Power Quality Improvement in Mosul City Using Shunt Active Power Filter

Faisal Falah Aiwa[1], Mahmood T. Alkhayyat[2], M. Y. Suliman[3]
{faisal.aiwa@ntu.edu.iq[1], m.t.alkhayyat@ntu.edu.iq[2], mohammed.yahya@ntu.edu.iq[3]}

1,2,3 Department of Electrical Power Techniques Engineering, Technical Engineering College, Northern Technical University, Mosul, Iraq
Corresponding author: Faisal Falah Aiwa, e-mail: faisal.aiwa@ntu.edu.iq
Co-authors: Mahmood T. Alkhayyat: m.t.alkhayyat@ntu.edu.iq , M. Y. Suliman: mohammed.yahya@ntu.edu.iq
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Abstract. One of the most important issues in Mosul is power quality. A power quality issue caused by current harmonic pollution caused by a wide range of nonlinear loads in the electrical power system. The shunt active power filter based on instantaneous active and reactive power theory is proposed to reduce these harmonics. In this paper, two locations in Mosul city have been chosen to be studied. The real measurements from the studied locations are simulated in Matlab/Simulation based on the current harmonic distortion produced by a nonlinear load to demonstrate the SAPF's ability to mitigate current harmonics and improve power quality.

Keywords: power quality, shunt active power filter (SAPF), PQ theory, total harmonics distortion (THD).

1. Introduction

With the widespread use of sensitive electrical equipment, power users are becoming more aware and sensitive to changes in power quality. The main electric power stations generate high-quality sine wave electrical energy [1]. But the large usage of power electronic equipment (non-linear loads) in the power systems generates harmonics and causes deviations from the pure sine waveform, and the power quality becomes poor. Poor power quality can lead to production interruptions and a significant financial loss [2].

The nonlinear loads, such as PCs, UPS, variable speed drives, and other electronic devices, lead to generating random harmonics [3]. Which represent a big problem in electrical power systems. These harmonics will cause heating, relay malfunction, reduction in power factor, decrease in efficiency, breakdown and harm to the power system grid and users' equipment [4].

Conventionally, passive filters are used to reduce harmonics, but these filters have problems and disadvantages, such as being heavy in weight, fixed compensation, higher in cost, large in size, and resonance problems-with loads [5]. As a result, the electrical power system has necessitated a focus on power electronic solutions, that is, active power filters (APF) [6].

One of the most common types of active power filters is the shunt active power filter (SAPF) as shown in figure (1), which is utilized to mitigate the harmonics in the electrical power system current [7]. The backbone of this filter is the use of power electronics to generate compensating current components that remove current harmonic components caused by non-linear loads [8].

This filter works like a current source, by injecting the components of the harmonics that are generated by the nonlinear load with a 180° phase-shift. Its controller calculates the reference compensating current in real time and compels a power electronic converter to correctly synthesize it [9].

SAPF is the most successful method for removing current harmonic pollution from power systems, and it has gotten a lot of attention because of its benefits, such as the ability to compensate for harmonics of randomly changing currents, fast response, high control precision, and high efficiency [10].

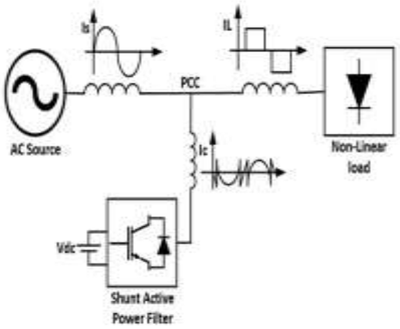

Figure 1: SAPF Schamtic diagram

Several research works to improve power quality depending on THD are conducted in the literature. The authors in [11] have presented a SAPF based on PQ theory with DC link voltage regulation by a PI controller. The gate pulses that regulate the voltage source inverter (VSI) switches are obtained via hysteresis current control. Simulation results show the effectivity of the SAPF in reducing the source current distortion at balanced and unbalanced load conditions. The author in [12] have presented the SAPF based on PQ and DQ theory and compared them at different load conditions. Hysteresis and PWM current control techniques are used to generate the gate pulse signals for the SAPF converter. Simulink results confirmed the effectivity of two methods in harmonics mitigition and power quality improvement.

In this paper, the total harmonics distortion (THD) for electrical grid current is measured at different locations in Mosul city using a power quality analyzer (HZCR5000). This device gives the possibility to save the measured current waveform as an Excel table containing 250 samples per one period. These readings have been entered into the Matlab simulation platform to prove the SAPF's effectiveness in power quality improvement by reducing the measured current harmonics.

2. Methodology

In this work, the instantaneous active and reactive power theory, also called PQ theory, has been utilized to extract the SAPF reference current that is used to generate the gate pulse signal to control the SAPF converter [13].

The PQ theory is based on a set of time-domain instantaneous values of active and reactive powers. It can be utilized in three-phase systems with or without a neutral wire and also in single-phase system. Therefore, it is effective and flexible for designing control strategies not only in steady-state but also in transient conditions [14].

In the PQ method, the reference current signal calculation is based on measuring the three-phase voltages and currents of the power system, then transforming them into (α-β) coordinates by an algebraic transformation (Clarke Transformation) [15]. Depending on the transformed voltage and current value, the instantaneous active and reactive power can be calculated. Low-pass and high-pass filters are used to extract harmonic active and reactive powers from instantaneous active and reactive powers [16]. From harmonic active and reactive powers, and using inverse Clark transformation, the reference current is derived [17]. The PQ theory Schematic diagram is shown in figure (2).

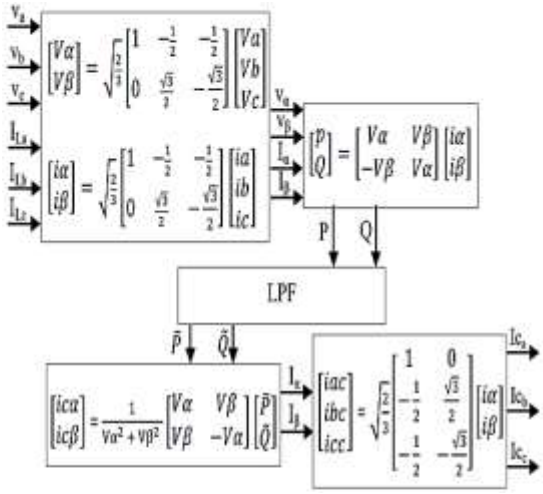

Figure 2: Schematic diagram of PQ theory

3. Locations of Studies

The current harmonics were measured at several locations in the city of Mosul. Current THD was measured at study sites at different times. Table (1) shows the THD of current measured in these locations.

Table 1. Current THD% at studies locations

NO.	Location	THD% of current at different time
1	Glass Tempering Factory	8 – 17 %
2	Right-Industrial Substation	7– 9 %

These locations are shown on the Mosul city map in figure (3).

Figure 3: Locations of studies in Mosul

4. Simulation in Matlab

The current waveform measured using the power quality analyzer was stored as an Excel file. This reading is programmed as (m-file) and simulated in Matlab as a controlled current source. A SAPF simulation circuit is used to reduce the THD% of these readings and improve power quality.

The nonlinear load in the SAPF simulation circuit is moduled as a harmonic current source fed resistive load. Since there is no programmable current source, a voltage-dependent current source is used for harmonic generation. The simulation circuit of SAPF and real reading simulated as the nonlinear load is shown in figure (4).

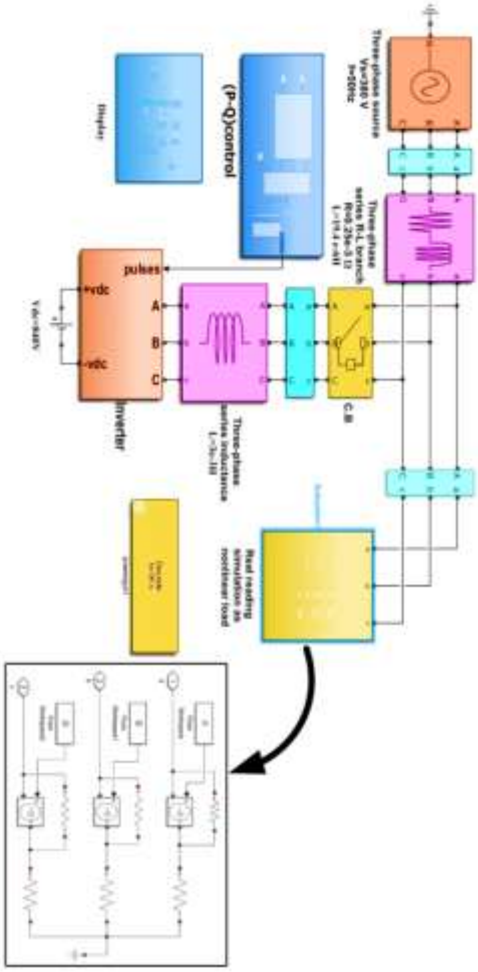

Figure 4: Simulation circuit of SAPF and real reading simulated as the load

5. Results

5.1 Glass Tempering Factory

Figure (5) shows the simulation source current waveform without SAPF in Matlab. That represents the measuring reading of the current waveform, which was measured in the glass tempering factory.

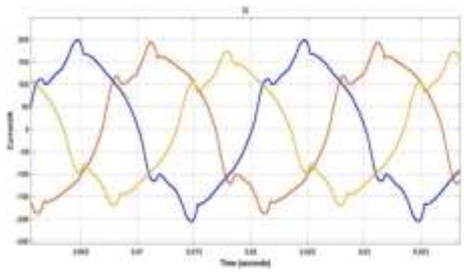

Figure 5: Simulation source current waveform before improvement in the glass tempering factory

Figure (6) and (7) shows the measured current waveform and F.F.T analysis for phase (B) by a power quality analyzer respectively, and the THD is about 8-15%.

Figure 6: The current waveform measured by a power quality analyzer in the glass tempering factory

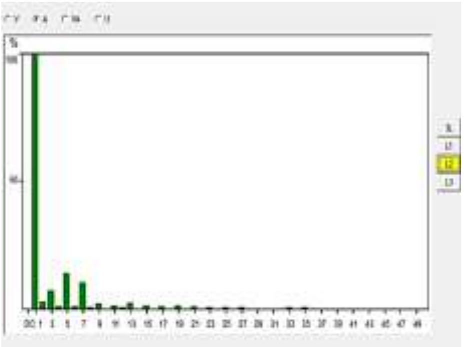

Figure 7: The F.F.T analysis of measured current by a power quality analyzer in the glass tempering factory

The phase (B) source current, SAPF injection current, and load current after compensation are shown in figure (8).

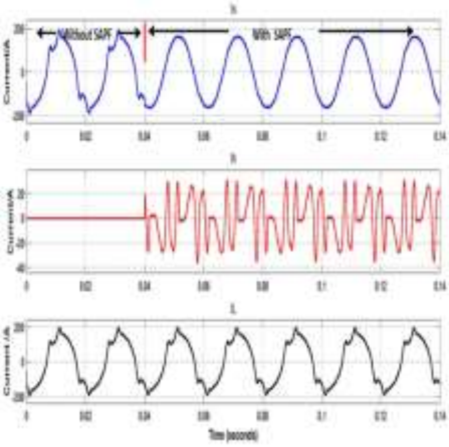

Figure 8: The source, SAPF injection, and load current waveform phase (B) in the glass tempering factory

The SAPF reduced the source current THD to 4.58% in phase (B). Figure (9) shows the F.F.T analysis of the improved source current phase (B).

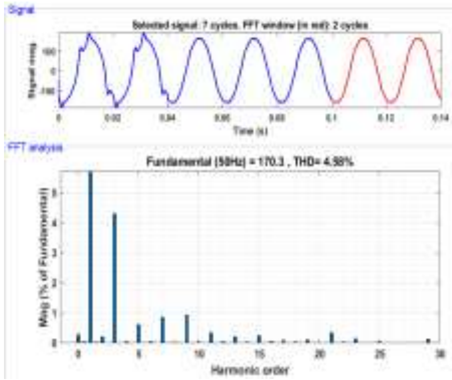

Figure 9: The F.F.T analysis of the improved current phase (B) in the glass tempering factory

5.2 Right-Industrial Substation

Figure (10) shows the source current waveform simulation without SAPF in Matlab. That represents the measured reading of the current waveform, which was measured at the Right-Industrial substation.

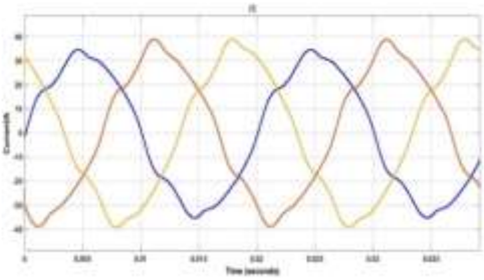

Figure 10: Simulation source current waveform before improvement in the Right-Industrial substation

Figure (11) and (12) shows the measured current waveform, and F.F.T analysis for phase (B) a by power quality analyzer respectively, and the THD is about 6-9%.

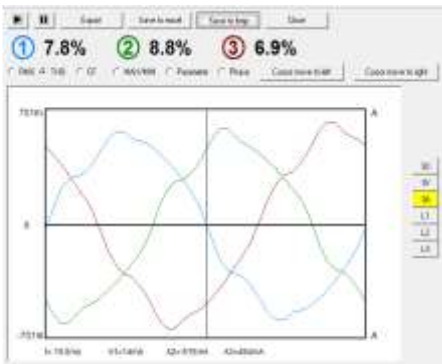

Figure 11: The current waveform measured by a power quality analyzer in the Right-Industrial substation

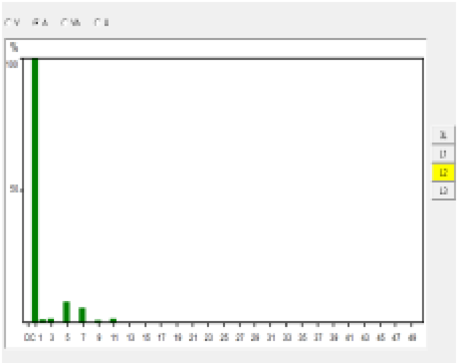

Figure 12: The F.F.T analysis of measured current by a power quality analyzer in the Right-Industrial substation

The phase (B) source current, SAPF injection current, and load current after compensation are shown in Figure (13).

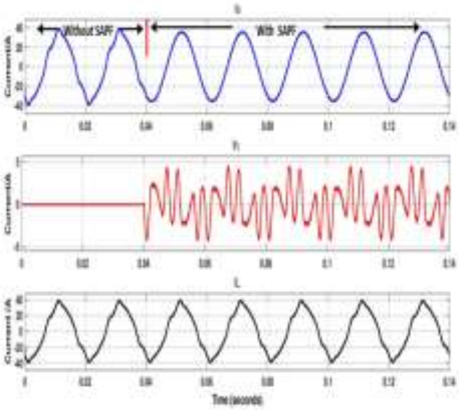

Figure 13: The source, SAPF injection, and load current waveform phase (B) in the Right-Industrial substation

The SAPF reduced the source current THD to 0.42% in phase (B). Figure (14) shows the F.F.T analysis of the improved source current phase (B).

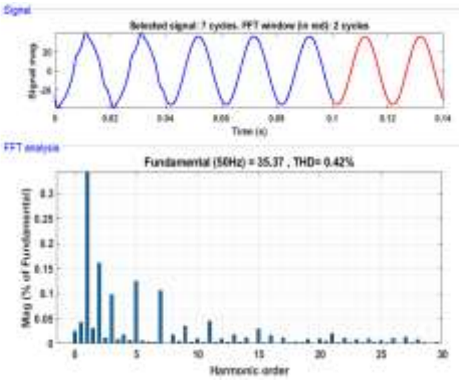

Figure 14: The F.F.T analysis of the improved source current phase (B) in the Right-Industrial substation

Table (2) shows the source voltage value (RMS) and its THD, as well as the source current value (RMS), and its THD without and with SAPF in studied locations.

Table 2. Source voltage and current THD at studied locations

Location	Source Voltage Value	THD%	Source Current Value	THD% Without SAPF	THD% With SAPF
Glass Tempering Factory	380 V	2.5	140 A	15	4.58
Right-Industrial Substation	380 V	1.5	30 A	8.8	0.42

6.Conclusion

In this work, it has been proposed to use the SAPF based on PQ theory to improve the power quality problem in Mosul city. The SAPF was utilized to mitigate the current harmonics problem that resulted from wide-spread use of non-linear loads. The SAPF confirmed its ability to do current harmonic mitigation and power quality improvement. It reduced the THD of the current in the first study location from 15% to 4.85% and in the second location from 8.8% to 0.42. SAPF is the best solution for reducing current harmonic pollution and ensuring the stability of Mosul's electrical grid.

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