SSRG International Journal of Recent Engineering Science
ISSN: 2349–7157 / https://doi.org/10.14445/23497157/IJRES-V10I4P102

Volume 10 Issue 4, 7-13, Jul-Aug 2023

Original Article

Integration of Multi-Terminal Unified Power Quality Conditioner in Microgrid System

M. G. Manjula[1], S. Surendra[2]

[1,2]*Department of Electrical & Electronics Engineering, JNNCE, Shivamogga, Karnataka, India.*

[1]*Corresponding Author : manju_mg@jnnce.ac.in*

Received: 03 May 2023 Revised: 09 June 2023 Accepted: 24 June 2023 Published: 08 July 2023

Abstract - *Electrical Power Quality (EPQ) is fetching more of a concern as smart grid technology advances in distribution systems. A proposal for MT-UPQC integration in a microgrid system (G) is presented here. This paper presents configurations of UPQC, MT-UPQC, UPQCμG and MT- UPQCμG and a comparison between them. MT-UPQCμG combines the advantages of both MT-UPQC and UPQCμG. The MT-UPQC can correct voltage quality issues, harmonic currents and reactive currents in a variety of ways depending on the needs of the user. On the MATLAB Simulink platform, a 3T-UPQCμG microgrid is constructed for simulation and verified the same. The obtained results of the simulation suggest that the proposed method is both effective and adaptable.*

Keywords - *Microgrid, Active Power Filter, Electrical Power Quality, Distributed Generation, Multi Terminals, Unified Power Quality Conditioners.*

1. Introduction

The solution for a small-scale power system is a Microgrid. It includes local generation and storage. Microgrids generate electricity using Distributed Energy Resources (DERs). Fuel cells, PV systems, and wind energy systems, which are renewable energy sources, are extensively utilised DERs [1]. EPQ issues are often caused by either supply voltage or load current distortion [2]. Maintaining EPQ is a critical consideration while running a microgrid system in either grid-connected or isolated mode. According to recent research, the UPQC is a low-cost power device that may be used at the PCC to safeguard the utility and the consumer against EPQ distortion [3].

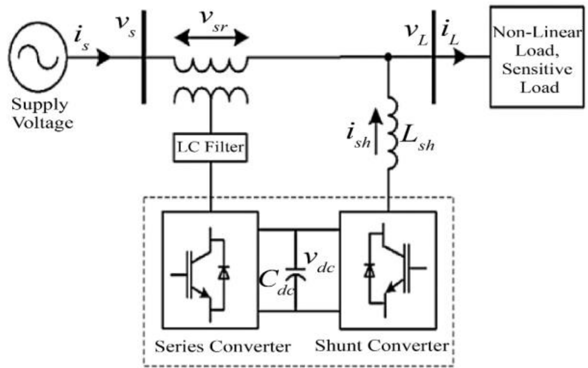

Fig. 1 Schematic diagram of the UPQC

A power quality control device named MT-UPQC consists of multiple shunt APFs near the end users and single series APFs on the grid side. MT-UPQC is already implemented in distributed generation [4-5]. This paper presents the Multi-terminal UPQC concept in the microgrid called MT-UPQCμG, which addresses PQ issues of multiple users connected to the different feeders. The MT-UPQC system comprises a series of APFs and many parallel APFs which share a common DC-link energy store capacitor in the Microgrid system. The proposed paper aims to deal with voltage imperfections of the grid and load current imperfections of the multiple users connected to the different feeders.

2. Configurations of UPQC, MT-UPQC, UPQCμg and MT- UPQCμg

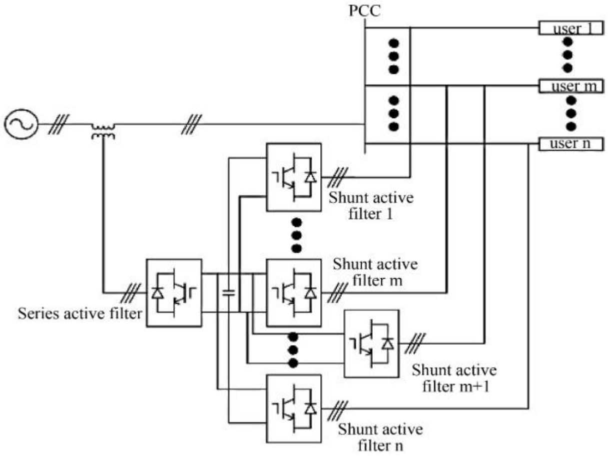

Fig. 2 Schematic diagram of the MT-UPQC

Figure 1 represents the schematic figure of the UPQC. It is an integrated system comprising a series APF and a shunt APF connected by the same DC capacitor to adjust for voltage swell/sag, disturbances in voltage, reactive power, and harmonic currents. A UPQC's primary function is correcting for harmonics, supply voltage flicker/imbalance, and reactive power. At the point of installation on power distribution or industrial power systems, the UPQC can improve power quality [6].

The schematic figure of the MT-UPQC system is represented in Figure 2. The MT-UPQC is a custom power device consisting of several parallel active filters near end users that can be linear or non-linear loads on the same feeder and require distinct power quality levels and a single series APF on the grid side. Each user has the ability to install an unlimited number of shunt APFs. All APFs are linked back to back on the DC side and share the same DC capacitor [7].

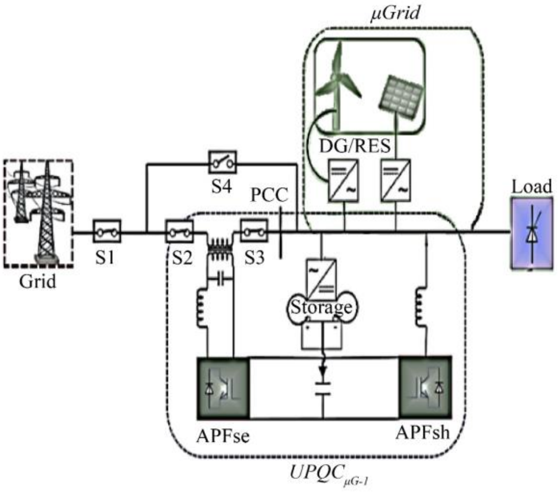

Fig. 3 Integration of UPQC in microgrid system

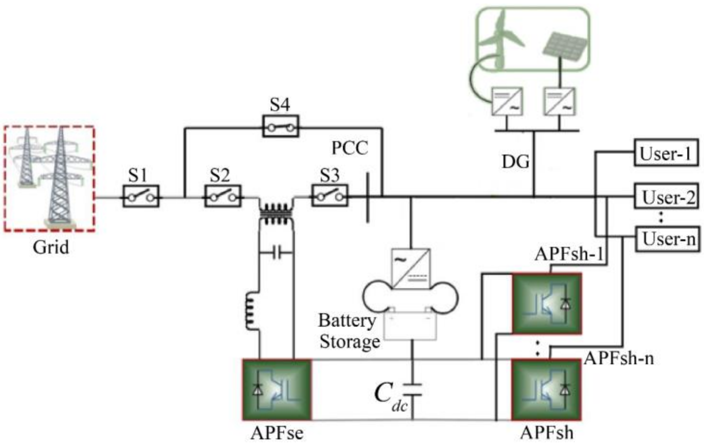

Fig. 4 Integration of MT- UPQC in microgrid system

The integration technique UPQC to grid-connected μG system is represented in Figure 3. It performs the common basic functions of the UPQC controller, with the exception of improved signal generation for the detection of islanding and reconnection [8]. A communication link between the $UPQC_{\mu G}$ and the microgrid is, in addition, necessary for islanding detection and reconnection. These scenarios generate signals due to sag/swell/interrupt/supply failure [9]. Figure 4 shows the Integration of MT- UPQC in the Microgrid system. It combines the configurations of both MT- UPQC and UPQCμG. The MT-UPQCμG is a custom power device comprising a single series and multiple shunt APF, which share a common DC link capacitor along with DG and storage [13]. It provides compensation for voltage and current imperfections of multiple users connected to different feeders in interconnected mode. MT-UPQCμG operates in both interconnected and islanded modes. The proposed MT-UPQCμG is used to provide the solution for the PQ issues like voltage sag, swell, reactive and harmonic compensation and voltage interruption in interconnected mode [11-12].

Table 1. Comparison between UPQC, UPQCμG, MT - UPQC & MT - UPQCμG

Parameter	UPQC	$UPQC_{\mu G}$	MT - UPQC	MT - $UPQC_{\mu G}$
Construction	One series and one shunt APF share a common DC-link energy store capacitor.	One series and one shunt APF share a common DC-link energy store capacitor along with DG and Storage.	One series and multiple shunts APF share a common DC-link energy store capacitor.	One series and multiple shunts APF share a common DC-link energy store capacitor along with DG and Storage.
Storage	Absent	Present	Absent	Present
Compensation	Voltage and Current imperfections.	Voltage and Current imperfections in interconnected mode.	Voltage and Current imperfections of multiple users connected to the same feeder in the distribution system.	Voltage and Current imperfections of multiple users connected to different feeders in interconnected mode.
No. of series APF	One	One	One	One

No. of shunt APF	One	One	It can install in any number depending on the requirement of the load.	It can install in any number depending on the requirement of the load.
PQ issues	Voltage sag/ swell Reactive power compensation, Harmonic compensation.	Voltage sag/swell reactive and Harmonic compensation, Voltage interruption in interconnected mode.	Voltage sag, swell, reactive and Harmonic compensation in the distribution system.	Voltage sag, swell, reactive and Harmonic compensation, Voltage interruption in interconnected mode.
Operating mode	Grid-connected	Interconnected and Islanded.	Grid-connected	Interconnected and Islanded.
User	Single user with a single load.	Single user with a single load.	Multiple users with different loads are connected to the same feeder.	Multiple users with different loads connected to different feeders.
Drawbacks/Merits	It cannot address current issues of more than one load.	Addresses current issues of one load in both modes of operation of the microgrid.	Addresses current issues of more than one load in the distribution system.	Addresses current issues of more than one load in both modes of operation of the microgrid.

3. 3T-UPQC$_{\mu G}$ Configuration

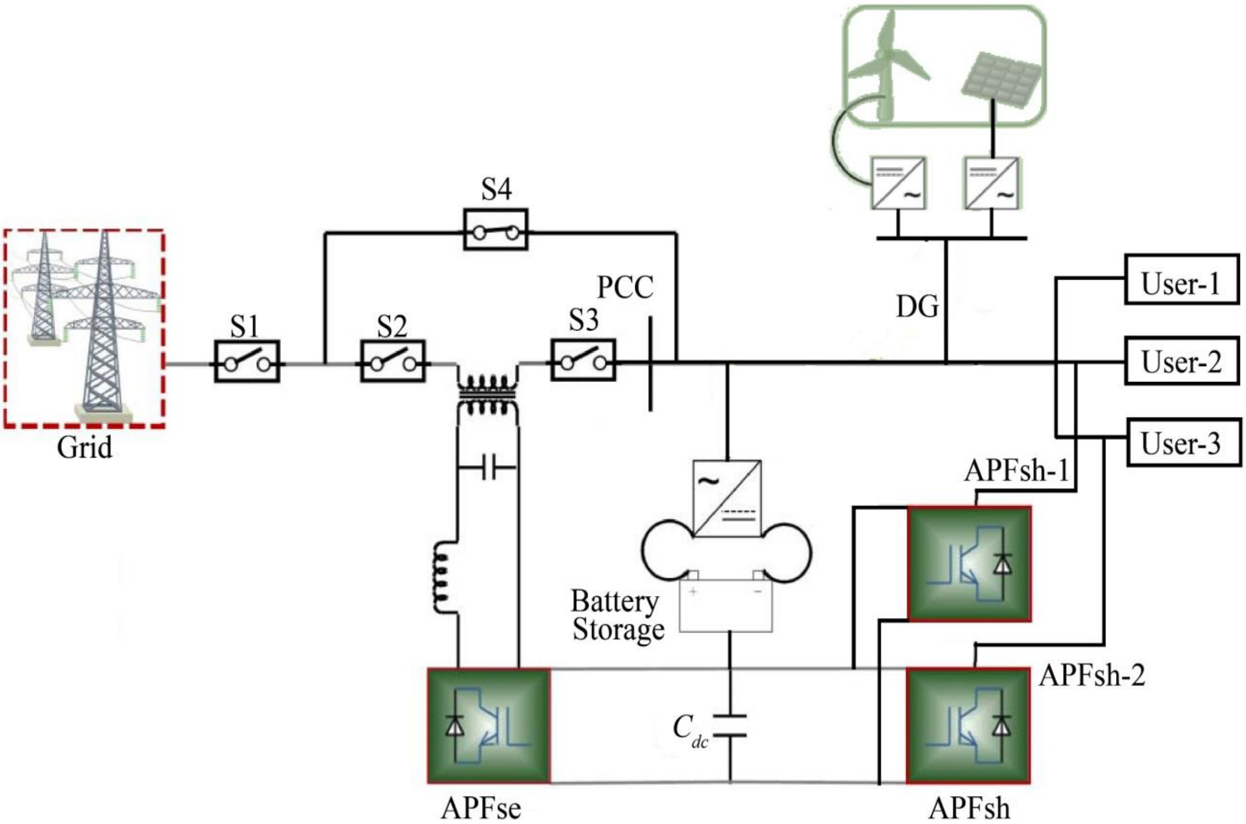

Fig. 5 Schematic diagram of the 3T-UPQC$_{\mu G}$

The integration of the 3T-UPQC (one series, as well as two shunt active filters, constitute 3T) in utility connected microgrid system is shown in the figure. It mainly operates in modes.

3.1. Interconnected Mode of Operation

- The basic active power to the grid, load and storage will be provided by the Distributed Generation (DG) source.
- In order to keep the Total Harmonic Distortion at the PCC as per IEEE standards, the Shunt Active Power Filters (APFsh) will correct the reactive and harmonic (QH) power of the loads connected to Non-linear and Unbalanced loads, respectively,
- Voltage sag/swell/interruptions can be adjusted for using active power from the grid or storage via the Series Active Power Filter (APFse).
- If there is a power interruption/blackout on the grid, the UPQC-Microgrid controller will island that part.

3.2. Islanded Mode of Operation

- Series APFse will be unplugged during the grid disconnection. However, the DG converter remains connected and maintains the needed voltage at the PCC.
- In order to supply or maintain undisturbed current at PCC for other linear loads, the Shunt Active Power Filters will continue to correct for reactive and harmonic power of non-linear and unbalanced loads.
- As a result, the DG converter with storage will only supply active power and so does not require to be unplugged from the system.
- APFse will be connected again after power in the grid is restored.

4. Simulation Model of Proposed System

The proposed structure MT-UPQCμG is designed in MATLAB, as shown in Figure 6. The structure is patterned as three phases and four wire system.

Simulation is conducted to analyse the proposed system and performance in interconnected and islanded modes. Simulation is conducted for 0.5 seconds.

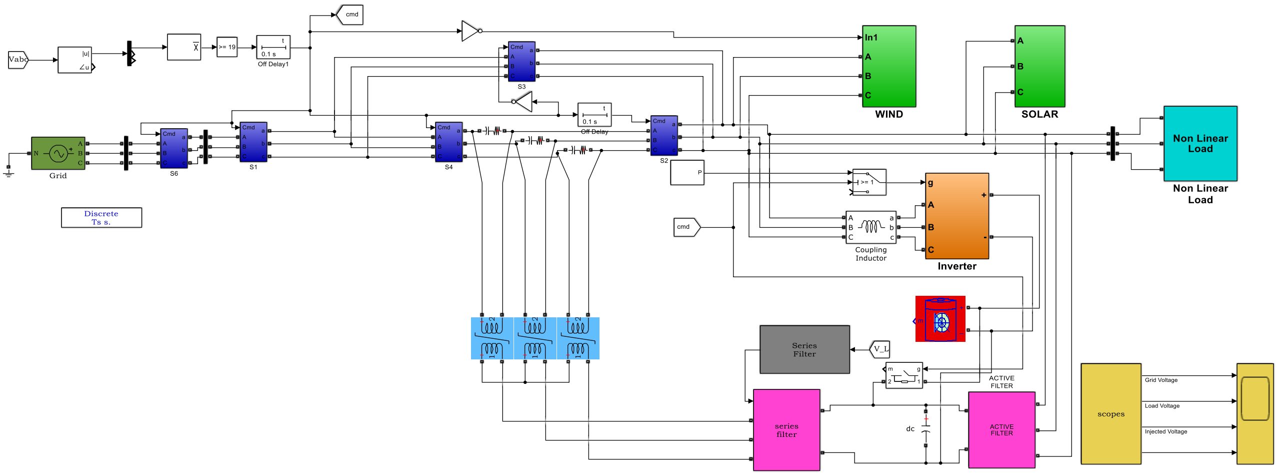

Fig. 6 Simulation model of 3T-UPQC$_{\mu G}$

5. Simulation Results

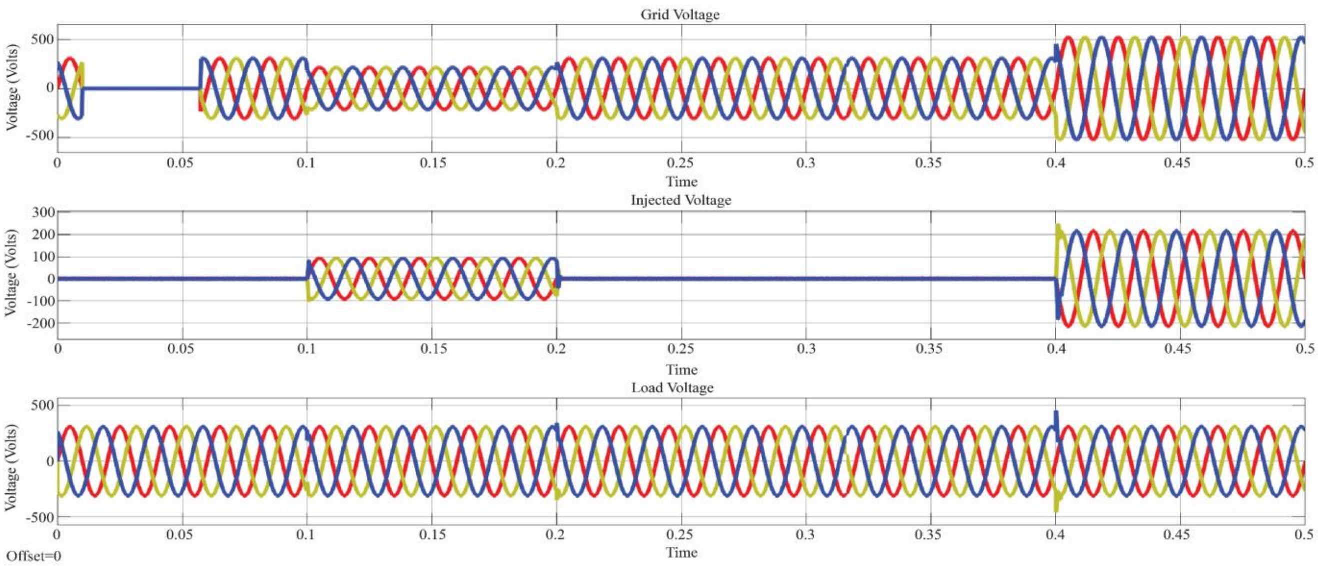

Fig. 7 Voltage waveforms at different positions of the switching network (a) Supply voltage, (b) Voltage Injected, (c) Voltage a/c load.

5.1. Islanded Mode

In Figure 8, APF_{sh} continues to operate in islanding conditions and compensates for non-active power. The load is supplied by DG source and storage. Hence, during islanding conditions, the DG will not be separated by removing its grid connection, and changing control action will not be required to meet the load's demand. In order to demonstrate this at t=0.01 sec grid is isolated, and due to this, the grid voltage becomes zero, as shown in Figure 6. The load voltage is maintained constant with DG source and storage.

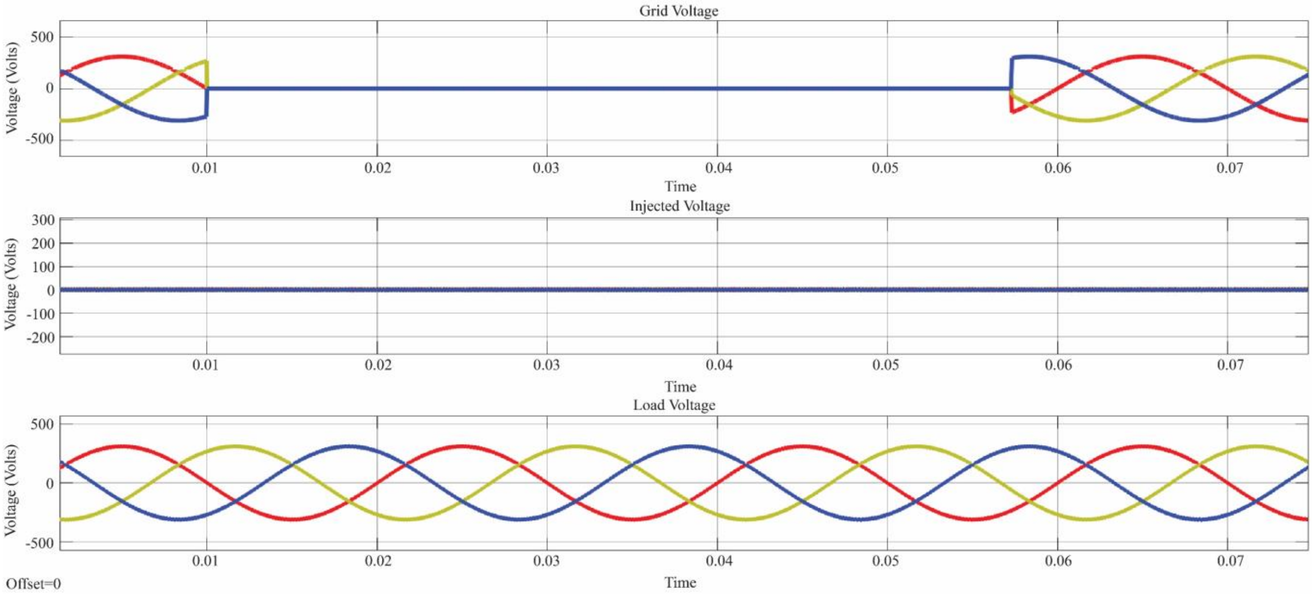

Fig. 8 Voltage waveforms during the islanded mode of operation.
(a) Supply voltage, (b) Voltage Injected, (c) Voltage a/c load.

5.2. Interconnected Mode

The distribution source supplies power towards the grid and loads depending on power availability so that the bidirectional flow will occur. One is the forward flow condition, and another is the reverse flow condition. In forward flow conditions, demand for the load is more than the DG power supply. Hence, DG will not be able to provide the load demand. Therefore, the remaining part of load demand is supplied utility. In Reverse flow mode, the demand of the load is less than the DG power supply. Hence, the utility and the storage system supply the extra power generated. So, it is called a reverse flow condition. In this condition, the grid current will be out of phase with respect to the PCC of the system. During normal conditions, UPQC will not provide any compensation; this condition is demonstrated in Figure 9. During any grid variation in terms of grid voltage variations like voltage sag, swell and harmonics, UPQC will provide the required component of voltage. Figrure-10 to 12 demonstrates the voltage sag, swell and harmonics in the grid voltage and corresponding UPQC compensation to keep the load voltage constant and distortion-free.

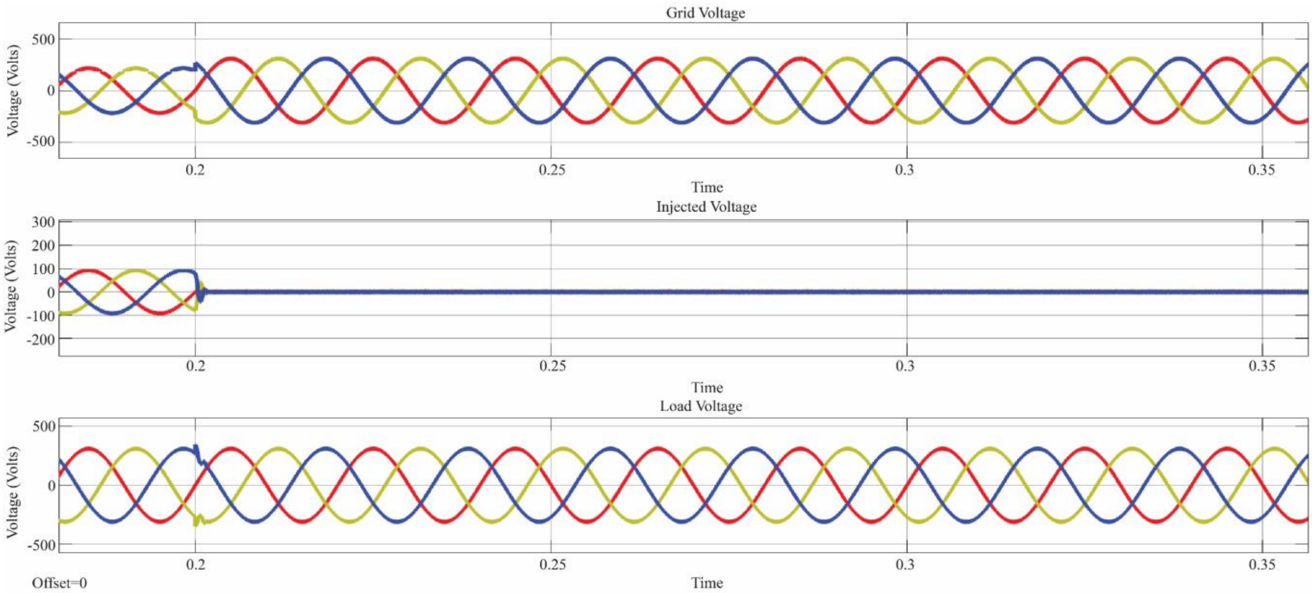

Fig. 9 Voltage waveforms during normal conditions.
(a) Supply voltage, (b) Voltage Injected, (c) Voltage a/c load.

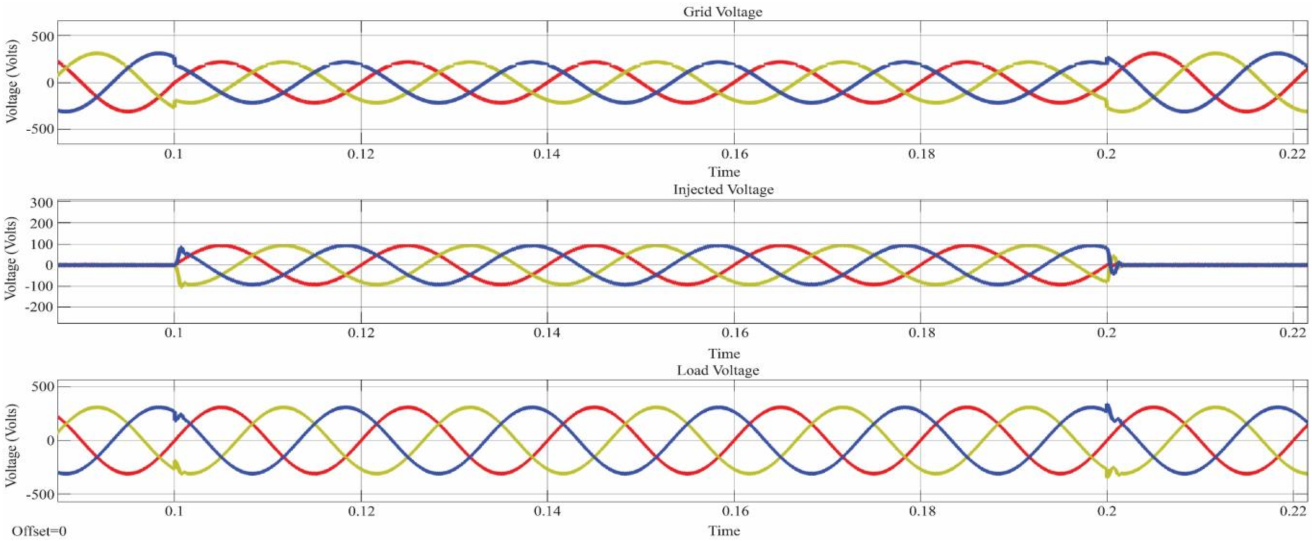

Fig. 10 Voltage waveforms during voltage sag
(a) Supply voltage, (b)Voltage Injected, (c) Voltage a/c load.

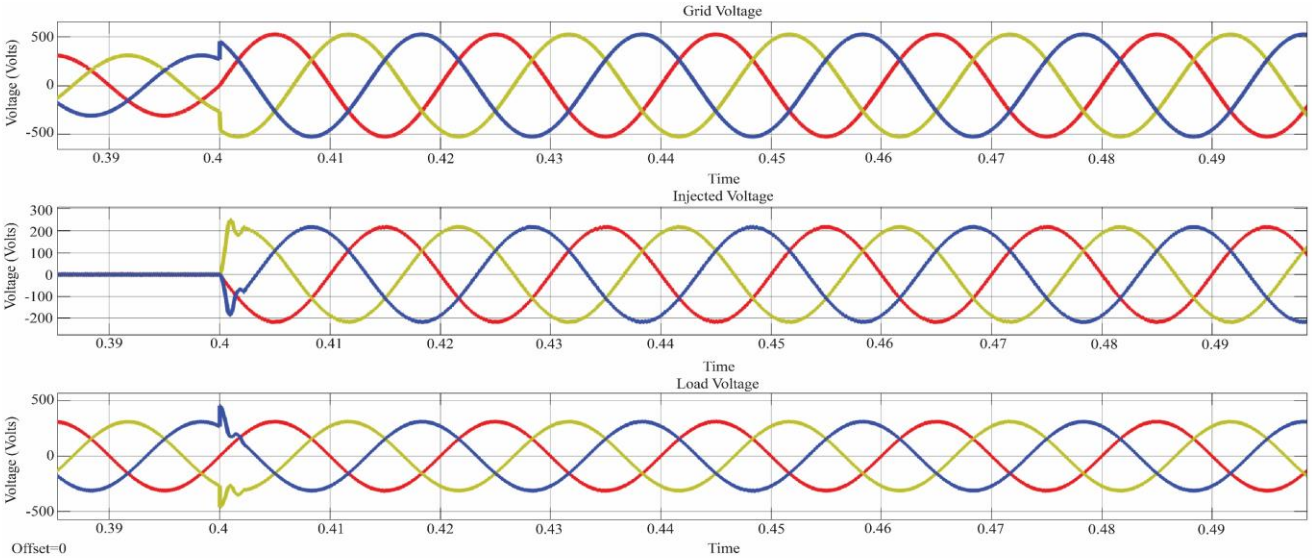

Fig. 11 Voltage waveforms during normal voltage swell
(a) Supply voltage, (b) Voltage Injected, (c) Voltage a/c load.

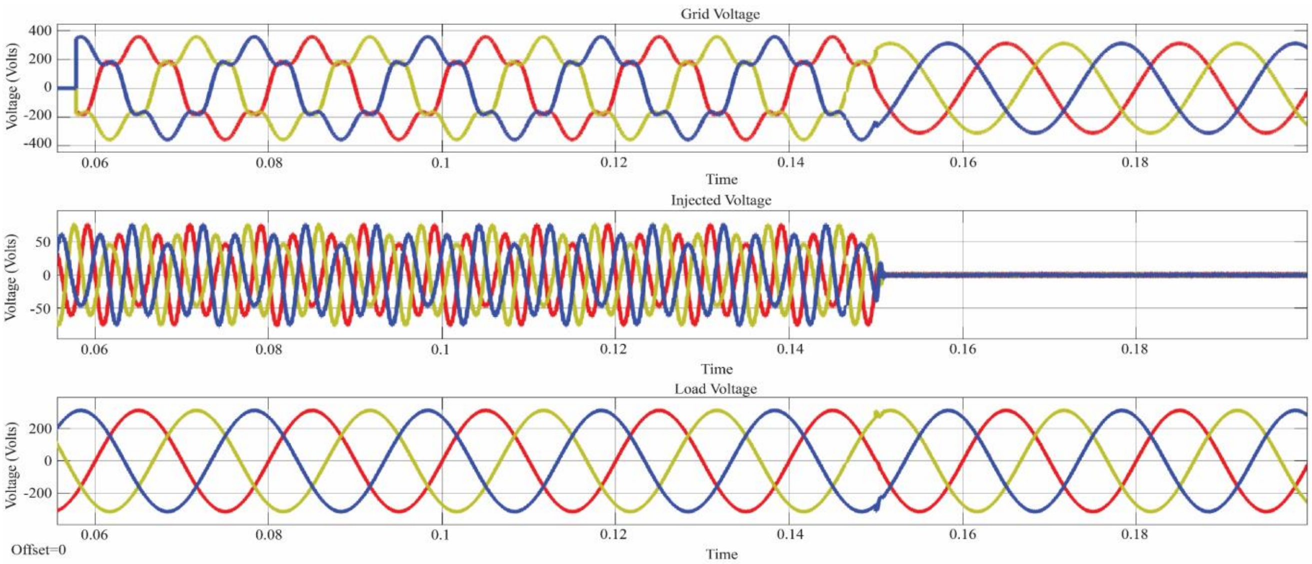

Fig. 12 Voltage waveforms during voltage harmonics
(a) Supply voltage, (b)injected voltage, (c)Load voltage.

6. Conclusion

The proposed MT-UPQCμG is the new integration and placement technique employed to solve the PQ issues in the Microgrid system. It operates in both grid-connected and islanded modes. The proposed method combines the advantages of both MT-UPQC and UPQCμG. It performs common fundamental functionality as the UPQC controller, with the exception of enhanced signal generation for islanding detection and reconnection capabilities. The main advantage of MT-UPQCμG is that it provides primary and secondary control (Level 1 and Level 2) for the Microgrid system. The simulation results are carried out for one load. The result shows that the proposed method is highly efficient and solves the PQ issues of the load.

References

[1] R. H. Lasseter, "Micro Grids," *IEEE Power Engineering Society Winter Meeting. Conference Proceedings*, pp. 305-308, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[2] R. V. D. Rama Rao, and S. Pragaspathy, "Enhancement of Electric Power Quality Using UPQC with Adaptive Neural Network Model Predictive Control," *2022 IEEE International Conference on Electronics and Renewable Systems*, pp. 233-238, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Ch. Phani Kumar et al., "Power Quality Improvement for a Hybrid Renewable Farm Using UPQC," *2021 IEEE International Conference on Artificial Intelligence and Smart Systems*, pp. 1483-1488, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[4] Zhuo Wang et al., "Distributed Transaction Optimization for Multiple Microgrids in Grid-Connected and Islanded Modes," *IEEE 3rd Student Conference on Electrical Machines and Systems*, pp. 398-402, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[5] Md. Shafiuzzaman K. Khadem, Malabika Basu, and Michael F. Conlon, "UPQC for Power Quality Improvement in DG Integrated Smart Grid Network-A Review," *International Journal of Emerging Electric Power Systems*, vol. 13, no. 1, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[6] Shafiuzzaman K. Khadem, Malabika Basu, and Michael F. Conlon, "A New Placement and Integration Method of UPQC to Improve the Power Quality in DG Network," *48th International Universities Power Engineering Conference*, pp. 1-6, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[7] Yunhao Zhao et al., "Design and Simulation of Multiple Terminal Unified Power Quality Conditioner," *IEEE Grenoble Conference*, pp. 1-6, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[8] Vinod Khadkikar, "Enhancing Electrical Power Quality Using UPQC: A Comprehensive Overview," *IEEE Transaction on Power Electronics*, vol. 27, no. 5, pp. 2284-2297, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[9] B. Han et al., "Combined Operation of Unified Power-Quality Conditioner with Distributed Generation," *IEEE Trans on Power Delivery*, vol. 21, no. 1, pp. 330-338, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[10] K. B. Veeresha, and A. H. Thejaswi, "Power System Faults Mitigation Using Generalized Unified Power Quality Conditioner," *SSRG International Journal of Electrical and Electronics Engineering*, vol. 7, no. 10, pp. 16-21, 2020. [CrossRef] [Publisher Link]

[11] Mojtaba Abbasi, Alexander G. Garganeev, and Ari Abdulla Rahim, "Control Strategies and Simulation of a Hybrid-Microgrid in Grid-Connected and Islanded Modes," *IEEE 61th International Scientific Conference on Power and Electrical Engineering of Riga Technical University*, pp. 1-5, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[12] Ankush Sharma, and Ashwani Kumar, "Optimal Location of UPQC in Fourteen Bus Distribution Network for Power Quality Improvement," *International Conference on Renewable Energy Integration into Smart Grids: A Multidisciplinary Approach to Technology Modelling and Simulation*, pp. 105-110, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[13] Remus Teodorescu, Marco Liserre, and Pedro Rodriguez, *Grid Converters for Photovoltaic and Wind Power Systems*, 1st Edition, Wiley, 2011. [Google Scholar] [Publisher Link]