Power Quality Improvement Using UPQC

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Abstract: This paper represents the improvement of power quality using Unified Power Quality Conditioner(UPQC). In modern days the use of power electronic converters has increased a lot which causes power quality issues and affects the equipment. Unified power quality conditioner is to mitigate the various concerns related to power quality such as harmonic current,voltage imbalance,sag and swell phenomena and reactive power compensation. The extensive simulation results are verified in matlab 2015a software. The simulation results are verified output voltage, output current and THD. By the results it is clear that using UPQC THD value reduced and achieved high capability of mitigating the harmonic current, voltage and current sag or swell and obtained improved power quality.

Keywords: Power Quality; UPQC(Unified Power Quality Conditioner); Voltage and Current Sag/Swell; Harmonics; THD(Total Harmonic Distortion).

1. Introduction

At the beginning, The main objective is to produce energy in the form of electrical and to supply this energy to the loads/devices at a felicitous voltage [1]. But the term power quality is much used and a very important aspect of power delivery mainly in the second half of the 1990s. Some examples for increasing interest in power quality in recent times are that loads/devices used becoming more sensitive to voltage disturbances, increase in use of electronic devices on a large scale, rapid growth of usage of electricity etc. Nonlinear loads and sensitive equipment are widely used in both the domestic sector and industrial sector. This power quality occurrence is a problem for users' equipment/loads[3]. The voltage quality and current quality combinedly known as power quality[2].

Voltage dip (or sag), extremely brief disturbances, extended disturbances, spikes in the voltage, swells in the voltage, fluctuations in the voltage, harmonic amplifications, voltage amplification and noise etc are the most frequent issues of quality of power [4]. Due to the above problems the sensitive equipment may damage or in the industrial sector they may get huge loss due to damages of high cost equipment or because of malfunctioning of equipment or stopping the devices due to power quality issues. So the interest in equipment for improving power quality is increasing i.e to mitigate the power quality issues[5].So as to continue proper power quality, it is required to include some kind of allowance of techniques[6]. Different ways have been proposed and developed to improve power quality and protect the sensitive loads against the disturbances[7]. There are many compensating type devices which are used for improvement of power factor, balancing load currents, filtering purpose, regulation of voltage. The compensating type devices are DVR (Dynamic Voltage Restorer), UPQC (Unified Power Quality Conditioner), DSTATCOM (Distribution static Compensator), Unified Power Quality Conditioner etc [8]. DVR, UPQC, and DSTATCOM solve the problems due to voltage and current on power quality[11]. The DSTATCOM is a device which is shunt connected and it is mainly for power quality disturbances due to current[9]. The DVR is a series connected device, it is mainly for power quality disturbances due to voltage[10]. The UPQC includes both shunt converter and series converter[12]. The separate use of parallel, series converters may not be economical. Hence, the UPQC which includes both parallel, series converters is used to observe the power quality improvement [13]. UPQC is used for improving the quality of power because it has advantages over DVR and DSTATCOM. Many papers reported that UPQC is utilized to improve power quality at distribution level[14]. In this paper we see the comparison of power quality of a given network with using UPQC and without UPQC i.e voltage and current sag/swell and THD during nonlinear load.

2. Power Quality of Basic Given Electrical Network.

For any basic system or in ideal condition the power quality is constant. But in practical it is impossible due to loads connected to it. Loads are considered as two types, they are 1.Linear loads 2.Nonlinear loads. In general, most of the loads are integration of both loads which are linear and also nonlinear. Mainly the power quality issue occurs due to nonlinear loads only. Due to nonlinear loads the output waveforms are not in pure form or in pure sinusoidal form. Due to this power quality issues or working of the electrical loads without accurate power causes the electrical devices or loads to fail, break down, or not operate at all.

This paper reviews the power quality problem of basic electrical given network when connected to loads and how to overcome this issue. The below Fig 1 shows the Simulink model of the basic electrical network. This does not include any power quality improving techniques.

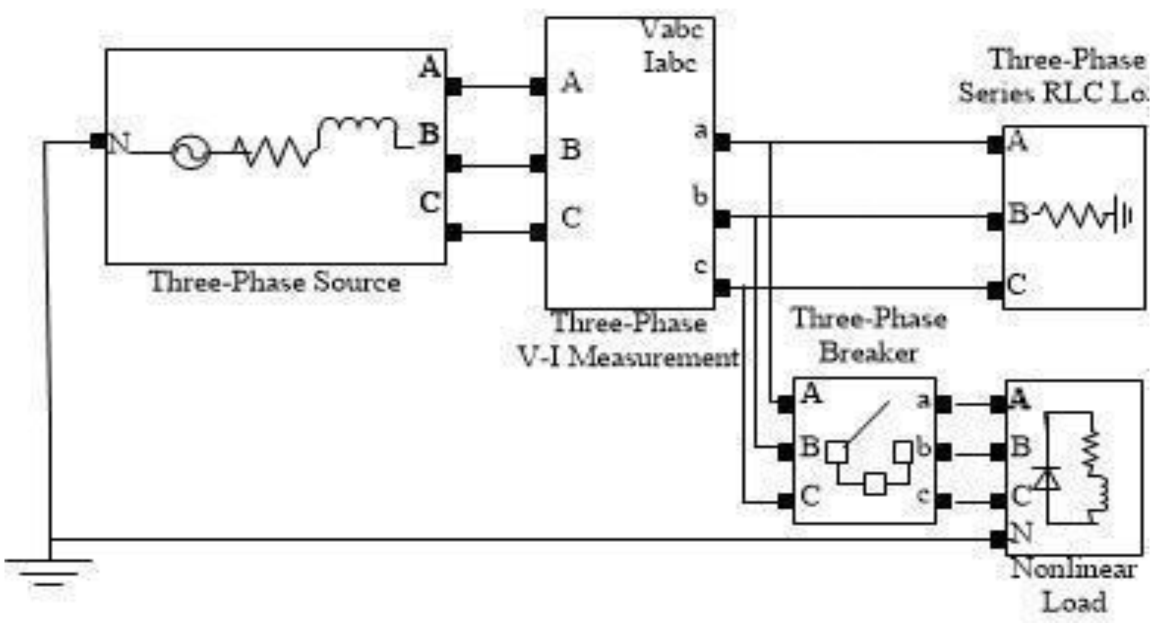

Figure 1. Simulink model of the basic electrical network

In this model supply source is three phase for a given network. V-I measurement is used to measure the magnitudes of the voltage and current. Linear load and Nonlinear loads are connected and nonlinear load is connected through circuit breaker as shown in Fig 1. Circuit breaker is used to connect the nonlinear load to the network for a specific duration.

The power quality error occurs when the circuit breaker is closed and nonlinear load connected to the network. This will cause the non-uniform waveform at the load side which may lead to the damage or malfunction of the electrical equipment or loads. This also induces the harmonics into the network which leads to increase the Total Harmonic Distortion (THD) value. To overcome the above power quality issues there are many power quality improvement techniques such as Active filter, Shunt filter, Static VAR Compensator (SVC), DSTATCOM, UPQC.

3. Proposed Topology

This topology proposes the UPQC (Unified Power Quality Conditioner) technique for boosting the quality of power in the given network. Below Fig 2 represents the Simulink model of the electrical network using UPQC.

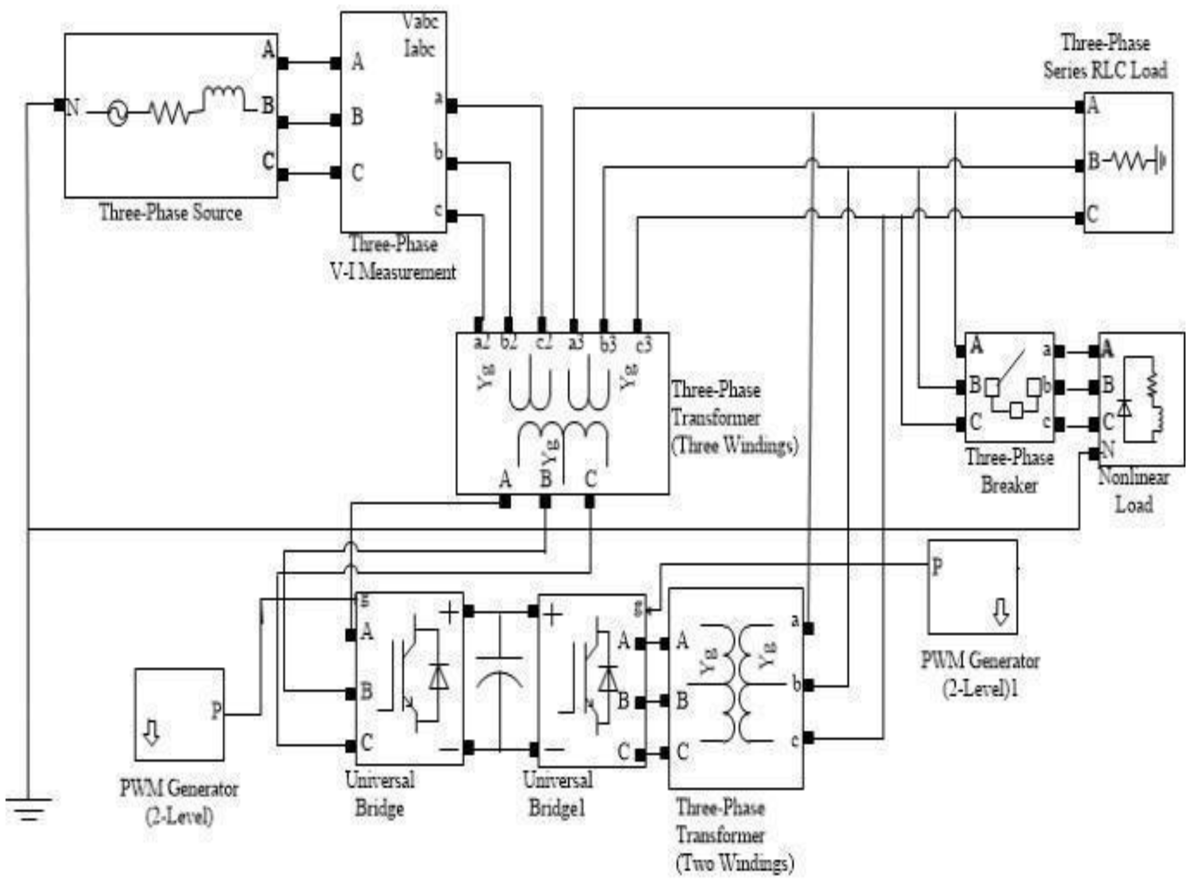

Figure 2. Simulink model of the basic electrical network with UPQC.

This Simulink model is similar to the basic electrical network Simulink model but it also includes Unified Power Quality Conditioner (UPQC) circuit as indicated in Fig. 2.

UPQC is an integration of active series and active parallel compensators These compensators are Voltage Source Converters (VSCs). The UPQCs shunt device is also named as DSTATCOM of full form Distribution Static synchronous Compensator, mitigates the current based power quality problems. In addition to balancing of load, currents in the neutral, harmonic diminishing, and indemnity are offered by the DSTATCOM. DSTATCOM is normally operated in PWM (Pulse Width Modulation) suitable voltage current mode injection in parallel in the network/system. UPQCs series device is also denoted as

DVR indicates full form of Dynamic Voltage Restorer, mitigates the problems in the quality of power (voltage-based).

DVR keeps the load end voltage insensitive to the supply voltage quality problems such as sag/swell, surges, spikes, notches or unbalance etc. In order to inject the proper voltages in series with the ac mains, the DVR is often operated in pulse width modulation voltage control mode.

Using an injection transformer, the UPQC's ac sides are coupled in series (DVR) of ac lines with the series and parallel compensators on a shared dc bus. Shunt (DSTATCOM) normally attached through an isolation transformer for high ratings.

So, by using UPQC we can overcome the problems with voltage and current quality such as surge, unbalancing currents, harmonics can be eliminated and pure sinusoidal waveforms are obtained and can prevent the electrical equipment or loads from damages and malfunctioning etc.

4. Results

Fig 3 depicts the output voltage waveform of the basic electrical network without UPQC Simulink model result. In the simulink model at initial the CB(Circuit Breaker) is at open position and only linear load acting on it. In order for the nonlinear load to be linked to the network at a certain time between 0.2 and 0.3 seconds, the CB must be in the closed position. At time 0.3 seconds, the CB must be opened to re-connect the load to the network. We can see that at linear load the waveform is in pure sinusoidal form but at the duration of nonlinear load connected to it the voltage sag is occurred, the voltage magnitude reduced to a very less value and the waveform also not in pure sinusoidal form.

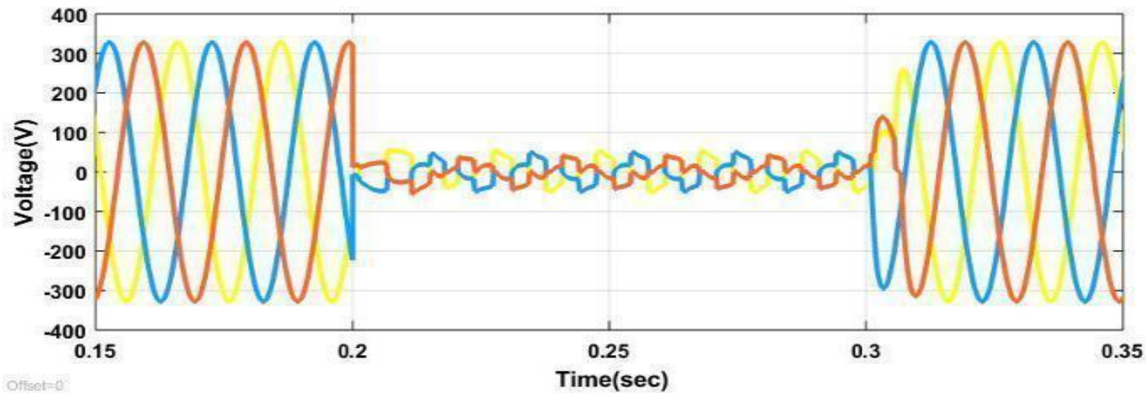

Figure 3. Output Voltage Waveform Without UPQC.

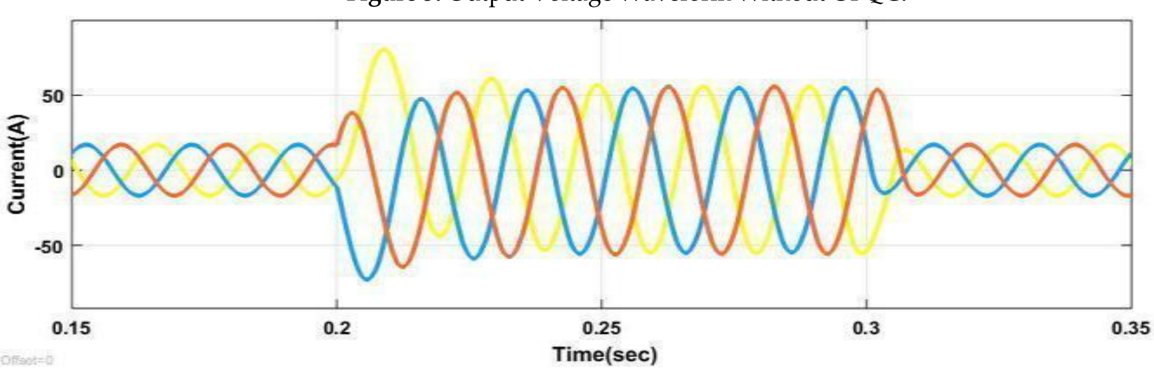

Figure 4. Output Current Waveform Without UPQC.

Fig 4 shows the output current waveform of the basic electrical network without UPQC Simulink model result. In this we can observe that current swell occurs during nonlinear load connected. The current magnitude becomes very high as we see in Fig 4.

Due to the above swelling and sagging of current and voltage respectively will cause the increase in THD(Total Harmonic Distortion) which results in power quality problems. Total Harmonic Distortion of a fundamental electrical network without the use of UPQC is displayed in Fig. 5 below, and we can see that it is quite high (43.47%), which is not permitted by IEEE regulations.

The following equation can be used to compute THD in current waveforms:

$$\text{THD} = \frac{\sqrt{\sum I_h^2}}{I_1}$$

Where I_1 is the primary component of current and I_h is the harmonic current of the h_{th} order. In this case, MATLAB's FFT (Fast Fourier Transform) Analysis Toolbox is used to determine the THD.

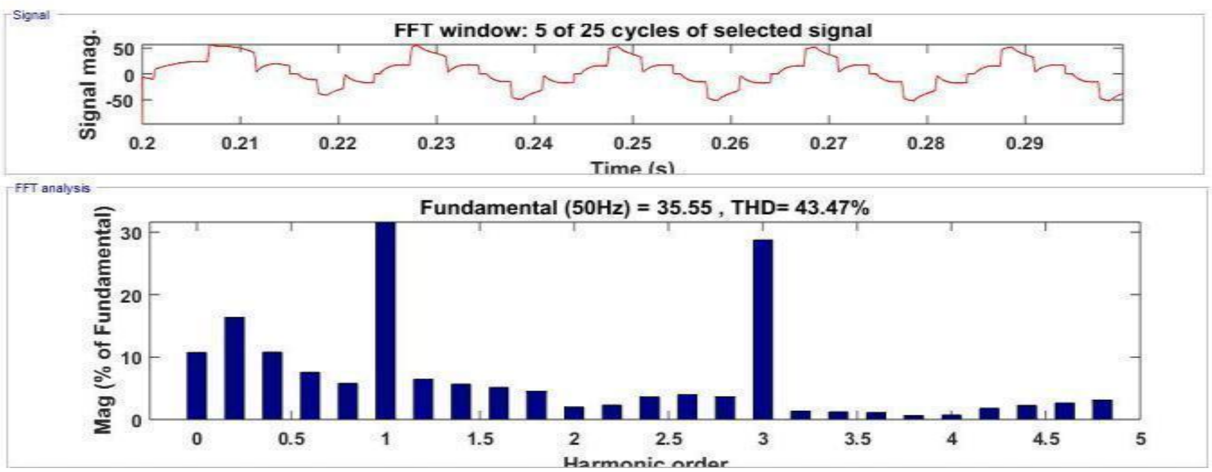

Figure 5. Without using UPQC THD of the electrical network.

Fig 6 depicts the electrical network's output voltage waveform and the UPQC Simulink model result. So, we can see that the output voltage waveform is in pure sinusoidal form even at nonlinear load connected duration. There is no voltage swell in the output voltage waveform. Thus by using UPQC the voltage waveform is in pure sinusoidal form and we avoided the disturbances at output waveform.

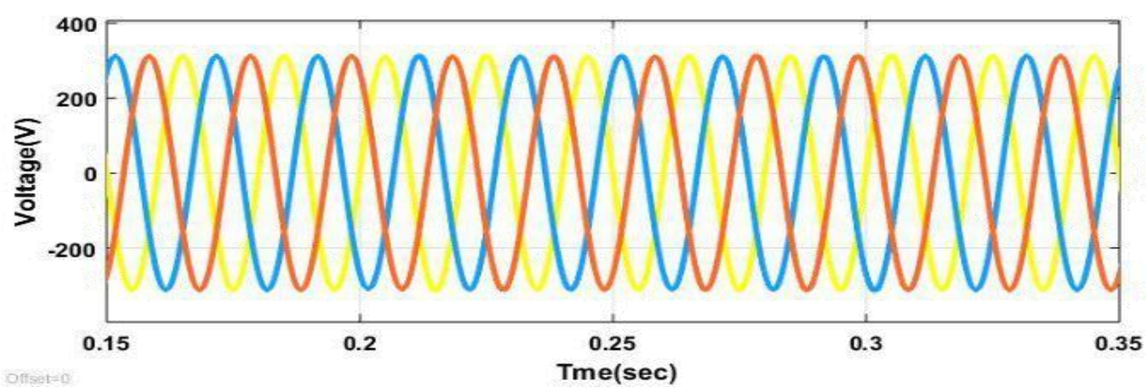

Figure 6. Output Voltage Waveform With UPQC.

Fig 7 shows the output current waveform of the electrical system with UPQC Simulink model result. We can see that the current waveform is in pure sinusoidal form and no current swells, rapid increase in magnitudes, and any disturbances in it.

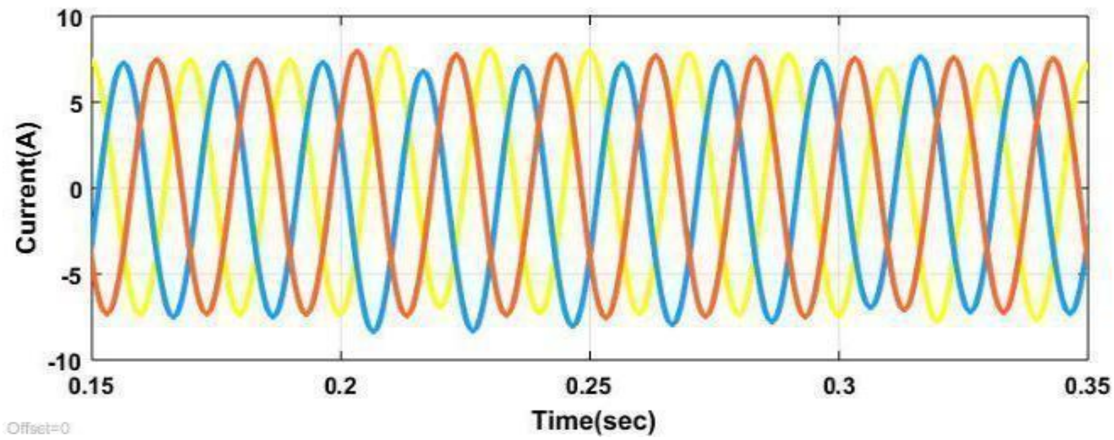

Figure 7. Output Current Waveform With UPQC.

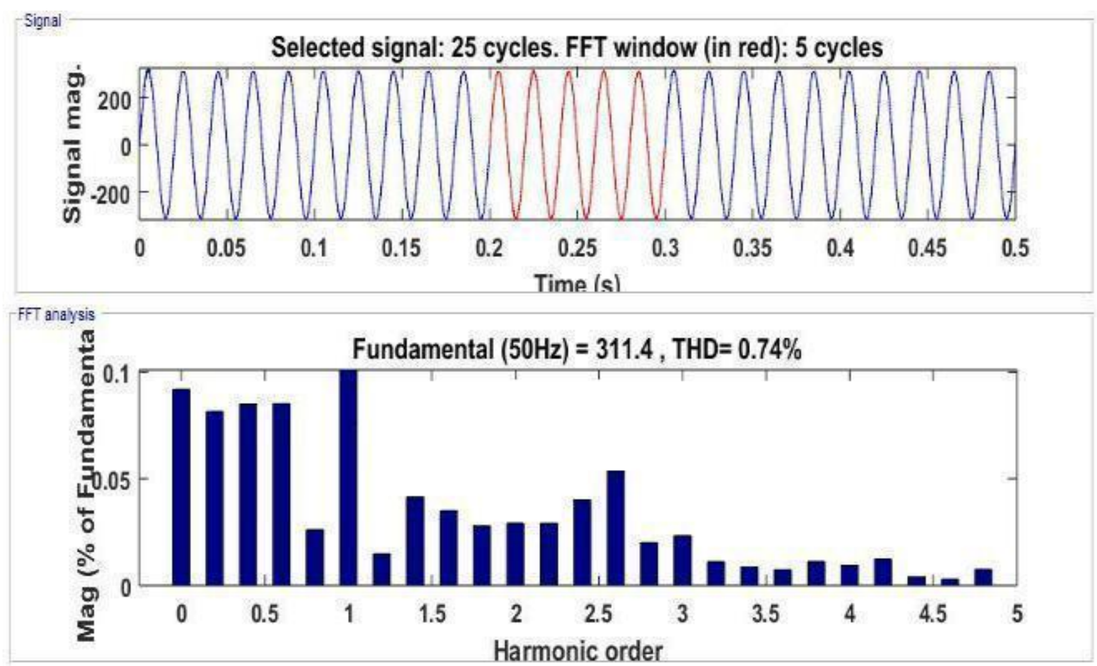

Figure 8. With using UPQC, THD of the electrical network.

Hence from above Fig 6 and Fig 7 we can say that power quality can be improved by using UPQC. Also, THD is decreased as depicted in Fig 8. Fig 8 shows the Total Harmonic Distortion of the electrical network using UPQC.

The THD is decreased to 0.74% by using UPQC, which is within IEEE requirements. By using UPQC we had achieved the power quality improvement as seen in the results waveforms such as output voltage and current waveforms and THD with using UPQC. The simulation results are verified output voltage, output current and THD i.e after successful running of the simulation model we had achieved it.

5. Conclusion

The goal of improving electricity quality has been achieved in this paper. The FFT analysis yields the THD using UPQC, which is displayed in Fig 8 It uses an electrical network simulation model with UPQC. The Total Harmonic Distortion (THD) in the data indicates that it is acceptable to fall below the 5% IEEE standard for THD. The output voltage waveforms and current waveforms are obtained and observed the results of waveforms without using UPQC and with using UPQC. We can see that the output voltage and current waveforms are in pure sinusoidal form by using UPQC.

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