such as cement manufacturing plants, are particularly affected by these problems. This paper presents a comprehensive study on harmonic mitigation using a hybrid filtering technique to improve power quality in an industrial power system.

The proposed hybrid filter integrates passive and active filtering components to reduce current and voltage harmonics generated by nonlinear loads. The system is modeled and simulated using MATLAB/Simulink, considering practical operating conditions and real motor data from Atbara Cement Mill Company in Sudan. The performance of the system is evaluated under four operating scenarios: without filtering, with passive filtering, with active filtering, and with hybrid filtering. Simulation results demonstrate that the hybrid filter provides the most effective harmonic reduction, significantly decreasing total harmonic distortion (THD) and enhancing overall power quality in the three-phase induction motor system.

Keywords: Power Quality, Harmonics, Hybrid Filter, Active Filter, Passive Filter, Induction Motor

Introduction

The rapid expansion of power electronic technologies has significantly improved the efficiency and controllability of electrical energy systems. However, the widespread use of nonlinear loads such as variable frequency drives, rectifiers, induction furnaces, and switched-mode power supplies has introduced serious power quality challenges. These nonlinear loads draw no sinusoidal currents from the supply, resulting in harmonic distortion of voltage and current waveforms throughout the power network.[1-2].

Harmonic distortion is one of the most critical power quality problems in industrial power systems. In three-phase induction motor applications, harmonics cause additional copper and core losses, excessive heating, mechanical vibration, acoustic noise, and reduced motor efficiency. Over time, these effects shorten equipment lifetime and increase maintenance costs. Consequently, effective harmonic mitigation techniques are essential to ensure reliable and efficient operation of industrial facilities.

Several harmonic mitigation methods have been proposed in the literature. Conventional passive filters are widely used due to their simplicity and low cost, but their performance is limited by resonance issues and sensitivity to system impedance variations. Active power filters provide dynamic harmonic compensation but require complex control strategies and higher investment costs. Hybrid filtering techniques, which combine passive and active filters, have emerged as a practical and efficient solution for industrial power quality improvement. This paper investigates the application of a hybrid harmonic filter for reducing harmonic distortion in a three-phase induction motor system.[3-6].

Harmonics in Electrical Power Systems

Harmonics are sinusoidal components of a periodic waveform whose frequencies are integer multiples of the fundamental frequency. In a 50 Hz power system, harmonic components appear at frequencies such as 100 Hz,

150 Hz, and higher-order multiples. These harmonics are primarily generated by nonlinear loads that exhibit non-proportional relationships between voltage and current.[5-7]

When harmonic currents flow through the power system impedance, they create harmonic voltages that distort the supply waveform[5]. Excessive harmonic distortion leads to a variety of operational problems, including overheating of cables and transformers, malfunction of protective devices, inaccurate power measurement, and reduced system efficiency. International standards such as IEEE 519 and IEC 61000 define acceptable harmonic limits and provide guidelines for harmonic measurement and evaluation[8-9]. Total Harmonic Distortion (THD) is commonly used as an index to quantify the level of harmonic distortion in voltage and current waveforms.

Harmonic Mitigation Techniques

Harmonic mitigation techniques can be classified into passive filtering, active filtering, and hybrid filtering methods. Passive harmonic filters are constructed using inductors and capacitors tuned to suppress specific harmonic frequencies. Although passive filters are cost-effective and simple, they may introduce resonance problems and are less effective under varying load conditions.[10]

Active power filters operate by detecting harmonic components in the load current and injecting compensating currents with equal magnitude and opposite phase. This approach allows real-time harmonic compensation but increases system complexity and cost.[11]

Hybrid harmonic filters combine the advantages of passive and active filters. The passive part is typically designed to eliminate lower-order harmonics and provide reactive power compensation, while the active part compensates higher-order harmonics and dynamic variations. This configuration offers an efficient and economical solution for industrial power quality enhancement.

Simple equation Calculation:

$$Cr = \frac{QC}{2\pi V2}$$

Inductance:

$$Lr = \frac{1}{(2\pi fr)^2 Cr}$$

Power factor:

$$Q = \frac{wlr}{R}$$

$$rth = \frac{fr}{f} \text{ Order of harmonic}$$

System Description and Methodology

In this paper, a three-phase industrial power system supplying induction motor loads is modeled using MATLAB/Simulink. Nonlinear loads are connected to the system to represent practical industrial operating conditions. A hybrid harmonic filter is designed by integrating passive filter components with an active filtering unit based on power electronic converters.

Two three-phase induction motors with rated powers of 7.5 kW and 11 kW are selected as representative industrial loads commonly used in cement mill applications. The motor parameters are obtained from practical equivalent circuit data (Table.1, 2). The hybrid filter is connected at the point of common coupling (PCC), and system performance is evaluated under balanced and unbalanced operating conditions.

RATED	
R1= 1.3220 omhs / 0.0687 p.u.	X1= 2.9124 omhs / 0.1513 p.u
R2'= 0.8769 omhs / 0.0455 p.u.	X2' =3.4945 omhs / 0.1815 p.u.

Rfe 2913.7620 omhs / 151.3383 p.u.	Xm= 90.9684 omhs / 4.7248 p.u.
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Table.1: 7.5KW/415 induction motor

RATED	
R1 0.9333 omhs / 0.0711 p.u.	X1 1.8031 omhs / 0.1374 p.u.
R2' 0.3930 omhs / 0.0299 p.u.	X2' 2.4278 omhs / 0.1849 p.u.
Rfe 2252.8770 omhs / 171.6177 p.u.	Xm 68.0720 omhs / 5.1855 p.u.

Table.2: 11KW/415 induction motor

Simulation Results and Discussion

Simulation results indicate that the system operating without any filtering exhibits significant harmonic distortion in both current and voltage waveforms due to the presence of nonlinear loads.

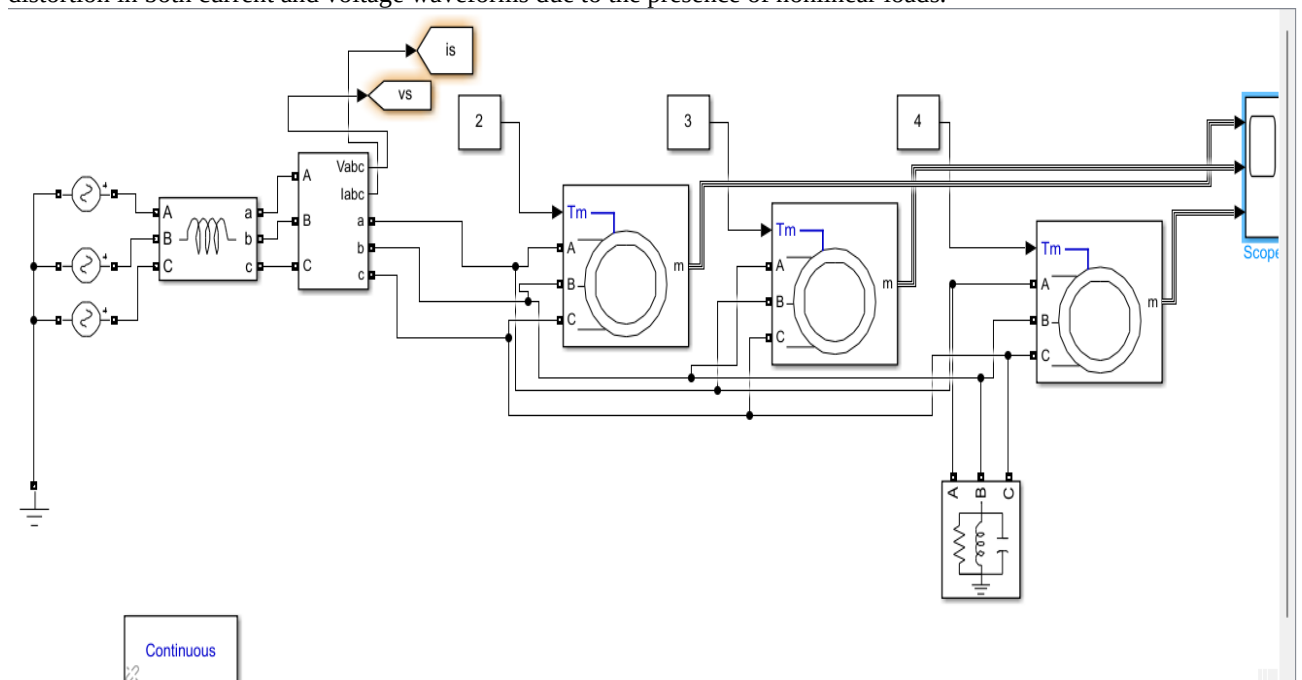


Fig.1: Circuit from three phase induction motor really data

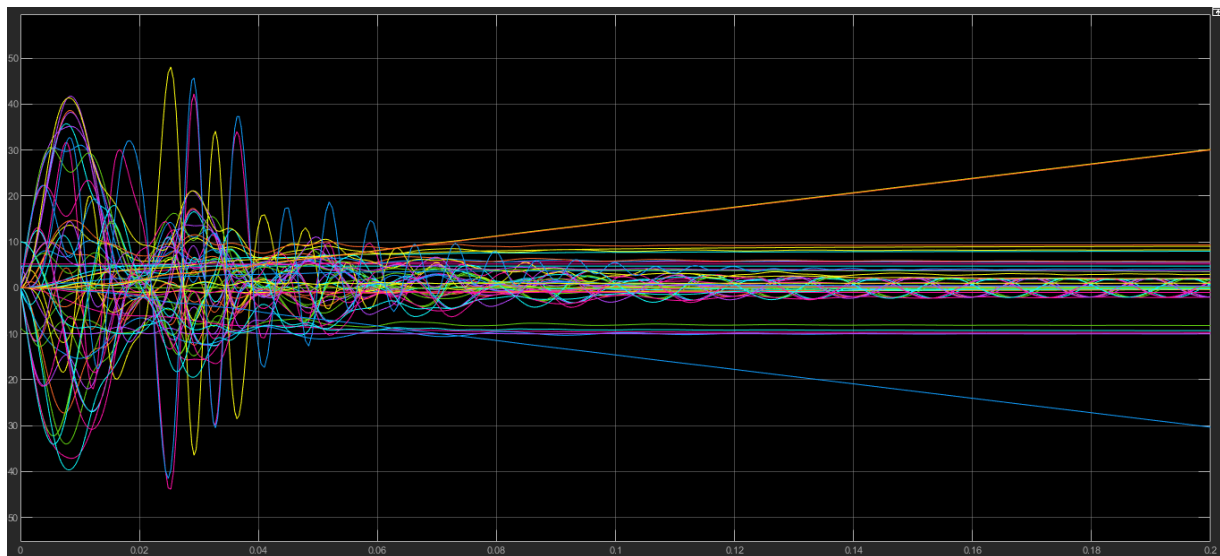


Fig.2: Wave form

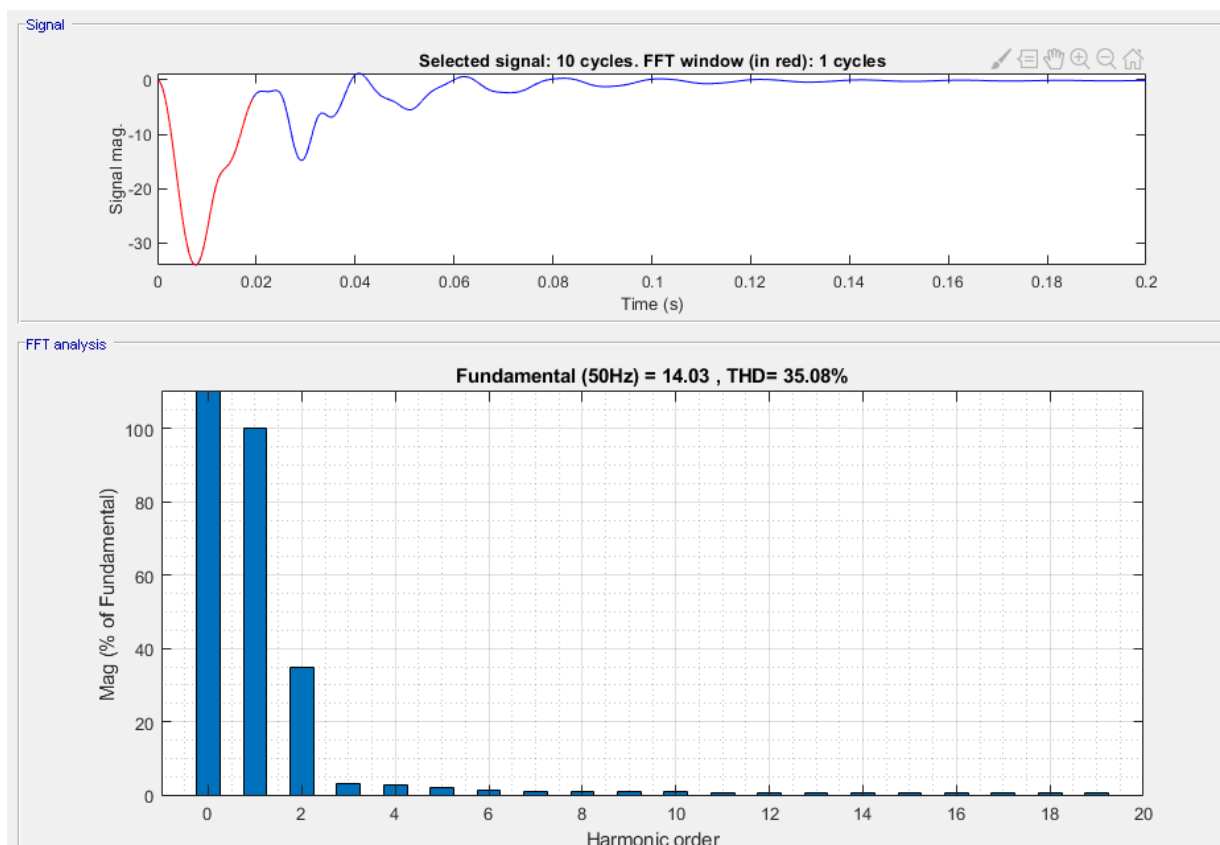


Fig.3: fft analyses

The application of a passive filter reduces specific lower-order harmonic components but is limited in performance under changing load conditions. Active filtering provides improved harmonic compensation; however, the hybrid filter demonstrates the most effective overall performance. The components of circuit

[amplitude peak voltage, v_i measurement, passive filter the inductance of it $100e - 2$] parallelled to three phase capacitance value $1e - 6$ and series three phase inductance value $10 - 4$.

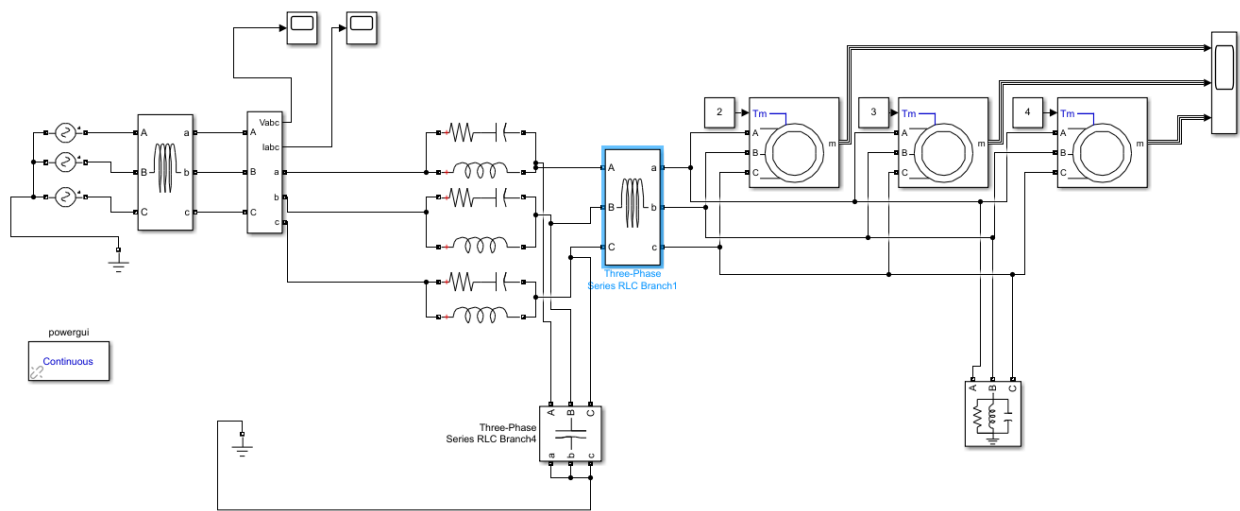


Fig.4: Circuit

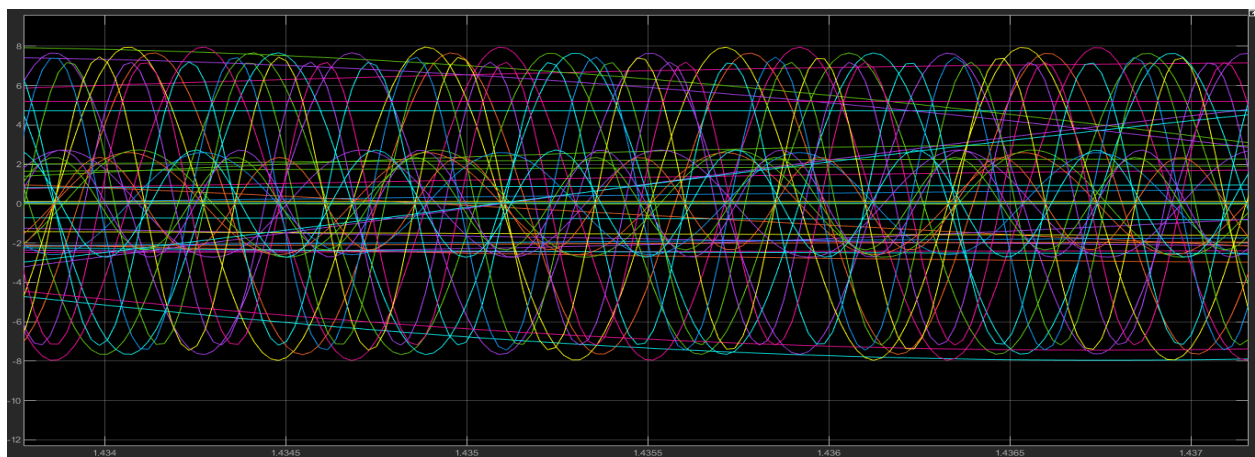


Fig.5: The wave form

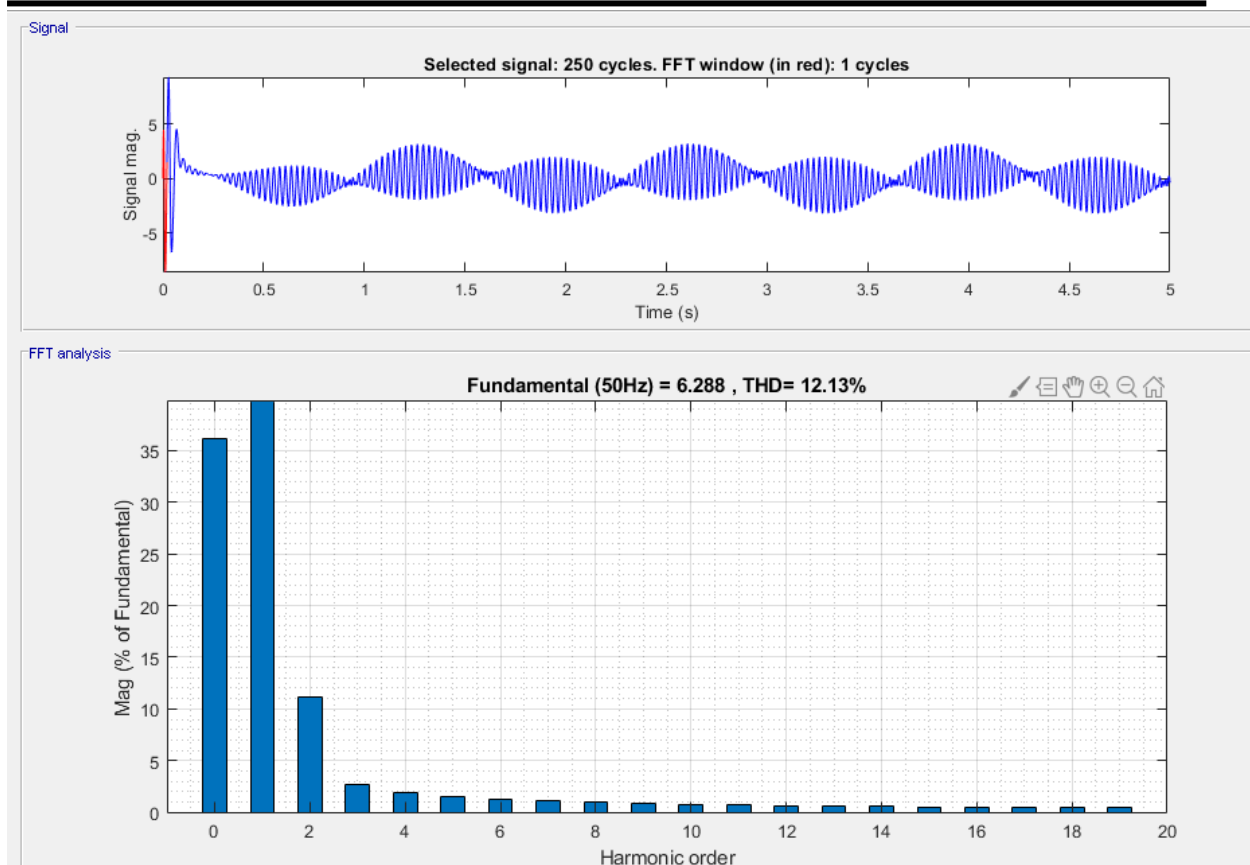


Fig.6: The fft analysis:

Fourier analysis of the induction motor current waveforms shows that the total harmonic distortion is reduced from approximately 35% without filtering to about 15% when the hybrid filter is applied. This reduction satisfies the harmonic limits recommended by international standards and significantly improves power quality in the industrial power system.

Conclusion

This paper presented an investigation of harmonic distortion in a three-phase induction motor system and proposed a hybrid harmonic filtering technique for power quality improvement. Simulation results confirm that the hybrid filter outperforms conventional passive and active filters in reducing harmonic distortion and enhancing system performance.

The proposed approach is well suited for industrial environments with high penetration of nonlinear loads, such as cement manufacturing plants. By effectively mitigating harmonics, the hybrid filter improves system efficiency, reduces equipment stress, and ensures compliance with international power quality standards.

References

- [1] S.L. Gb adamosi, A.O.Melodi “ (2013) 10 Harmonic Distortion from Induction Furnace Loads in a Steel Production Plant”. Network and Complex Systems, Vol.3, No.10
- [2] S.Ravi, C.Sujitha, Bakery Diarra, P.Sukumar, (2017) . “Design and Development of fuzzy system based unified power quality Conditioner for harmonic elimination”. , Indian Journal of Science And Technology, Vol.10, No.6, pp. 1-5. .
- [3]Ying-Tung Hsiao (2001) “Design of Filters for Reducing Harmonic Distortion and Correcting Power Factor In Industrial Distribution Systems”. ” Taking Journal of Science and Engineering, Vol. 4, No. 3, pp. 193-199,

4. [4] International Journal of Engineering & Technology, 7 (3.10) (2018) 179-183
5. [5] Chang-Song Li, Zhi-Xuan Bai, Xian-Yong Xiao, Ya-Mei Liu and Yi Zhang,(2016) . "Research of harmonic distortion power for harmonic source detection," . International Conference on Harmonics and Quality of Power (ICHQP), Belo Horizonte, 2016, pp. 126- 129, doi: 10.1109/ICHQP.2016.7783437.
6. [6] S.Ravi, V.Mezhuyev, K I Annapoorani, P.Sukumar,(2016) . “Design and Implementation of a microcontroller based buck boost converter as a smooth starter for permanent magnet motor”
7. Indonesian Journal of Electrical Engineering and Computer Science, Vol.1, No.3, pp.566-574.
8. [7] S. S. Patil, R. A. Metri and O. K. Shinde,(2017) "Shunt active power filter for MV 12- pulse rectifier using PI with SMC controller,". International Conference on Circuit ,Power Computing Technologies (ICCPCT), Kollam, India, 2017, pp. 1-6, doi: and 10.1109/ICCPCT.2017.8074260.
9. [8] J. Dolezal, P. Santarius, J. Tlustý, V. Valouch and F. Vybíralík,(2003) , "The effect of dispersed generation on power quality in distribution system,"," CIGRE/IEEE PES International Symposium Quality and Security of Electric Power Delivery Systems, . CIGRE/ PES 2003., Montreal, QC, Canada, 2003, pp. 204-207, doi: 10.1109/QSEPDS 2003.159821
10. [9] W. A. W. I. Gabr and Salem, (2018) . “Impact of Grid Connected Photovoltaic System on Total Harmonics Distortion (THD) of Low Voltage Distribution Network. A Case Study,” Twentieth International Middle East Power Systems Conference (MEPCON), 2018.
11. [10] "IEEE Standard(2010), Definitions for the Measurement of Electric Power Quantities under Sinusoidal, Non sinusoidal, balanced, or Unbalanced Conditions - Redline," in IEEE Std 1459-2010 (Revision of IEEE Std 1459-2000) - Redline, vol., no., pp.1-52, 19 March 2010, doe: 10.1 109/ IEEESTD.2010.5953405.
12. [11] M. E. Balci and M. H. Hocaoglu, Quality "On the validity of harmonic source detection methods and indices,"
13. Proceedings of 14th International Conference on Harmonics and Quality .