Renewable Energy Based Grid System Using UPQC for PQ Improvement

K Murugan¹*, B Guruprasad², Varatharaju Perumal³, and T G Arul⁴
¹Department of Mechanical Engineering, Government Polytechnic College, Thiruvarur, Tamil Nadu, India.
²Department of Mechanical Engineering, Alagappa Chettiar Government College of Engineering and Technology, Karaikudi, Tamil Nadu, India.
³Department of Automotive Technology, Federal Technical and Vocational Education and Training Institute, Ethiopia.
⁴Department of Mechanical Engineering, St.Mary's Engineering College, Hyderabad, Telangana, India.
Email: murugan.thermal@gmail.com¹*, tellprasadcdm@gmail.com², varatharaju_p@yahoo.co³, tgarul5776@gmail.com⁴

Abstract: This paper proposes the grid-connected renewable energy sources (RES) based power quality (PQ) improvement is accomplished using the power compensation device of a unified power quality conditioner (UPQC). In recent days, power quality improvement is essential to the grid system and connected sensitive loads. The photovoltaic (PV) system is utilized to the power provision for the UPQC device through a boost converter which improves the DC link voltage with pulse width modulation control. The inverters in the UPQC device are controlled using the model predictive controller (MPC), improving the voltage and power compensation. The proposed system results are validated using the MATLAB/Simulink environment.

Keywords: UPQC, boost converter, RES, PV system, Model predictive controller, DC link voltage improvement.

1. Introduction
The compensation devices of traditional systems have a low performance, leading to developing advanced technology for power quality issues compensation devices based on the power electronics components. The characteristic changes in the load connected with the power systems result from technology development and increasing the electricity demand that introduces power quality problems.

The power generation uses renewable energy sources, an excellent solution for the conventional power system energy generation that uses fossil fuels as the major source [1-3]. Normally, the inconsistent supply is obtained from renewable sources such as wind, solar, etc. To give a solution for this problem is the energy management system (EMS), which is utilized in that the battery or supercapacitor with the bidirectional power flow converter which is performing both power flow directions of forward and reversed. The bidirectional power flow operation is accomplished in between the power lines to the EMS system, which is used for backup energy storage. The EMS system is charged while the power available from the wind system extensively [4-8]. When the power supply availability is not sufficient, the EMS's energy flows to the power line that is battery charging. The bidirectional converter is simple to design and performs the power flow in both directions. The
energy access shortage is rectified using the renewable-based grid system, which is a key solution for providing the neediness of end energy [9-12]. The grid system consists of various integration of the renewable source that generates electricity and power converters to control the power conversion for power demands in the distribution networks and control the power network for achieving stable power supply [13-15].

In this paper, the renewable energy systems that integrated with the grid system-based UPQC system are proposed to mitigate the PQ issues in the distribution network and mitigate the equipment failures. The DC link voltage is maintained perfectly by using the boost converter, which is achieving high energy gain from the PV system. The MPC controller is used for the control of the switching signal in the UPQC system.

2. Proposed System
In this system as shown in fig.1 the UPQC system is used to compensate for the RES-based grid system's PQ issues, which is integrated with the sensitive loads. The grid integrated renewable energy sources are used in power systems for energy distribution and the unified power quality conditioner (UPQC).

![Diagram of the proposed system of grid integration of RES based block diagram](image)

3. Boost Converter
The purpose of DC-DC converters is to regulate the converter's output voltage that is the source supply is extracted to high power for providing a grid-connected inverter system. The ripples in the PV current are rectified using inductor in the boost converter.

The boost converter consists of a single diode, power semiconductor components, MOSFET and dc-link capacitor, and inductor. The circuit diagram of the DC-DC boost converter is shown in fig. 2.
4. MPC Controller
The UPQC compensates the power quality issues in the distribution network that link with renewable energy sources. This proposed power compensation device is controlled by MPC control. The main merit of the proposed control method has low power loss. It is suited for loads that are not affected by discrete switching. The model predictive control is determined as continuous optimization or integer problem-based methods. The MPC control is presented for the complex functions, and the computational cost is low. It performs the optimization offline for all parts or certain parts because of this event; the long predictions have achieved the addressing using MPC control as shown in fig.3.

5. Proposed System Results
The PQ issues are reduced and compensated by using the FACTS devices such as UPQC, DVR etc. In this proposed system, the UPQC device is utilized to compensate for the distribution network’s power issues. The overall Simulink model is illustrated in fig. 4, and the voltage compensation and load voltage are shown in fig. 5. The inverter is used to compensate for the sag voltage, which is controlled through the MPC control. The current compensation and DC link voltage are shown in fig.6.
The PV system is integrated with the UPQC power compensating device to maintain the DC link voltage constant for providing power supply to both shunt and series inverters of the proposed system. The input PV voltage is improved by the power converter of the boost converter to achieve high voltage gain.

**Figure 4:** Simulink model of the proposed system

**Figure 5:** proposed UPQC with ESS system voltage sag, injected voltage, and load voltage
6. Conclusion
In this paper, the power quality issues are controlled and compensated by the proposed system of predictive model controller-based UPQC, providing a stable power supply to sensitive loads connected with a grid system. The DC link voltage is enhanced using a step-up converter, which is a direct-to-constant maintenance. The power compensated done in shunt and series converter compensation, and trough this compensation achievement the PQ issues are mitigated. The results are verified and obtained by using in MATLAB/Simulink.

References
[1] Samal, S., & Hota, P. K. (2018). Wind Energy Fed UPQC System for Power Quality Improvement. *Bulletin of Electrical Engineering and Informatics*, 7(3), 495-504.
[2] Tien, D. V., Gono, R., & Leonowicz, Z. (2018). A multifunctional dynamic voltage restorer for power quality improvement. *Energies*, 11(6), 1351.
[3] Galma G., Pattanaik B. (2019). Current fed switched inverter using sliding mode controller (SMC) for grid application. *International Journal of MC Square Scientific Research*. 11(4), 34-43.
[4] Kadam, P. H. (2019). Review of Power Quality Problem Improvement by Integration of Solar PV Panel and DFIG Wind Farm System with UPQC.
[5] Sumithra, M., & Sujatha, B. C. (2020). Enhancement of Power Quality by the Combination of D-STATCOM and UPQC in Grid Connected to Wind Turbine System. In *Innovations in Electrical and Electronics Engineering* (pp. 173-180). Springer, Singapore.
[6] Manogna, K., Tejaswi, P., & Sujatha, G. (2019, November). Sag and Swell mitigation and Power quality improvement in grid connected hybrid system using UPQC. In *Journal of Physics: Conference Series* (Vol. 1362, No. 1, p. 012075). IOP Publishing.
[7] Wang, S., Janabi, A., & Wang, B. (2020, October). Generalized Optimal SVPWM for the Switched-Capacitor Voltage Boost Converter, *ECCE*, (pp. 2708-2711). IEEE.
[8] Gibbons M. S., Gilbert C. L, Deshpande M. S., (2019 May 2), inventors; Lear Corp, assignee. Methodology of maximizing charging power transfer for electric vehicle when ac voltage sags. *United States patent application US 15/801,772*.
[9] Anitha, S., Keerthana, A., Kaviya, S. and JayaRajan, R., 2017. QUADRIPLEGIC AMBULATING ADDENDUM. *International Journal of MC Square Scientific Research*, 9(2), pp.15-23.
[10] Anjana, R. (2019, Feb). Fuzzy and PI Based Speed Control of BLDC Motor using Bidirectional Converter for Electric Vehicle Application. *Trends in Electrical Engineering*, 8(3), 35-45.

[11] Yadav, D., Parekh, U., Patel, K., Parmar, R., & Prakash, M. (2019). Application of Modified Three Phase Conduction Method to Minimize Torque Ripple in BLDC Motor. *IJRAR*, vol. 6(1), 155-156.

[12] Rajkumar, S., Sundaram, C. S., Sedhuraman, K., & Muruganandhan, D. (2019, March). Performance Analysis of Hub BLDC Motor Using Finite Element Analysis. In *2019 ICSCAN*, (pp. 1-5). IEEE.

[13] Gibbons, M. S., Gilbert, C. L., & Deshpande, M. S. (2019). *U.S. Patent Application No. 15/801,772*.

[14] Nasiriani, K., & Pasandi, M. (2020). Dynamic Voltage Restorer (DVR) For Protecting Hybrid Grids. arXiv preprint arXiv:2006.16452.

[15] Swain, P., Panigrahi, B. K., Dalai, R. P., Mohnaty, J., Medinray, S. S., & Ray, S. P. (2019, May). Mitigation of Voltage Sag And Voltage Swell By Dynamic Voltage Restorer. In *2019 International Conference on Intelligent Computing and Control Systems (ICCS)* (pp. 485-490). IEEE.