International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 12, December - 2020, Pages: 128-137

A study of Harmonic Control 33/11 kv Transformer of AL OMERA Substation SEDC network

Elebaid Khalid Elsayed , Ahmed Mohammed Alsayed , Mohammed Ali AbulGasim , Hisham Hussein Bahar Aldein , Rahama Ibrahim Adam , Hashim Omer Hassan Musa

Electrical Engineering Department
Sudan University of Science and Technology
Khartoum, Sudan
Email: elebaid89.4@gmail.com, alsaginy.ahmed@gmail.com, hishamh1997@gmail.com , hashimo440@gmail.com

Abstract*—The Harmonics in Distribution Systems come from transformers or saturation reactors, arc furnace, welding machines, florescent lamps, rotating machines and power electronics devices. In general, the nonlinear loads in which the relationship between the voltage and current is not constant. A case study of (SEDC) network (AL OMERA Substation) was investigated using Network Analyzer (AR5) for the reading, and ETAP simulation program. The results of harmonic analysis were compared with IEEE519-1992 limits (5% VTHD). It was found that the total harmonic distortion limit for current in the simulated case study network exceeded the limits (8.9 %VTHD). Hence harmonic mitigation solution chosen was the passive filter.*

Keywords— SEDC, VTHD, AL OMERA, ETAP, VTHD, AR5

1. Introduction

An electrical power system is an energy supply, transmission and usage system. The power infrastructure is known as the grid and can be separated into generation, transmission and delivery networks. The transmission system is a link between generation and delivery networks. The basic aim of the transmission system is to transfer electricity from generation plants to distribution centers at various locations. Generally, the transmission grid consists of transmission lines and substations.

The substation is a system for adjusting, regulating and optimizing the characteristics of the energy supply (voltage, frequency, power factor etc.). The clustering relies on various modes, such as the classification of voltage, transformer power and transmission, delivery substation according to requirements.

In the transfer of electricity from generation to load, substations play a central role. At the moment substations help monitor and secure the power grids and have a great deal to enhance the efficiency of output of electricity, because electricity is like any commodity that needs to be measured from various viewpoints as technical, stable and costumers' equipment. In the power system performed on a voltage and frequency that remains within the limits, it would be an essential step in compliance with this substation configuration.

If the non-linear load is attached to the system, such as a rectifier, the current draws a current which is not inherently sinusoidal. Depending on the type of loads and their association with other system elements, the current waveform may become quietly complex. No matter how complex the current waves get, it can be breaking down to a simple sinusoidal wave, beginning at the frequency of the basic power system, as defined by Fourier's series analysis [1].

In the majority of situations, the source of harmonics is electronic power systems. Harmonics are also created with a wide range of traditional equipment such as power generation equipment, "slot-harmonic" induction generator, "saturated harmonic," converting "over excitement leading to saturation," magnetic fluorescent light "arcing," and an ac electric furnace.

2. Problems

As technical and economic losses result in reduction the system’s efficiency, also it affects the equipment performance characteristics. Center area of Khartoum suffering severe under voltage, equipment’s work at values less than the rated because of increasing load and low capacity of transformers, thus it affects continuity of supply and service reliability. Since the supply doesn’t meet the specification requirement of the system that causes economical losses.

The proper design according to national standard and the country requirement avoid these technical and economic losses and leads to good results.

3. Objectives

- To present general characteristics of the harmonics, harmonic indices and measure the distortion of the wave.

- To identify the harmonics sources and explain the harmonics effects in the different components of a distribution system.
- To study the methods used in harmonic analysis and scenarios of harmonic mitigation.
- Take a case study for harmonic analysis using simulation program. If the distortion exceeds the acceptable limit mitigation must be done.

4. METHODOLOGY:

The data was collected by different method. Some of these data was collected from The Sudanese Electric Holding Company. Data was also collected by reading meters and nameplates of some equipment. The simulation was done by using ETAP program. This simulation is concerned with load flow and short circuit studies. Analytical calculations are used to obtain results from planning study. Google earth was used to determine the area of the substation and the path of underground cable.

5. BACKGROUND:

5.1 Nature of harmonics

Any distortion that occurs in waveform of voltage called harmonic phenomena and main reason refers to non-linear load that connected to the system. Also, any oscillation or perturbations in waveform that let it in abnormal condition which called harmonics. Waveform distortion, often referred to as dirty power, becomes serious when the power deviates significantly from a pure sine wave.

The electronic devices being used the term harmonics comes into use.

Harmonic should be taken seriously but they are not the only used cause of electrical problem. If have tried everything and are still having problem and have a lot of electronic devices it is something to think about. Any distortion in the voltage or current wave causes harmonics [2].

5.2 Source of harmonic

Two different kinds of loads are used to produce harmonics in power system:

a) Linear Loads

These loads display constant steady–state impedance during the applied sinusoidal voltage. As an example, transformers and rotating machines, under normal loading conditions [3].

b) Nonlinear Loads

These loads do not display a lasting impedance during the cycle of the sinusoidal voltage applied. Any examples are non-linear loads such as: Arc furnaces, Variable frequency drive systems (VFDs), UPS, correction equipment, fluorescent lighting, power supplies transferred to the mode, modulated pulse width transformers (PWMs) [4], [5,].

5.3 Effect of Harmonic

There are many effects of harmonic in substation which depend of load, following loads example of effects [3],[4]:

A. Motors and Generators:
Increased heating due to iron and copper losses, Reduced efficiency and torque, Higher audible noise, Cogging or crawling, Mechanical oscillations

B. Transformers:
Parasitic heating, Increased copper, stray flux and iron loss

C. Switchgears
Increased heating and losses, reduced steady-state current carrying capability, Shortened insulation of components life

5.4 Harmonic Mitigation Techniques

With the increase in consumer nonlinear loads, the harmonics injected into the power Supply system and their consequent effects are becoming of greater concern. Efforts is done to reduce these problems by suggest many solutions such as [3], [4], [6]:

a) The equipment can be designed to withstand the effect of harmonics, e.g. transformers, cables, and motors can be de-rated.
b) Passive filters at suitable locations preferably close to the source of harmonic generation can be provided so that the harmonic currents are trapped at the source and the currents propagated in the system are reduced.
c) Active filtering techniques, generally, incorporated with the harmonic producing equipment itself can reduce the harmonic generation at source.
d) Hybrid combinations of active and passive filters are also a possibility.
e) Alternative technologies can be adopted to limit the harmonics at source

5.5 Information about the EL OUMERA Substation

The Sudanese electricity distribution company represents the operation of overall power system in the Sudan including substation. The research is comprised of studding information from EL OUMERA SUBSTATION which fed from (2*15MVA) power transformers and two capacitor banks with 4.5MVar capacity for each section.

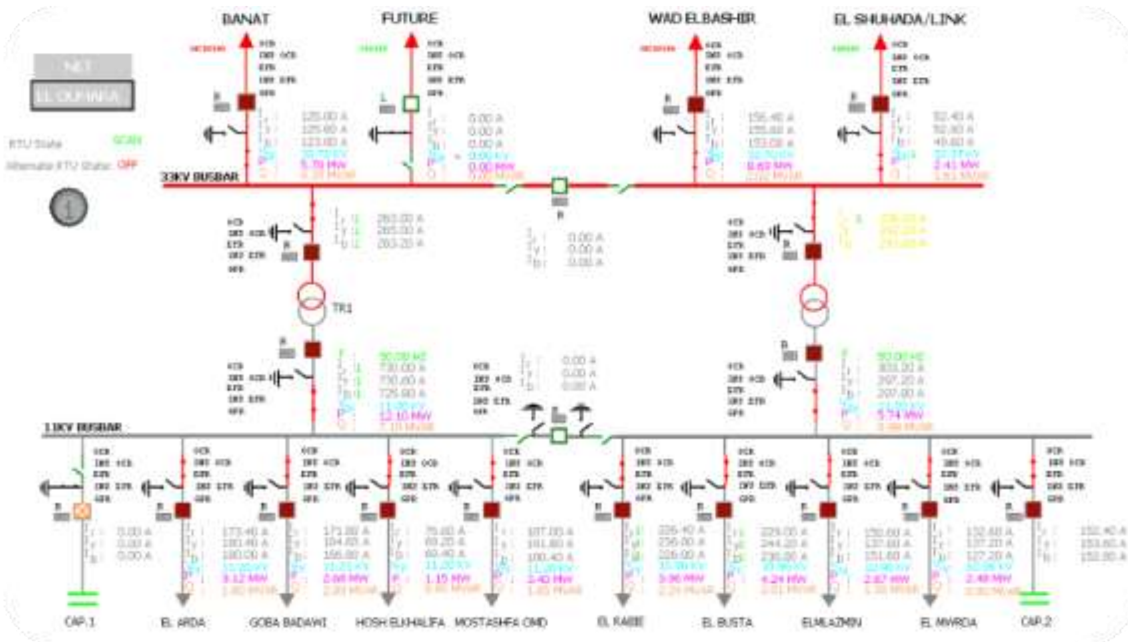

Fig. 1. *Single line diagram of EL OUMERA substation*

5.6 ETAP software program:

It is a true 64-bit program developed for the Microsoft® Windows® 2008 R2 (SP1), 2012/R2, 7 (SP1), 8/8.1, 10 operating systems. It gives you the opportunity to explore the many features and capabilities of ETAP including Arc Flash, Load Flow, and AC/DC Short Circuit (Refer to the demo restrictions document for a full list of capabilities).

6. CASE STUDIES WITH DISCUSSIONS

This section shows the power flow solution of the system, solved using the ETAP12.6 Newton- Raphson algorithm which includes the PF, load current, in this study the targeted buses and transformer(TR-2).Load flow analysis and harmonic load flow of the system had been carried out by ETAP 12.6 and the following three scenario was applied:

- Without capacitor bank.
- With capacitor bank.
- With capacitor bank and single tuned filter

a) Scenario 1(Load flow analysis by ETAP without capacitor)
The following result shown in tables (1, 2) represent the load flow result for first scenario.

Table 1: Load flow bus data

Bus ID	***Nominal KV***	***Voltage %***
Bus 10	33	100
Bus 11	33	100
Bus 9	11	98.18
Bus 5	11	94.02

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 12, December - 2020, Pages: 128-137

Table 2: Load flow data

ID	*Rating*	*Rated KV*	*MW*	*Mvar*
ELBOSTA	3696 Kva	11	3.180	3.610
ELRABEI	1943 Kva	11	2.936	2.579
ELMORDA	4592 Kva	11	4.169	3.094

Actual readings at site:

Readings was taken from substation using portable Network Analyzer PWS at 8:00 pm because the price of the kwh at night is less than the morning for industrial load. The device show there is individual harmonic distortion order 5^{th} With value 8.9 and the total harmonic distortion THDV are 11.3 AL BOSTA feeder 11kv . The device and wiring diagram are shown in figure 2 and figure 3.

Fig. 2. *Portable Network Analyzer PSW2.3*

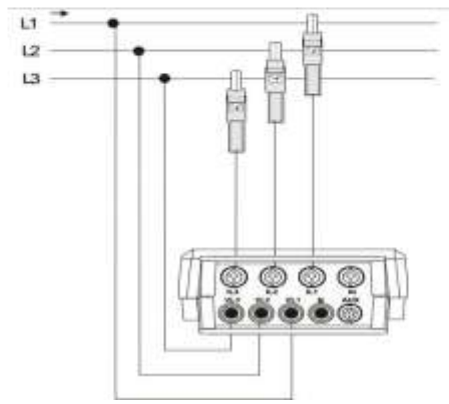

Fig. 3. *Connection diagram of PSW2.3 phase*

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 12, December - 2020, Pages: 128-137

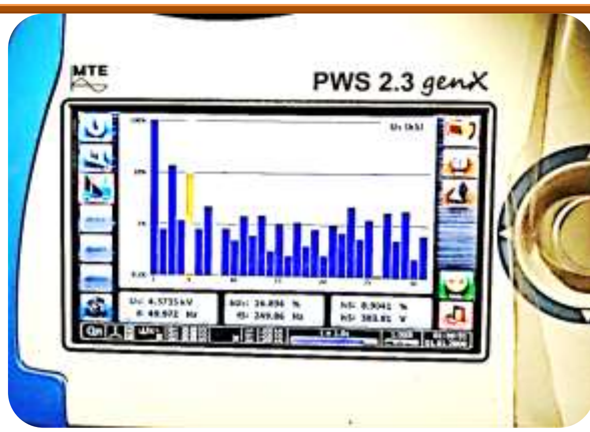

Fig. 4. *Actual reading from PSW2.3*

Harmonic Analysis by ETAP:

This section presents the harmonic analysis of the system, Newton Raphson algorithm which total harmonic distortion (THD), individual harmonic distortion (IHD) with an indication to which of them had exceed the limits referring to the IEEE519-1992standards.

First scenario results: Harmonic load flow result without capacitor bank

Table 3: VIHD (individual harmonic distortion report) Bus Voltage Distortion

ID	***KV Fund %***	***Fund %***	***VHD %***	***Order***
Bus 5	11.00	96.44	8.9	5

Indicates buses with IHD (Individual Harmonic Distortion) exceeding the limit

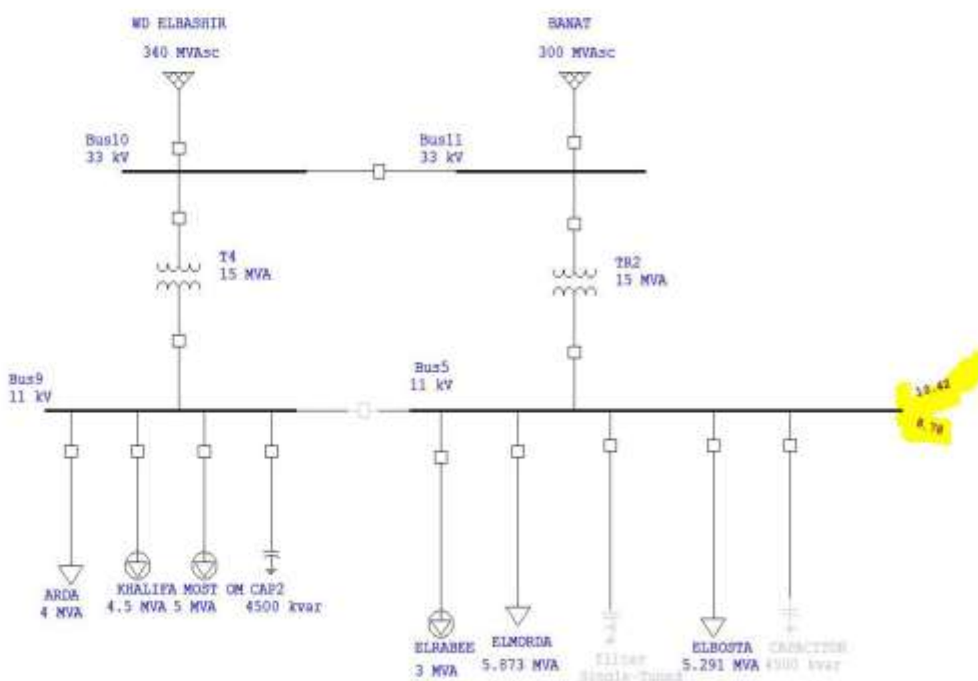

Fig. 5. *Indicates buses with THD(Individual Harmonic Distortion)*

Discussion of scenario one result

It's clearly that there is significant total harmonic distortion (THD) at Bus5

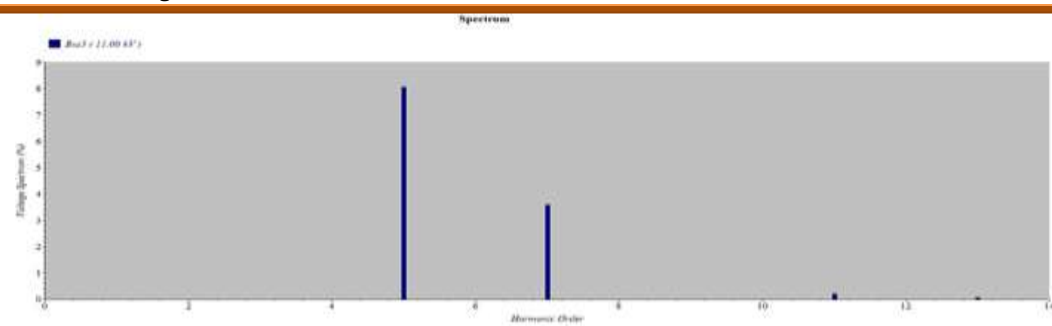

Fig. 6. *Bus 5 spectrum*

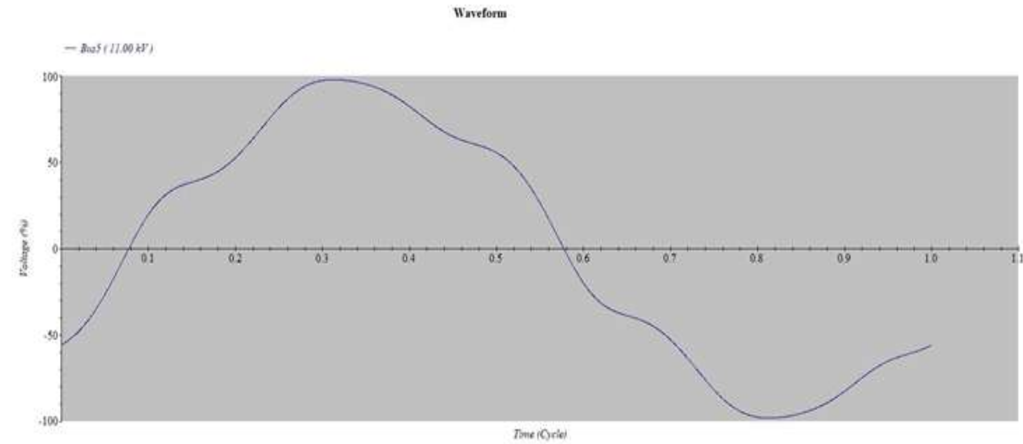

Fig. 7. *Bus 5 wave form*

Second scenario:

Insertion of 4.5Mvar capacitor bank atbus4:

Tables 4 show the result of harmonic load flow for the second scenario

Table 4: VTHD (Total Harmonic Distortion) report

Bus Voltage Distortion

* Indicates buses with THD (Total Harmonic Distortion) exceeding the limit

Table 4: VIHD (individual harmonic distortion report) Bus Voltage Distortion

ID	*KV*	*Fund %*	*VHD %*	*Order*
Bus 3	11.00	96.5	8.9	5_{th}

Discussion of Second scenario:

Obviously after insertion f4.5 Mvar capacitor bank at Bus5 the total harmonic distortion (THD) of overall system increase dramatically as shown in figure (4) and this will effect of all equipment through the system specially on transformer and capacitor bank. Figures below shows the harmonic voltage and current spectrum and their waveform for each element on Bus3.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 12, December - 2020, Pages: 128-137

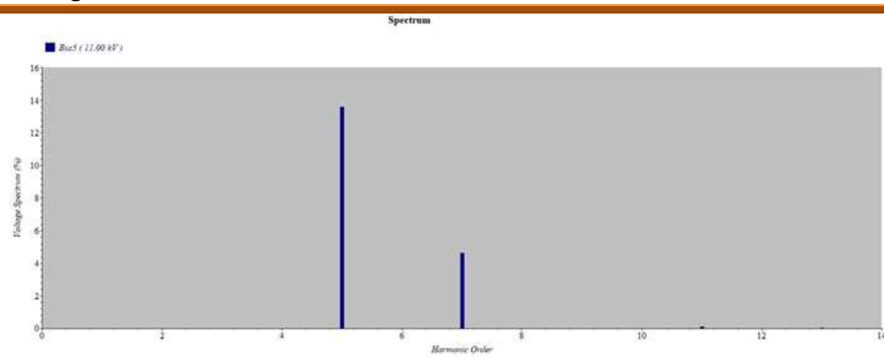

Fig. 8. *Voltage spectrum at Bus3*

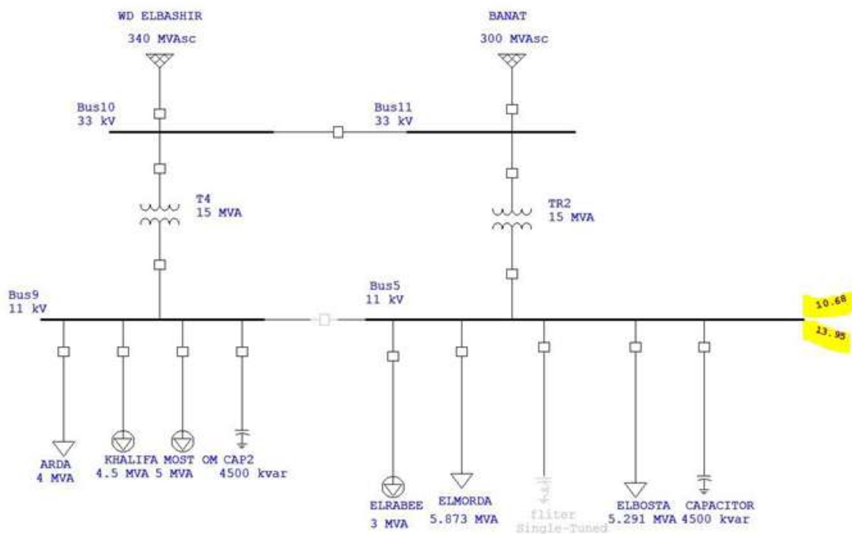

Fig. 9. *Overall system harmonic load flow result for the second scenario*

Last scenario:

Insertion of single tuned filter at bus5: ETAP automatically sizing the filter and calculate filter parameter Figure 8 show the results of third scenario.

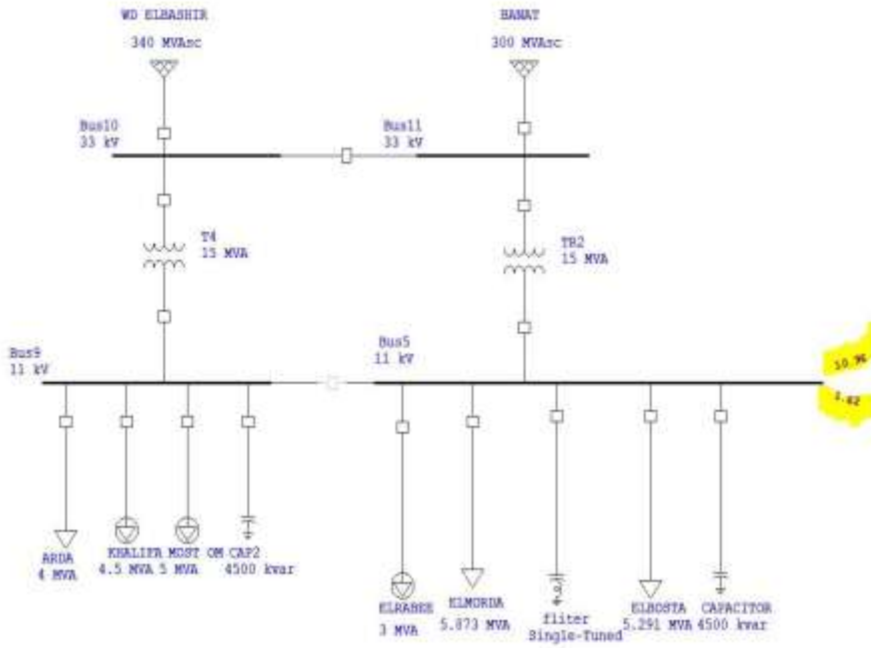

Fig. 10. *Overall system harmonic load flow result for the third scenario*

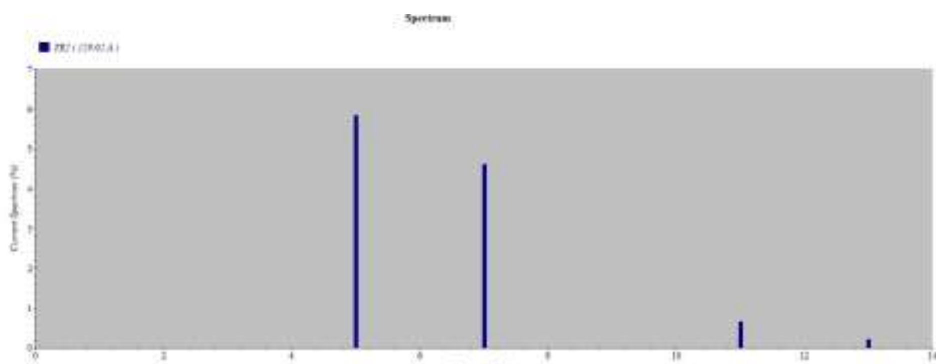

Fig. 11. *Spectrum at fliter at transformer*

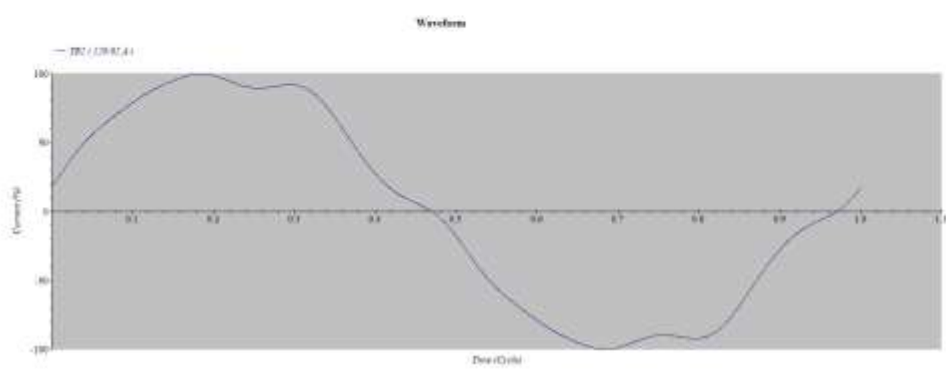

Fig. 12. wave form at fliter

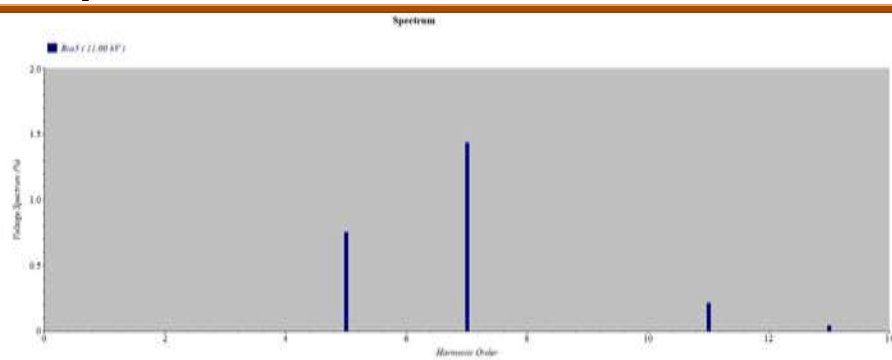

Fig. 13. Bus5 Spectrum at fliter

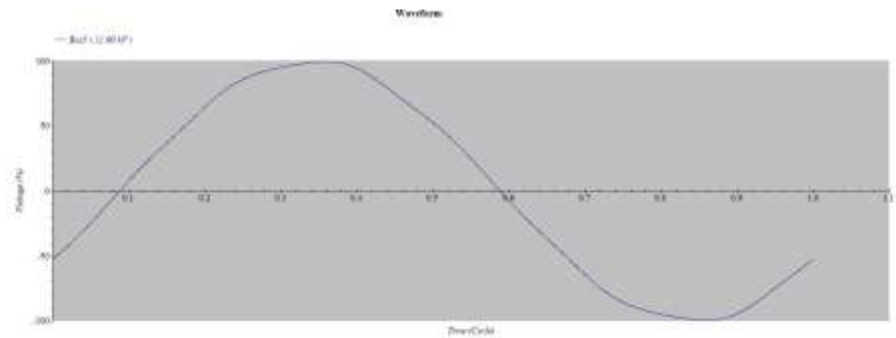

Fig. 14. Bus 5 wave form at filter

Discussion of last scenario

It’s clearly that the total harmonic distortion (THD) is successfully reaches the acceptable limits. (3%), and the wave form had been cleared near to pure sinusoidal after adding the filter.

7. Conclusion:

In this study, harmonic phenomena is explored as a whole. There were also harmonic origins, results, empirical approaches and methods of mitigating. A case study was performed by using ETAP software and harmonic distortions were identified after readings and simulation scenarios on the platform. The network of the Sudanese Electricity Distribution Company (SEDC). Then the results showed that comparing the proposed solution to the problem with before solution is very good. And the results show that on the substation the condenser banks can magnify the harmonic effect; the following points can be inferred from this research: The most powerful and popular method for managing harmonic distortion in industry is passive filtering techniques. Harmonic effects depend on the type of stress and distortion levels. The ETAP simulation program is very simple and powerful software for the study of the dynamic network. since it gives a reactive compensation away from filtering operation.

8. References

[1] Francisco C. De La Rosa,(2006). “Harmonic and Power Systems”, Taylor & Francis Group, LLC.

[2] A. S, (1991),”Disturbances in mains supply nework”,part 2; “limitation of the harmonics caused by industrial equipment” ,standards Austeralia 1991.

[3] Jos Arrillaga, Bruce C Smith Neville R Watson, Alan R Wood (2000). Power System Harmonic Analysis, 2nd Edition, University of Canterbury, New Zealand.

[4] Young, M. (1989). The Technical Writer’s Handbook. Mill Valley, CA: University Science.

[5] IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Systems (1992), Standard 519.

[6] Ewald F. Fuchs, Mohammad A.S. Masoum, (2008) Power Quality in Power Systems and Electrical Machines, 1st Edition, University of Colorado, USA.

[7] Timothy James Browne,(2008). Harmonic management in transmission networks, Ph.D. thesis, University of Wollongong, Australia.

Authors

Elebaid Khalid Elsayed, Received the B.Eng in Electrical Engineering of Science and Technology, He interested on control engineering especially nonlinear and robust with applied in drone vision. Also, He interested in Artificial Intelligence especially machine learning and deep learning and currently, applied computer vision for drone and developed algorithm for this application.

Ahmed Mohammed Alsayed, Received the B.Eng in Electrical Engineering from Sudan university of Science and Technology, interested on control engineering especially optimal, nonlinear and robust as well as the new trend of fractional order control. Also, He interested in Artificial Intelligence especially machine learning and deep learning and currently He worked as a junior machine learning engineer as well as an instructor for machine learning and natural language processing (NLP) workshops.

Rahama Ibrahim Adam
B.Eng In Electrical Engineer
Sudan University for Science and Technology
Electrical Power

Hisham Hussein Bahar,
B.Eng In Electrical Engineer
Sudan University for Science and Technology
Electrical Power

Mohammed Ali AbulGasim
B.Eng In Electrical Engineer
Sudan University for Science and Technology
Electrical Power

Hashim Omer Hassan Musa
B.Eng In Electrical Engineer
Sudan University for Science and Technology
Electrical Power
.