As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 9(03): 218-224, 2023

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0903033
Available online at: http://www.ijmtst.com/vol9issue03.html

Improved Power Quality Using D-Q Theory-Based Three-Phase Unified Power Flow Controller

Nagendra Uggirala, Abhishek Kumar, Praveen, K. Aruna Sri

Department of Electrical Engineering, Godavari Institute of Engineering and Technology(A), Rajahmundry, A.P, India.

To Cite this Article
Nagendra Uggirala, Abhishek Kumar, Praveen and K. Aruna Sri. Improved Power Quality Using D-Q Theory-Based Three-Phase Unified Power Flow Controller. International Journal for Modern Trends in Science and Technology 2022, 9(03), pp. 218-224. https://doi.org/10.46501/IJMTST0903033

Article Info
Received: 28 February 2023; Accepted: 18 March 2023; Published: 19 March 2023

ABSTRACT

In this study, an unique approach is presented to be used for a unified power flow controller (UPFC) that operates in voltage control mode. In order to produce the reference stator current, D-Q theory is used. This, in turn, results in a reduction in the total harmonic distortion (THD) of the source current. The technique that has been presented offers a number of advantages over the voltage-controlled UPFC that is the industry standard. Under typical circumstances of operation, the achievement of unity power factor (UPF) by the load terminal is ensured by the method that has been described. The UPFC controller not only prevents problems with voltage sag in the distribution system, but it also adjusts for reactive power. According to the data, the approach that was presented is an excellent strategy for maintaining a healthy ecology. When evaluating the performance of the whole system, a MATLAB model is put through its paces.

KEYWORDS: UPFC, D-Q Theory, voltage control, Reactive power, Stator current.

1. INTRODUCTION

Power quality issues, including voltage fluctuation, sag, and brief interruptions, are widely recognised for the economic costs and negative consequences they have on businesses and society. Users are putting pressure on utilities to provide multi-type power quality management. Domestic and international researchers have conducted extensive study, gathered a plethora of research data, and produced matching management devices in an effort to mitigate the economic losses brought on by the power supply quality issue. A power quality enhancement device for medium-voltage distribution networks is created, complete with a power unit and charging circuit architecture established and a fixed-voltage, slow-closed-loop control technique offered to better serve the distribution network's sensitive load. The efficiency and power production of the PV system are maximised by operating at the voltage operating point where the greatest energy is produced [1]. For the modified dual output cuk converter fed SRM drive [2], two distinct control strategies are used: constant DC link voltage based control and a variable DC link voltage based control. The SRM drive is fed by a PFC-based dual output converter, which is a hybrid of the Cuk and SEPIC converters. A voltage follower strategy is used to achieve in-built PFC [3]. The overestimation of parameters in all three converters is less influential than the underestimating of parameters. Analysis and comparison of MPC-based MPPT techniques for a number of widely used power converter topologies. [4]. A power quality enhancement device for medium-voltage distribution networks is created, complete with a power unit and charging circuit layout, in order to boost the power quality of the distribution network's sensitive loads [5]. For reactive power adjustment and harmonic reduction, the MG includes a series active power filter (APF) at the point of common coupling, close to the load bus [6]. Power electronics controllers are receiving more attention from power providers, users, and manufacturers of specialised power devices as a means of enhancing power quality. [7] The current and voltage quality issues may be eliminated with the help of the universal power quality conditioner (UPQC), which provides compensation in the distribution system. Non-linear loads of various types are serviced by the distribution grid [8]. The nine-switch UPQC functions as a shunt converter and a series filter, resulting in reduced switching stress, less commutation, lower losses, and lower costs [9]. An open universal power quality conditioner (UPQC-O) with a storage unit for reducing power loss and enhancing power quality in radial distribution networks [10]. Here, the most adaptable and all-purpose FACTS tool is the Unified Power Flow Controller (UPFC). By adjusting the impedance, voltage, and phase angle of transmission lines, it regulates the flow of electricity. Each UPFC has two Voltage Supply Inverters—a series converter (SSSC) and a shunt converter (STATCOM). When used in series with the line, SSSC allows for the addition of a regulated voltage of a certain magnitude and phase angle. This project provides the active and reactive power regulation via a transmission line by positioning the UPFC using computer simulation, while shunt converter STATCOM is employed to give reactive power to the ac system. The UPFC may function in a variety of modes: Different control modes are available, including automated voltage regulation, automatic voltage control, direct voltage injection, phase angle shifter emulation, Line impedance emulation, and automatic power flow control.

2. PROPOSED SYSTEM

Due to the dynamic nature of the electric power system, disturbances occur often, and achieving a good power quality is challenging because of the increasing number of nonlinear loads. So, limiting these disruptions and minimising power quality problems is essential for enhancing performance. When it comes to improving the power handling capacity and management of AC transmission systems, the Flexible Alternating Current Transmission System (FACTS) is a crucial component. Using the D-Q Theory The newest fact gadget, the unified power flow controller, can regulate the transmission lines' reactive and active power by combining the features of series and shunt compensators. As shown in this work, UPFC may mitigate voltage fluctuations. The UPFC circuit model is developed using the fundamental principles of the rectifier and inverter circuits. By adjusting the angle of control, the receiving end experiences a shift in both real and reactive capabilities.

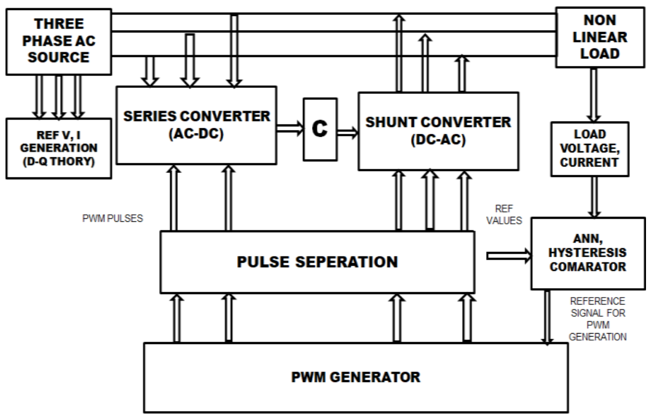

Figure 1: Proposed block diagram

By adjusting the reactance of the line and modulating the flow of power across the transmission and distribution lines, UPFC may concurrently compensate for voltage, phase angle, and impedance. In UPFC, you'll find a shunt converter and a series converter, both of which may be used to convert the voltage coming from different sources. A shared dc connection joins these converters together. Shunt and series transformers are used to link converters to the transmission line.

The following equations define how the unified power flow controller regulates the real and reactive powers.

$$P = \frac{V_S V_R}{X} \sin(\alpha - \beta) \quad (1)$$

$$Q = \frac{V_R}{X} (V_S - V_R) \quad (2)$$

Parallel and series converters are subject to the effects of dc-link voltage ripple, which may be mitigated by the use of appropriate management measures. To lower the total harmonic distortion (THD) of the grid current, a notch filter is used in the voltage loop and specific order harmonic currents correction is offered in the inner current loop of a parallel converter. With the introduction of the dc-link voltage feedback control, the modulation signal may be adjusted in real time for the series converter. In this work, we examine the factors affecting the compensation voltage and current, as well as the method by which the ripples are generated in the dc-link voltage. A approach for controlling the single-phase UPQC is presented to reduce the impact. A series transformer connects the series compensator in series with the transmission line. A capacitor stores the DC voltage produced by the converter after it has rectified the AC current. It is the job of the shunt converter to change the DC voltage that has been stored into the AC voltage that is used in all three phases. Through the transformer, this voltage is sent to the non-linear load. The input voltage and current are used by D-Q theory to produce the reference current. When the real current is lower than the reference current, the hysteresis current controller will send out a pulse. The shunt converter receives this pulse as input. In a similar vein, PWM pulses represent the inaccuracy when comparing the reference value with the actual voltage. The series converter is activated by these impulses. With the aid of the series converter, the PI controller and fuzzy logic controllers keep the DC voltage in the capacitor at a steady state. This UPFC setup is capable of shunt and series compensator function, meaning it can balance out voltage and current. The shunt converter introduces anti-harmonics into the power factor correction (PFC).

A. UPFC SYSTEM DESIGN

The series compensator is connected to the transmission line in a series configuration through a series transformer, and the UPFC system as a whole is made up of two converters: the Static Synchronous Series Compensator (SSSC) and the Static Synchronous Parallel Compensator (STATCOM). A capacitor stores the DC voltage produced by the converter after it has rectified the AC current. It is the job of the shunt converter to change the DC voltage that has been stored into the AC voltage that is used in all three phases. Through the transformer, this voltage is sent to the non-linear load. The input voltage and current are used by D-Q theory to produce the reference current. When the real current is lower than the reference current, the hysteresis current controller will send out a pulse. The shunt converter receives this pulse as input. In a similar vein, PWM pulses represent the inaccuracy when comparing the reference value with the actual voltage. The series converter is activated by these impulses. With the aid of the series converter, the PI controller and fuzzy logic controllers keep the DC voltage in the capacitor at a steady state. The UPFC block diagram is shown in Figure 1. In this case, the UPFC functions in a voltage control mode. This UPFC setup is capable of shunt and series compensator function, meaning it can balance out voltage and current. The shunt converter introduces anti-harmonics into the power factor correction (PFC).

B. PROPOSED D-Q THEORY MODELING FOR UPFC SYSTEM

The notion of d-q axis control provides the basis for both the D-Q transformation and the UPFC's mode of operation. To monitor line-wide variations in parameters such as alternating current (AC) voltage, direct current (DC) link voltage, actual power, and reactive power, the UPFC uses a d-q axis control system. By using a d-q axis controller, we can lessen the mutual influence of actual and reactive power and achieve a faster reaction time. This control system allows for the independent regulation of real and reactive power as well as the regulation of the local bus voltage by performing Park's transformation from a three-phase system to d-q quantities and from d-q to three-phase quantities. It was proposed that the UPFC be controlled in accordance with the idea that the real power is affected by the phase angle and the reactive power is affected by the voltage magnitude. Accordingly, the series UPFC controller modifies the phase angle of the series compensation voltage to manage the actual power flow in the transmission line, and the series voltage's amplitude is adjusted to manage the reactive power flow.

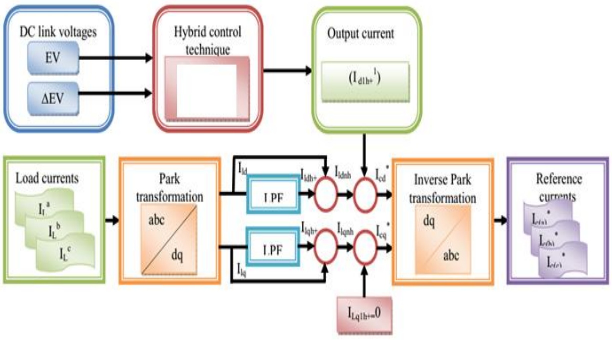

Figure 2: Reference Current Generation Using D- Q Theory

The three-phase alternating current voltage has been disassembled into its component parts, which are referred to as the positive, the negative, and the zero sequence elements.

$$\begin{bmatrix} V_{Sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} = V_a \begin{bmatrix} \cos(\omega t + \phi_0) \\ \cos(\omega t + \phi_0) \\ \cos(\omega t + \phi_0) \end{bmatrix} + V_b \begin{bmatrix} \cos(\omega t + \phi_1) \\ \cos\left(\omega t - \frac{2\pi}{3} + \phi_1\right) \\ \cos\left(\omega t + \frac{2\pi}{3} + \phi_1\right) \end{bmatrix} + V_c \begin{bmatrix} \cos(\omega t + \phi_2) \\ \cos\left(\omega t + \frac{2\pi}{3} + \phi_2\right) \\ \cos\left(\omega t - \frac{2\pi}{3} + \phi_2\right) \end{bmatrix} \quad (2)$$

Where Vsa,Vsb,Vsc are three-phase AC voltages, whereas Va ,Vb ,Vc are zero, positive and negative sequence voltages, respectively.

$$V_S = \begin{bmatrix} V_{Sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} = \begin{bmatrix} V_{a0} \\ V_{b0} \\ V_{co} \end{bmatrix} + \begin{bmatrix} V_{a1} \\ V_{b1} \\ V_{c1} \end{bmatrix} + \begin{bmatrix} V_{a2} \\ V_{b2} \\ V_{c2} \end{bmatrix} \quad (3)$$

Three-phase source current is represented as follows

$$I_S = \begin{bmatrix} I_{Sa} \\ I_{sb} \\ I_{sc} \end{bmatrix} = \begin{bmatrix} I_{a0} \\ I_{b0} \\ I_{co} \end{bmatrix} + \begin{bmatrix} I_{a1} \\ I_{b1} \\ I_{c1} \end{bmatrix} + \begin{bmatrix} I_{a2} \\ I_{b2} \\ I_{c2} \end{bmatrix} \quad (4)$$

Apparent power is given as

$$S_s = P_s + jQ_s = V_S * I_S^* (5)$$

The D-Q theory general equation is given $S_{s012} = S_{1012} + S_{F012}$

$$S\_1012 = S\_s012 + S\_h012$$

$$S_{1012} = P_{s012}(t) + Q_{Q012}(t) + p_{h012}(t) + q_{1012}(t) (6)$$

Real power, denoted by the letter P, and reactive power, denoted by the letter Q, are respectively denoted by the words P and Q term. The voltage and current from the input three phases are converted to αβ0 parameters by using Clarke transformation.

$$V_{\alpha\beta o} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} V_s \quad (7)$$

$$I_{\alpha\beta o} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} I_s \quad (8)$$

Aβ parameters are calculated from the above equations.

$$V_{\alpha\beta} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} V_s \quad (9)$$

$$I_{\alpha\beta} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} I_s \quad (10)$$

From the positive and negative sequence elements αβ and parameters are calculated.

$$V_{\alpha\beta} = V_1 \begin{bmatrix} cos(\omega t + \varphi_1) \\ \sin(\omega t + \varphi 1) \end{bmatrix} + V_2 \begin{bmatrix} cos(-\omega t + \varphi_1) \\ \sin(-\omega t + \varphi 1) \end{bmatrix}$$
(11)

$$V_{dq1} = V_{\alpha\beta} \begin{bmatrix} cos(\omega t)\ sin(\omega t) \\ -\sin(\omega t) cos(\omega t) \end{bmatrix} \quad (12)$$

$$V_{dq2} = V_{\alpha\beta} \begin{bmatrix} -cos(\omega t) - sin(\omega t) \\ \sin(\omega t)\ \ -cos(\omega t) \end{bmatrix} \quad (13)$$

$$V_{dq1} = V_1 \begin{bmatrix} cos(\varphi_1) \\ \sin(\varphi_1) \end{bmatrix} + V_2 \begin{bmatrix} cos(\varphi_2) & sin\,\varphi_2 \\ -\sin\varphi_2 &)cos(\varphi_2) \end{bmatrix} \begin{bmatrix} cos(2_{\omega t}) \\ \sin(2_{\omega t}) \end{bmatrix}$$
(14)

$$V_{dq1} = V_2 \begin{bmatrix} cos(\varphi_1) \\ \sin(\varphi_1) \end{bmatrix} + V_{dq2} \begin{bmatrix} cos(2\omega t) \\ -\sin(2\omega t) \end{bmatrix} + V_{q2} \begin{bmatrix} sin(2\omega t) \\ cos(2\omega t) \end{bmatrix} (15)$$

$$V_{dq2} = V_2\begin{bmatrix}cos(\varphi_2)\\ \sin(\varphi_2)\end{bmatrix} - V_{dq1}\begin{bmatrix}cos(\omega t)\\ \sin(\omega t)\end{bmatrix} + V_{q1}\begin{bmatrix}sin(2\omega t\\ -cos(2\omega t)\end{bmatrix}$$
(16)

The following equation is used to determine the reference signal based on D-Q theories for UPFC:

$$P_0 = \frac{3}{2}\begin{bmatrix}V_{d1} & -V_{q1} & -V_{d2} & V_{q2}\end{bmatrix}\begin{bmatrix}I_{q2}\\ I_{d2}\\ I_{q1}\\ I_{d1}\end{bmatrix} (17)$$

$$Q_0 = P_2 = \frac{3}{2}\begin{bmatrix}V_{d1} & V_{q1} & V_{d2} & V_{q2}\end{bmatrix}\begin{bmatrix}I_{q2}\\ I_{d2}\\ I_{q1}\\ I_{d1}\end{bmatrix} (18)$$

Both the amplitude and the phase angle of the series compensating voltage impact the actual and reactive power flows down the transmission line. This means the reactive power flow might be considerably impacted by the actual power controller. The reactive power controller modifies the actual power flow by adjusting the magnitude of the series voltage to control the reactive power. As a result, the outputs of the two controllers will interact with one another.

We use Park and Clarke transformations to derive the reference signals from the source voltage and currents. A hysteresis comparator then compares the reference signal with the actual value. PWM pulses are output by the hysteresis current controller and supplied into the series and shunt converters. With the help of PI and fuzzy logic controllers, the DC link voltage is kept stable. MATLAB simulation is used to verify the proposed system's findings.

3. RESULTS

The simulation results are examined using a software MATLAB/SIMULINK.

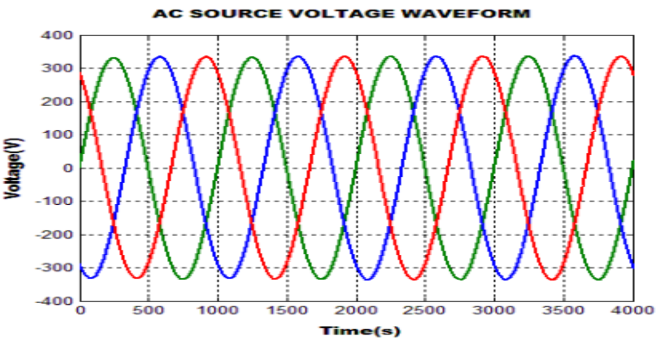

Figure 3: Extended vision of the input voltage waveform

The performance analysis of UPFC with DQ theory has been analyzed by introducing voltage sag at the time period of $2 \times 10^4 to\ 3 \times 10^4$seconds and from the source voltage depiction it has been revealed that the voltage has been reduced and during the remaining time period, voltage is in the range of +320V to -320V.

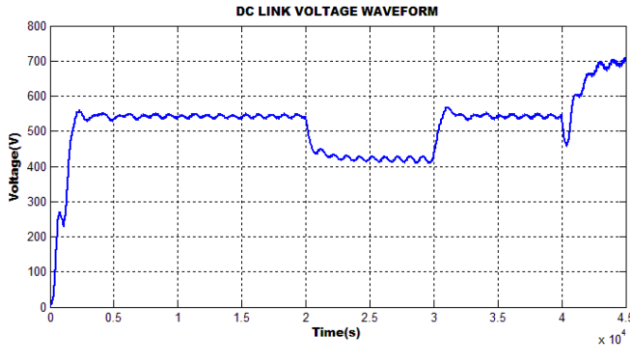

Figure 4: DC-link voltage waveform

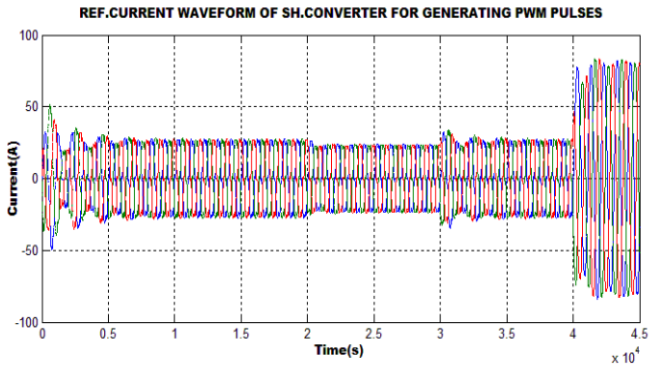

Figure 5: Generated reference current by DDSRF theory

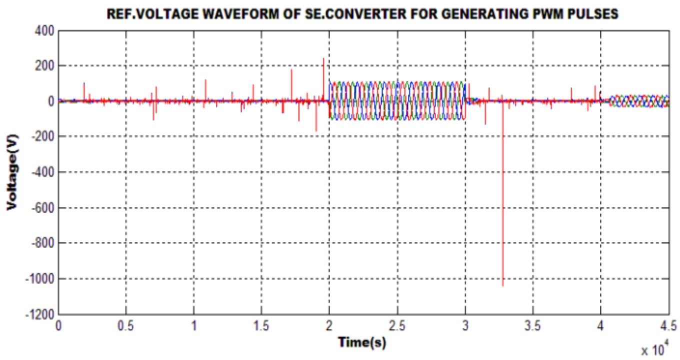

Figure 6: Generated reference voltage by DQ theory

After the implementation of DQ theory, the reference current and the reference voltage has been generated, which is then analogized with the actual current and voltage (Figure 5 and figure 6) thereby generating the PWM pulses for the shunt and the series converter.

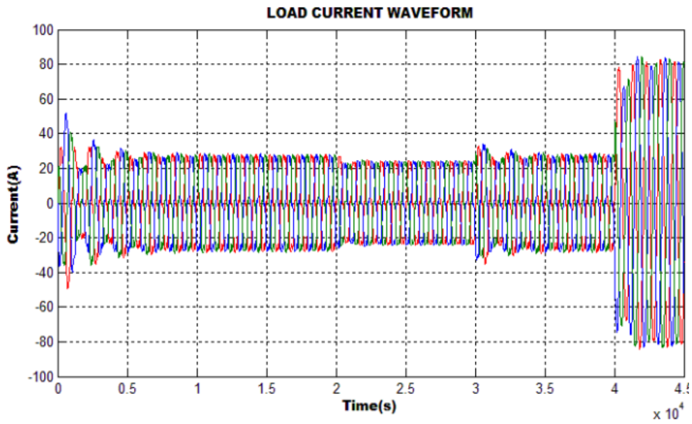

Figure 7: Load current waveform

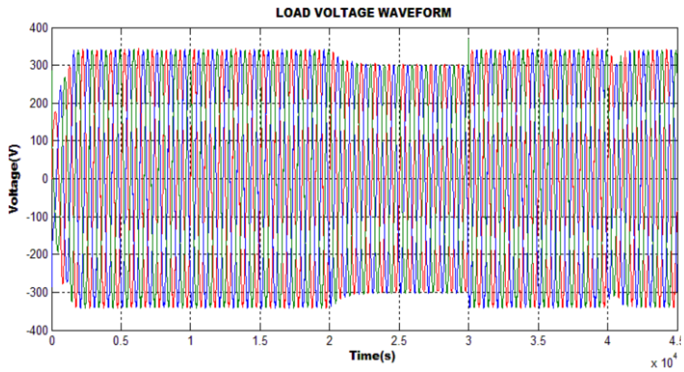

Figure 8: Load voltage waveform

Figure 8 shows the load voltage waveform, voltage is in the range of +320V to -320V.

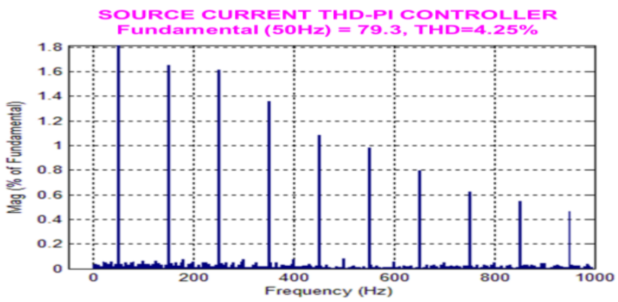

Figure 9: Source current THD using PI controller with theory

4. CONCLUSION

UPFC allows for quick regulation of the active and reactive power of a transmission line. This regulation is effective immediately. By applying the D-Q theory to the shunt converter of the UPFC, it is possible to obtain a response that is sufficiently quick and to restrict the interaction between the flow of real power and the flow of reactive power. As the results of the simulation show, the transient response is adequate, with little overshoot and oscillations. Furthermore, when the issue has been fixed, an excess current may be created due to the delayed response of the integral gains in the control loop of a conventional controller. The d-q control system may aid in the attainment of fast power flow regulation and also assist to improve the stability of the transmission systems. The suggested approach ensures that the load terminal always has a power factor of unity (also known as UPF) under typical operating conditions.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Jonatan Rafael Rakoski Zientarski ; Mário Lúcio da Silva Martins ; José Renes Pinheiro ; Hélio Leães Hey, Year: 2018 ,"Series-Connected Partial-Power Converters Applied to PV Systems: A Design Approach Based on Step-Up/Down Voltage Regulation Range", IEEE Transactions on Power Electronics, vol. 33, no. 9 ,pp. 7622–7633.

[2] Aniket Anand ; Bhim Singh, Year: 2018, "Power Factor Correction in Cuk–SEPIC-Based Dual-Output-Converter-Fed SRM Drive", IEEE Transactions on Industrial Electronics, vol. 65, no. 2 , pp. 1117–1127.

[3] Abderezak Lashab ; Dezso Sera ; Josep M. Guerrero ; Laszlo Mathe ; Aissa Bouzid,Year: 2018, "Discrete Model-Predictive-Control Based Maximum Power Point Tracking for PV Systems: Overview and Evaluation, IEEE Transactions on Power Electronics, vol. 33, no. 8, pp. 7273–7287.

[4] Aniket Anand; Bhim Singh, Year: 2019, "Modified Dual Output Cuk Converter-Fed Switched Reluctance Motor Drive With Power Factor Correction", IEEE Transactions on Power Electronics, vol. 34, no. 1, pp. 624–635.

[5] W. Hu, Y. Shen, F. Yang, Y. Lei and M. Zhang, "Power Quality Improvement Device for Medium-Voltage Distribution Network," 2019 IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia), 2019, pp. 2240–2244.

[6] M. T. L. Gayatri and A. M. Parimi, "Power Quality Improvement of PV-WECS micro grid Using Active Power Filter in Real-time," 2018 53rd International Universities Power Engineering Conference (UPEC), 2018, pp. 1–6.

[7] S. Praveena and B. S. Kumar, "Performance of custom power devices for power quality improvement," 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), 2017, pp. 912–917.

[8] K. N. Kumar and S. Srinath, "Integration of UPQC with New Converter Transformer for Power Quality

Improvement," 2018 National Power Engineering Conference (NPEC), 2018, pp. 1–6.
[9] S. Vijayasamundiswary and J. Baskaran, "A novel approach to nine switch unified power quality conditioner for power quality improvement," 2017 International Conference on Innovative Research in Electrical Sciences (IICIRES), 2017, pp. 1–5.
[10] S. Lakshmi and S. Ganguly, "Steady-State Model for Open Unified Power Quality Conditioner for Power Quality and Energy Efficiency Improvement of Radial Distribution Networks," 2018 2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE), 2018, pp. 1–6.