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PRc-PID with Teaching Learning Based Optimization Algorithm (TLBO) Based UPQC to Improve Power Quality in Standalone Microgrid

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ABSTRACT- Isolated microgrids (MG) have become increasingly popular due to their enhanced adaptability in addressing customer needs, but pollution has also increased as a result. When integrating renewable energy sources with different loads, the MG will experience increased power quality (PQ) issues. Reducing MG's PQ problems is the main objective of this paper. PQ problems can be resolved with the help of the system's Unified PQ Conditioner (UPQC) device. UPQC performance is improved by integrating PRc-PID with a Teaching Learning Optimization Algorithm-based controller in series with a shunt active power filter to lessen current and voltage PQ issues. Solar cells and wind turbines are all proposed for a separate MG. To ensure the optimal supply to the converter, UPQC shunt and series regulators use an integrated proportional resonant cascaded proportional-integral-derivative (PRc-PID) controller. PQ issues like current and voltage are fixed by a control process to improve MG's steady and reliable operation. The Simulink platform is used to implement the proposed work. Three different scenarios are used to confirm the efficacy of the proposed method. The total harmonic distortion (THD) of the proposed method is 10.56%. Investigations are conducted into harmonics and other PQ issues, including swell and SAG.

Keywords: Power quality, Microgrid, PI controller, Unified Power Quality Conditioner, PRc-PID controller, Teaching Learning Optimization Algorithm, Active Power Filters.

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1. INTRODUCTION

Conventional power systems have faced several problems related to power generation and environmental concerns. The balance between driving factors and requirements varies by application. MG is the basic element that plays an important role in the integration of renewable energy sources (RES) [1, 2]. Due to its numerous benefits, the energy system is continuously evolving to bring benefits in multiple areas. Regardless of system variations, the MG components should be in the optimal range [3]. The MG can be controlled via three strategies, primary, secondary and tertiary controls, and each is used to control the source, modes of operation and coordination. It should be noted that the operation of MG can be monitored by the primary and secondary control systems, while the tertiary control is on the utility grid. As a result, MG offers greater flexibility to the distribution network by meeting consumer demand. This resulted in the MG technology for regional power supply [4].

The MG is connected to the utility grid under normal conditions and disconnected under faulty conditions. However, both modes of operation should be operated within a specific range. The MG is connected to the utility grid through the power electronic converters, which are also important for RES integration. However, the higher switching frequency in these devices may destroy the PQ in the system [5]. The quality of power is defined based on the frequency and magnitude of the voltage in a specified range with non-oscillating signals. The increasing demand for reliable operation of power grids has increased the demand for higher PQ. While integrated Distributed Generation (DG) sources have several advantages, they also cause power quality problems in the MG power distribution network [6]. Due to the merging of innovative Power Electronics (PE) converter technology with Renewable Energy (RE) sources' intermittent nature, Power Quality (PQ) issues occur. Additionally, it appears that the existence of nonlinear and unbalanced loads in MG affects the PQ of the energy supply in the power distribution network. Overvoltage, flickers, loss of power factor (PF), and harmonic distortion of current and voltage are some of the PQ issues that can arise with grid-connected photovoltaic (PV) systems. Used power conditioning interface units or low load situations are common causes of harmonic distortion in these systems. In grid-connected wind energy systems, power quality (PQ) issues include harmonics and inter-harmonics, voltage variations (sags and swells), and disruptions [7].

In [11], the voltage is regulated by a fuzzy PID, in which the control gains are chosen by the modified slimmed algorithm (MSMA). One of the main issues with the current power system is the power quality. Power quality problems are mostly caused by synchronization errors, voltage imbalances, modifications to the appliances that make up the load, and harmonic impacts. Although several compensating devices are implemented, interline unified power quality conditioners are crucial for enhancing power quality in multi-feeder microgrid-based power systems. UPQC is a combination of two converters series and shunt converters connected back-to-back. In addition, parallel active power filters (PAPF) and series active power filters (SAPF) are widely used to cancel current and voltage harmonics due to non-linear loads [12]. Therefore, the combination of SAPF and PAPF is an effective way to improve system operation, leading to UPQC [13]. At the same time, the compensation of UPQC is an important research topic in both PQ and energy management. More attention is paid to the unified PQ conditioners (UPQC) to alleviate the PQ problems in the distribution network [14, 15]. The UPQC has recently been improved with the addition of an additional controller to enable better operation [16]. In addition, it has been extended in the medical field to solve PQ deformation. UPQC's shunt and series compensators are used to reduce the PQ issues in voltage and current waveforms [17, 18]. In line with these approaches, several approaches based on optimization algorithms are implemented in the hybrid AC-DC MG to optimize the control gains. The biogeography-based optimization is used with the UPQC in a hybrid solar-wind connected energy system to solve the PQ problems [19]. Several methods for solving the problems of unbalanced voltage and frequency are presented in the literature. It is quite difficult to meet the PQ requirements in load variation and fault conditions in multiple DG connected systems [20].

However, local optimal trapping can occur with the above methods. The main objectives of the proposed designs are listed below:
To enhance the power generation by adding solar, wind turbine, tidal and fuel cell distributive generations in the power system. TLBO based PRc-PID controller strategy is developed on the UPQC device to reduce the PQ failures and load requirement. Improving the PQ by controlling the harmonics, voltage deviation, sag and swell in the presence of system uncertainties. Enable the smooth operation under applying fault conditions.

The rest of this paper is organized as follows; *Section 2* elaborates on the detailed standalone MG with renewable energy method, UPQC device, controller and optimization method used in this method. The various simulation result comparison is explained in *section 3*. The conclusion of this method is in *section 4*.

2. MATERIALS AND METHODS

The RESs and DG naturally lead to MG consisting of generation, storage and loads. Load is a decentralized power system that can operate without the support of a large power system. Future infrastructure could consist of a significant number of interconnected MGs, each containing renewable energy sources and storage devices. A standalone MG system has multiple power inputs, uncertain optimal scheduling, flexible system structure, and multiple power reliability requirements. This undoubtedly makes modelling and solving the optimal scheduling problem more difficult. The proposed block diagram for a standalone MG is shown in *figure1*.

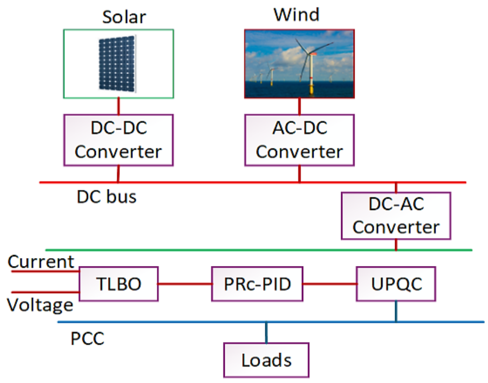

Figure 1. Block diagram for standalone microgrid

In this work, gird was divided into three parts source, converter and PQ issues solver methods. Initially, renewable energy sources were based on hydro, solar, wind and fuel cells. The voltages from these energy sources are converted to DC voltages using converters and then connected to the DC bus. Inverter is used to convert DC power to AC power and fed this AC power to the UPQC device. The implementing method is kept between the alternate current bus and the point of common coupling. Between these, a UPQC is connected to improve the PQ of the system. The PRc-PID controller is connected instead of series and shunt active filters, respectively. A Teaching Learning Optimization Algorithm is used to tune the controlling parameter.

2.1. Solar Cell

A solar cell is fundamentally a *p-n* junction fabricated on a thin semiconductor wafer. In solar energy, electromagnetic radiation can be converted directly into electricity via the photovoltaic effect. The output power of PV is given below:

$$P_{PV} = \eta_g N_{PV} A_m G_i \tag{1}$$

Where N_{PV} and η_g represent the PV modules number and generation efficiency. G_i and A_m indicates the total irradiance from the PV panel and the area of one module.

2.2.Wind Turbine

Wind turbine technology uses rotor blades to collect the kinetic energy of the wind as water flows. WT blades capture the wind's kinetic energy and convert it into mechanical

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energy. The numerical design of the wind turbine is crucial for determining its operation. The Mechanical power of this unit is:

$$P_W = \frac{1}{2}\rho C_P \pi R^2 V_W^3 \tag{2}$$

Where C_p represent the coefficient of performance, ρ is the air density, V_w indicates wind speed and R is the blade length.

2.3. Unified Power Quality Conditioner

A UPQC is a flexible tool that simultaneously reduces grid-side voltage disturbances and load-side current disturbances. The proposed MG system is built to operate loads using multiple feeders and linear loads. In UPQC, a custom power device connected between the feeders is used to mitigate the issues brought on by these various loads. *Figure 2* depicts the design of the interline UPQC. It has a series and shunt active power filter that are connected together by a common DC link. Shunt active power filters are reconnected backwards, and the dc-link is connected to a series of capacitors.

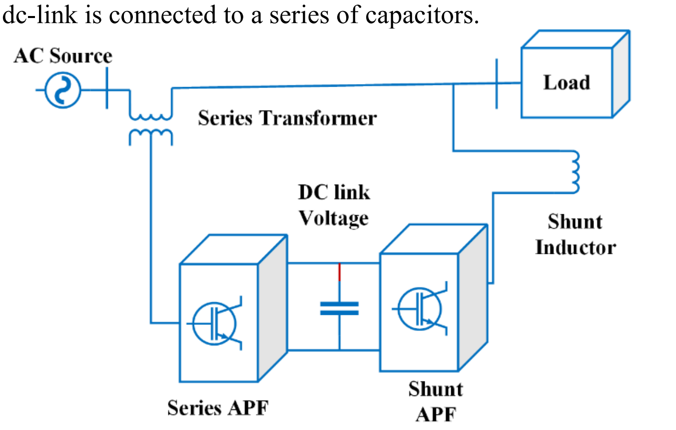

Figure 2. Line diagram of UPQC

Shunt converters are connected in parallel using the point of common coupling (PCC). Series filters are used as voltage sources, and shunt filters are used as current sources in UPQC arranged designs. UPQC can be used to overcome the PQ problems with current and voltage signals in standalone MG systems. The main objectives of a shunt converter are to reduce load current harmonics and to regulate dc-link voltage. There is no doubt that shunt converters are used on the supply side of renewable energy sources to correct voltage spikes and sags [26]. The series filter protects the system from voltage imbalances, flickering and other potential system threats while reducing harmonics at the transmission and distribution levels. In the event of a line fault caused by an excessive demand for reactive power or a voltage drop in the grid, the fixed speed induction generator will fail and lose connection to the grid. The implementation of UPQC can be the best result in the integration of the Renewable Energy System (RES) and the grid and protect the system from voltage imbalances. This voltage drop leads to the turbine over speeding and thus, to a protection trip.

2.3.1. Series Active Power Filter

This type of active power filter is designed to rectify voltages. The input to the control block is intended to calculate the instantaneous power PCC phase voltage with line current compensation of non-linear loads. Three-phase voltage $\left(V^{s(abc)}\right)$ was altered before the *d-q* coordinates were created in the series active power filter controller.

$$\begin{pmatrix} V^{s0} \\ V^{sd} \\ V^{sq} \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin(\omega t) & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{pmatrix} \times \begin{pmatrix} V^{sa} \\ V^{sb} \\ V^{sc} \end{pmatrix} \tag{3}$$

Three phase source voltage such as phase a, phase b, and phase *c* were described as V^{sa}, V^{sb} and V^{sc} respectively.V^{sq}, $V^{sd}$is denoted for the quadrature axis and direct voltage. The equation given below is used to find direct axis voltage.

$$V^{sd} = \hat{V}^{sd} + \overline{V^{sd}} \tag{4}$$

The below mentioned equation is used to compute the load voltage

$$\begin{pmatrix} VR^{la} \\ VR^{lb} \\ VR^{lc} \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \sin(\omega t) & \cos(\omega t) & 1 \\ \sin\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) & 1 \\ \sin\left(\omega t + \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) & 1 \end{pmatrix} \times \begin{pmatrix} \overline{V^{sd}} \\ 0 \\ 0 \end{pmatrix} \tag{5}$$

Voltage error is calculated by the *equation;*

$$E(V) = VR^{labc} - V^{sabc}$$

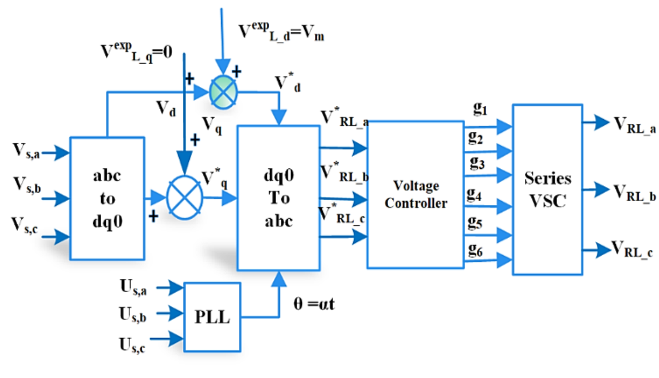

Figure 3. *Control diagram of Series APF*

2.3.2. Shunt Active Power Filter

A zero powered zero-sequence component is produced in a three-phase system without a neutral by using some of the oscillating active load current to supply the shunt power. The system's current harmonics are managed using the notion of instantaneous reactive power. Three-phase voltages and currents are translated using the coefficients α and β. The following formula determines active and reactive power:

$$\begin{pmatrix} P \\ Q \end{pmatrix} = \begin{pmatrix} V^{\alpha} & V^{\beta} \\ -V^{\beta} & V^{\alpha} \end{pmatrix}\begin{pmatrix} I^{\alpha} \\ I^{\beta} \end{pmatrix} \tag{6}$$

In α-β coordinates, the shunt APF reference current is

$$\begin{pmatrix} IR^{\alpha} \\ IR^{\beta} \end{pmatrix} = \frac{1}{V_{\alpha}^{2}+V_{\beta}^{2}} \begin{pmatrix} V_{\alpha} & V_{\beta} \\ -V_{\beta} & V_{\alpha} \end{pmatrix} \begin{pmatrix} \bar{p}\_P_0 + P_{loss} \\ 0 \end{pmatrix} \quad (7)$$

$$E(I) = IR^{sabc} - I^{labc} \quad (8)$$

$E(I)$ Used to compute the error current in the method. After comparing these reference source current signals, three-phase source currents are detected. A hysteresis band PWM controller processes the errors to produce the necessary switching signals for the shunt APF switches.

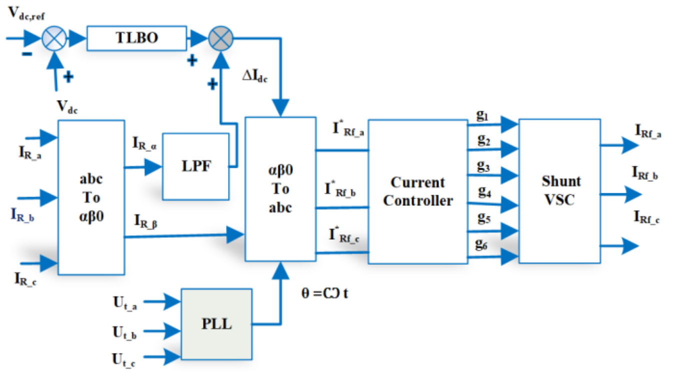

Figure 4. Control Diagram of shunt APF

2.4. PRc-PID controller

2.4.1. PR Controller

The ideal PR controller behaves like a network with an infinite quality factor, but it is a challenge to implement in practice. Initially, neither an analog nor a digital system can achieve the infinite quality factor produced by the PR controller's infinite gain. Finally, the gain of the PR controller decreases significantly at other frequencies.

$$G_S(S) = K_p + \frac{2K_i s}{s^2+\omega_0^2} \quad (9)$$

$$G_{PR}(s) = K_p + K_I \frac{2\omega_c s}{s^2+2\omega_c s+\omega_0^2} \quad (10)$$

Where, $G_{PR}(s)$ is the PR current controller, K_I is the integral gain term, K_p is the proportional gain term, $\omega_c$is the bandwidth around the frequency of ω_0 and ω_0 is the resonant frequency. *Equation (9)* illustrates an ideal PR controller, due to its stability gain, it may have stability issues. The PR controller can be rendered less than ideal in order to avoid these issues by introducing damping, as shown in *equation (10)*. The ac frequency $\omega_0$is finite with the gain of the PR controller in *equation (10)*. However, it is still big enough to provide only a minor steady-state error. Due to the finite precision of digital systems, this equation also makes the controller more easily realizable. When designing cascade controllers, the dynamics of the inner and outer loops must be separated. It is common for the inner loop to be faster than the outer. But it is insufficient to eliminate harmonic effects caused by grid voltages; therefore, PID is integrated with this controller.

2.5. Teaching Learning Based Optimization Algorithm (TLBO)

The metaheuristic optimization technique known as TLBO. The population size and maximum number of iterations are the only algorithm-specific parameters needed for this optimization algorithm. TLBO begins with a randomly generated population of possible solutions, just as other population-based algorithms. Next, the "Teacher Phase" and the "Learner Phase" comprise the two stages of the TLBO process. A teacher raises the mean level of students during the "Teacher Phase." A competent teacher raises the level of knowledge in the class by bringing the students up to speed with their own understanding. This isn't always the case in practice, though, as learners' abilities, efforts, and dedication to learning all play a role in determining their level. Therefore, the only thing a teacher can do is raise the mean level of their students. During the "Learner Phase," students gain more knowledge by collaborating with one another and with themselves. A student i engages in conversation with a randomly chosen student j. If another learner is more knowledgeable than the first, the first learner gains new information.

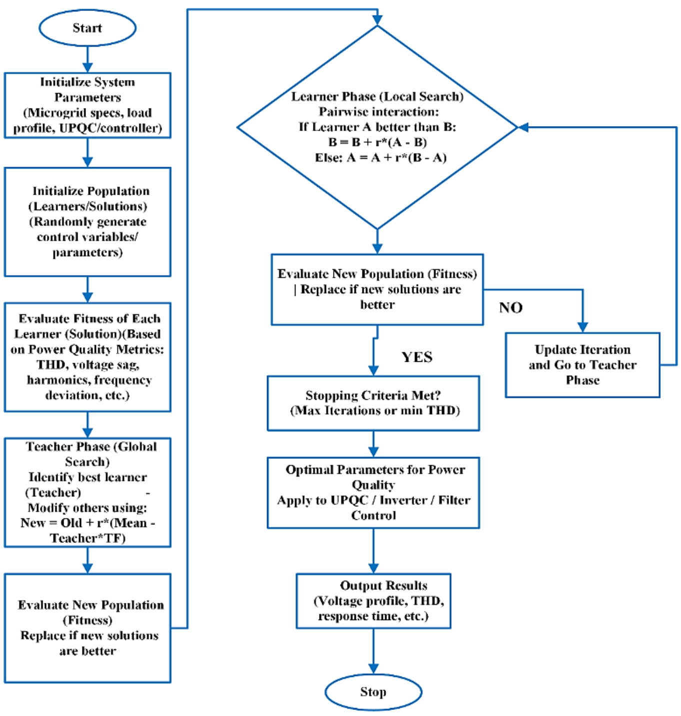

Figure 5. Flow chart of TLBO for proposed work

2.5.1. Pseudo Code

Each solution represents a set of control parameters in your microgrid (like inverter gain, reactive power, etc.).

The fitness (objective) could be:
*Fitness = w1*THD + w2*Voltage Deviation + w3*Unbalance*

The teacher phase makes every solution learn from the best one.

The learner phase lets solutions learn from each other.

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Finally, the best solution gives minimum distortion and better voltage quality.

3. SIMULATION RESULTS

In this section, various cases with results are discussed. Simulation is performed using the Simulink environment in order to validate the proposed method.

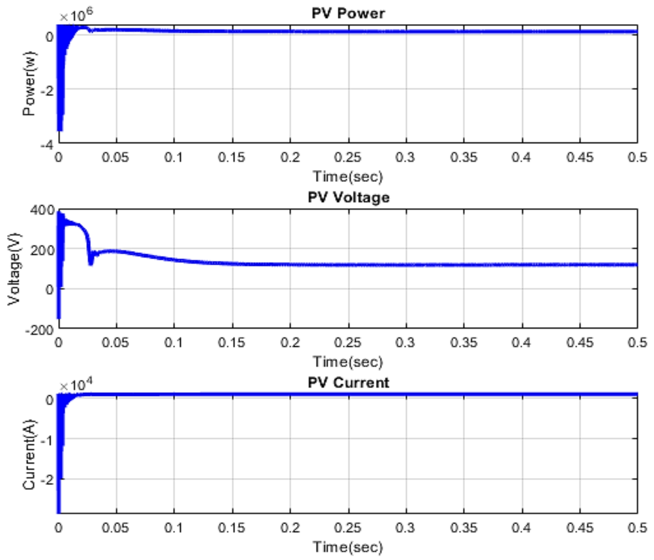

Figure 6. Results of PV panel

Due to this Voltage, current, and power output from a photovoltaic panel are displayed in *fig. 6*. Power from photovoltaic (PV) sources is depicted in this figure at 124 KW, voltage at 120V, and current at 1035A. The battery's findings were shown in *fig.7*, where the discharging voltage reached 162V in 0.05 seconds, the current reached 232A, and the state of charge decreased from 100 to 99.83.

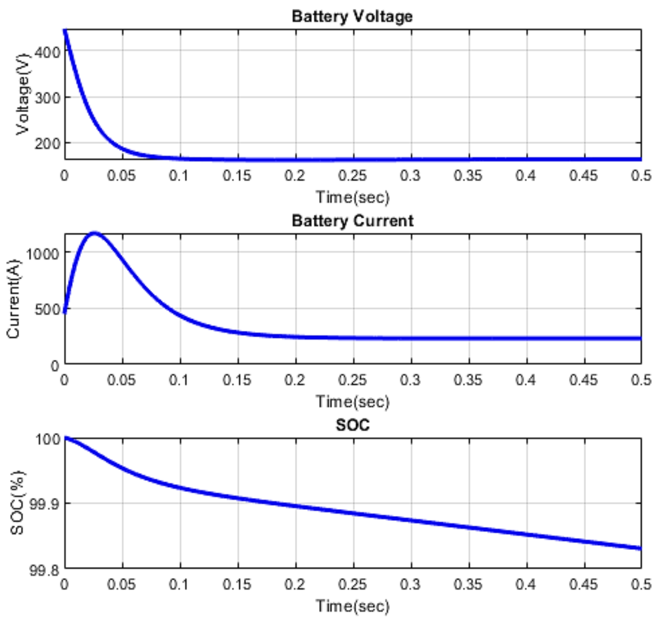

Figure 7. Results of Battery

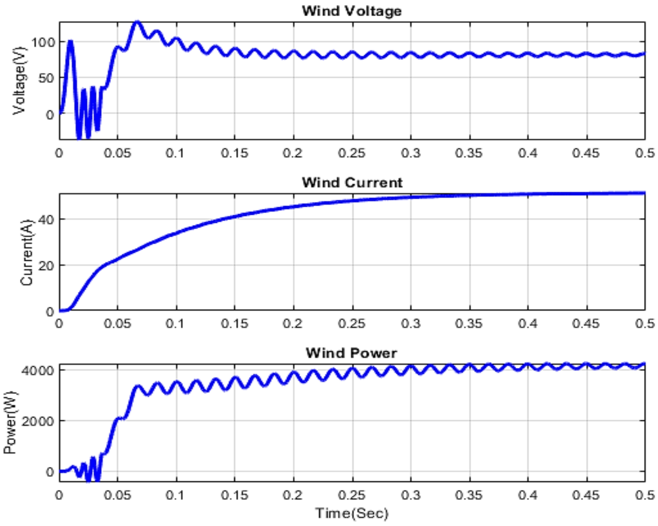

Figure 8. Outcomes of WT

With the WT voltage set at 85V, the battery current reached 51A, and the battery power reached 4335W, as shown in *fig.8*, the results of the WT were obtained.

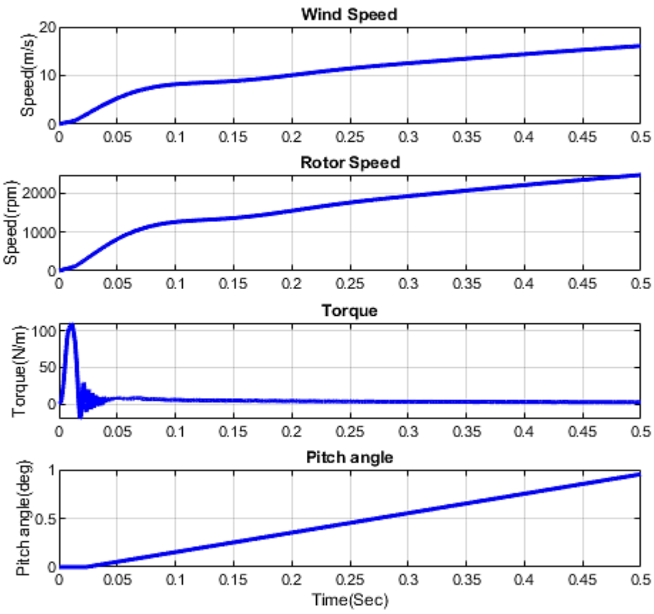

Figure 9. Outcomes of WT parameters

At a wind speed of 12 m/s, the WT parameters' outcomes were displayed in *fig. 9* with 2.8 Nm of torque and 2500 rpm selected, the pitch angle is 1 degree.

In this work, PQ problems are reduced by using controller and optimization methods. This work shows a PQ improvement by reducing the THD when applying the fault. The performance is assessed by measuring the current and voltage with waveforms that are injected, compensating and creating problems. By comparing the proposed controller with other controllers to show better performance. Different PQ issues like sag swell and harmonics are used to validate the proposed controller with optimization. In this work, PQ is measured in terms of comparing the THD under different cases, also

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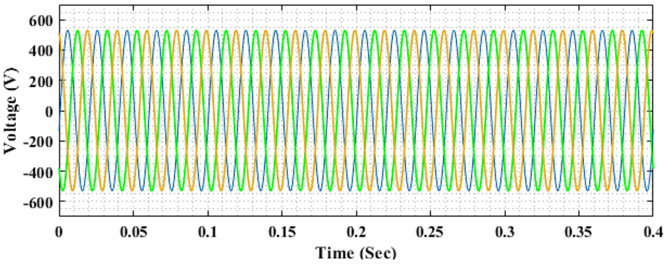
measured by occurred sag and swell while applying fault in the inputs. For high PQ, it also compares voltage readings between two accurate voltmeters measuring the same system voltage under different cases. Three instances are assessed to show the stability and reliability of the controller, which are tuned with optimization. Three cases are listed below:

- ***Case 1***: With PRc-PID controller
- ***Case 2***: With PRc-PID controller and Teaching Learning Based Optimization Algorithm (TLBO)
- ***Case 3***: PRc-PID controller and Teaching Learning Based Optimization Algorithm (TLBO) with fault

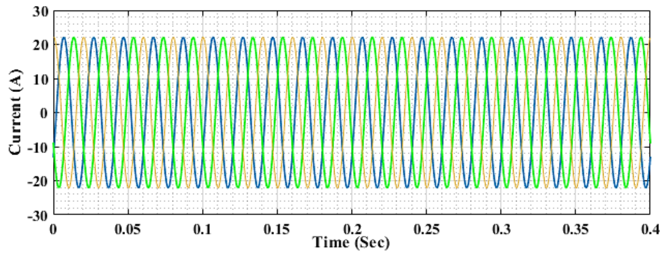
To evaluate the performance of the suggested technique, four different cases are used. In the first and second cases, PRc-PID controllers are utilized with optimization methods (without Fault), however in the third situation, PRc-PID controllers using TLBO algorithms (with Fault) are used. Finally, the fault is used in the suggested approach to testing its validity based on PQ concerns. By including disturbances in the proposed method, PQ characteristics are measured based on harmonics, sag and rise. The electricity required to meet demand is provided by PV and WT systems. These scenarios are detailed in detail below, along with a design presentation.

Case 1: With PRc-PID controller

In this case, the validation is performed with the PRc-PID controller. The source is kept the same as per case1. But in this section, the controller is changed instead of PI-PID to PRc-PID. The voltage and current quality are improved by this PRc-PID controller. The simulation results for current and voltage are shown in *figure 10*. The active power is increased from 10×10^4 to 2.5×10^5, and the reactive power is increased from 7×10^4 to 14×10^4as compared to case 1. *Figure 11* demonstrates this power in a graphical manner. The ratio of THD is analyzed to evolve the performance of this controller. With the PI-PID controller, get a THD of 23.60%, and it reduced to 22.11% in this case.

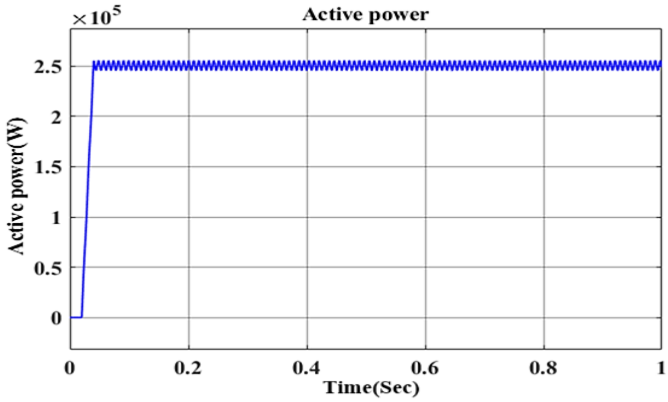


(a)



(b)

Figure 10. Simulation result for voltage and current with PRc-PID controller



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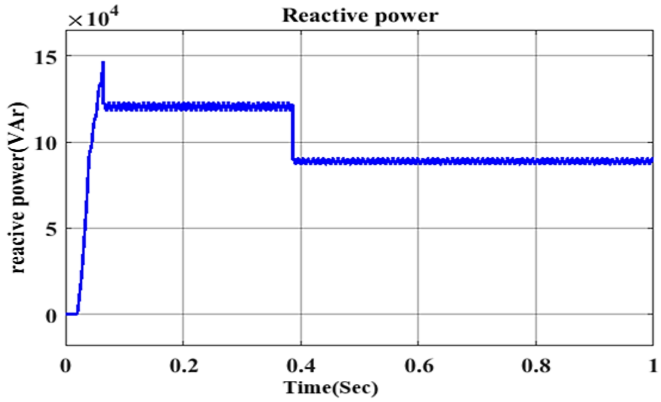
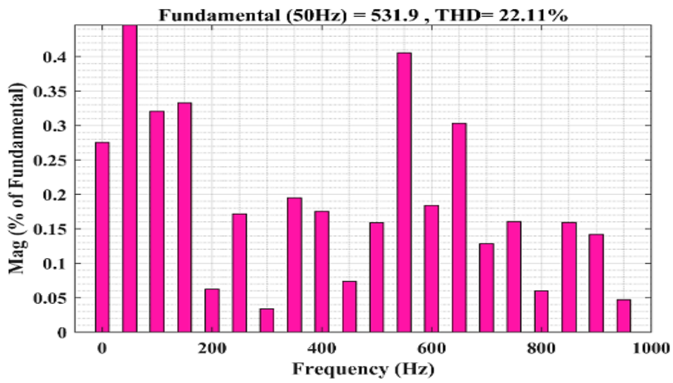


(b)

Figure 11. Active and reactive power with PRc-PID controller



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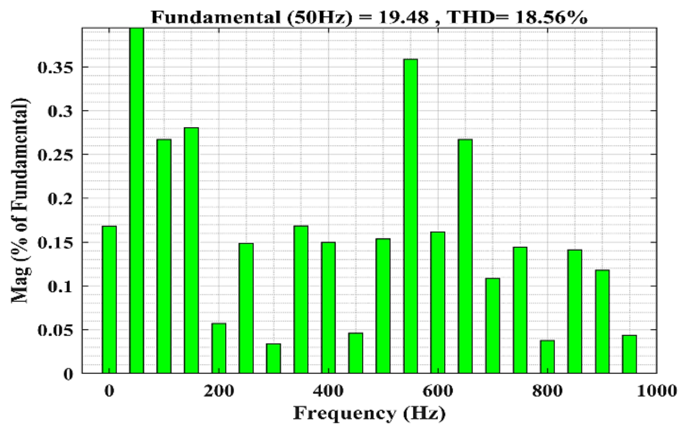

(b)

Figure 12. THD for current in case 1

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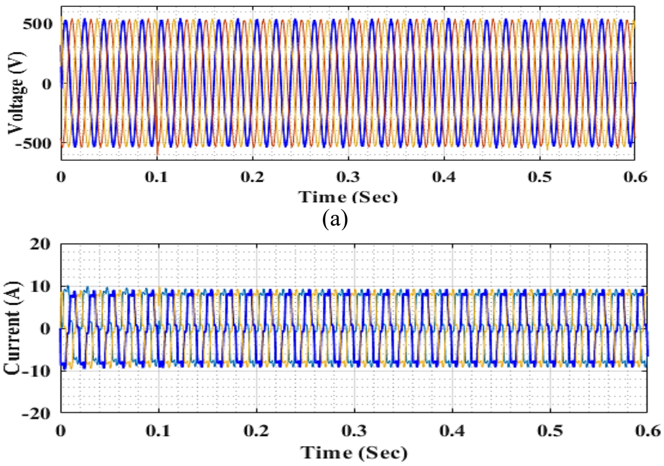
Fig. 12 demonstrates the THD value for voltage and current with the PRc-PID controller. This controller gives the output of THD as better than the PI-PID controller. Compared to the above case, it performs well. The active power is high, and the reactive power is high at the initial stage, but it falls within 0.4 sec. This controller is not much stable and reliable for PQ issues.

Case 2: With PRc-PID controller and TLBO algorithm

The proposed PRc-PID controller with TLBO is used to validate this section. The output of UPQC is given to the load. TLBO takes the input from the load, and this algorithm provides the input to the controller. This controller minimizes the harmonics and generates pulses with the help of pulse width modulation. The selected pulse is given to the series and shunt active power filters in the UPQC. The range for voltage is 500, shown in *fig. 13 (a)*, and the current is 10A, shown in *Fig. 13 (b)*, for the proposed method with optimization. The time needed to validate the performance is 1s, as for case 1 and case 2. *Fig. 15* shows the simulation output result for voltage and current for this case. The output of this case is best when compared to the case 1 and 2. *Fig. 14* represents the active and reactive power output for the proposed method. Active and reactive power is 3.8×10^5, and 2.3×10^5respectively, this power is very high when compared to case 1. PRc-PID controller with optimization provides better THD value than PRc-PID controller without optimization algorithm. THD for voltage and current is shown in *fig.15*.



(a)

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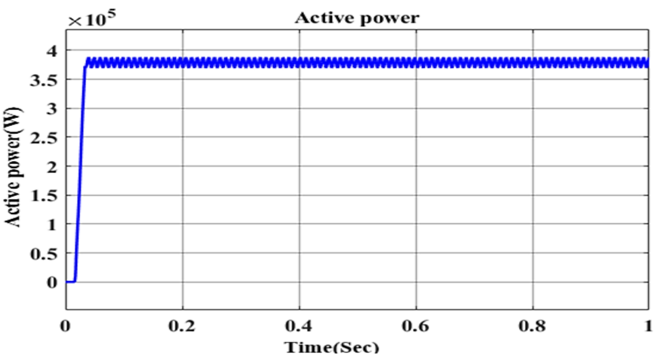
Figure 13. Simulation result for voltage and current with PRc-PID controller and TLBO



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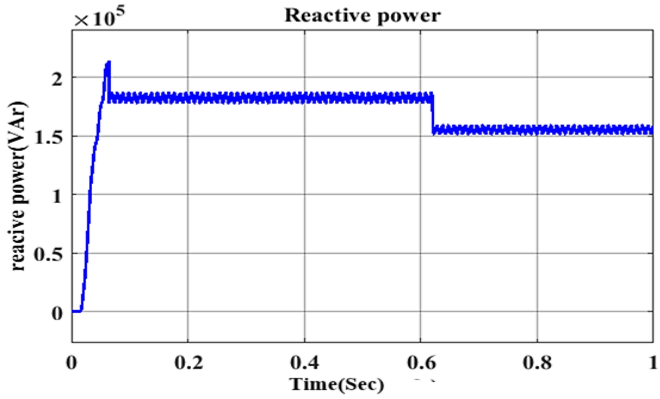
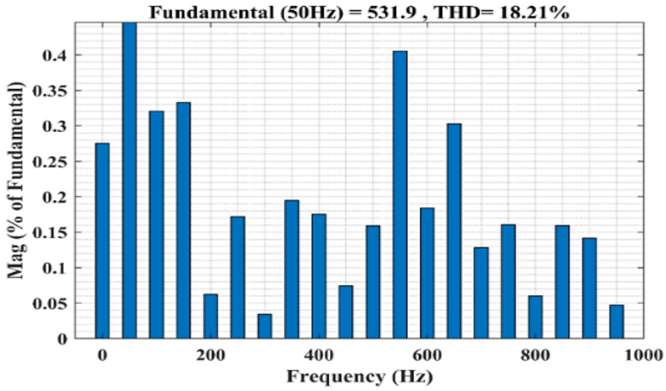
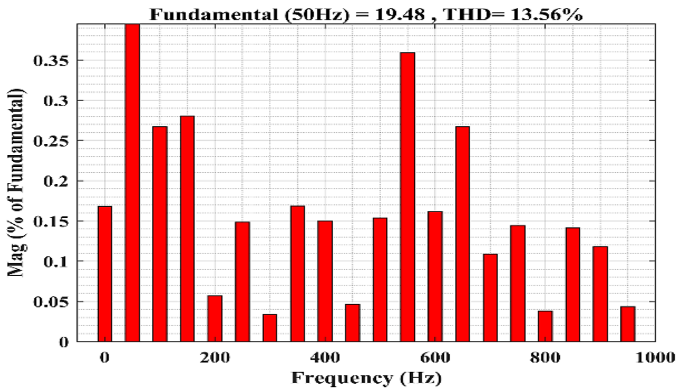


(b)

Figure 14. *Active and reactive power with PRc-PID Controller and TLBO*



(a)



(b)

Figure 15. THD for current in case 2

Case 3: PRc-PID controller and TLBO algorithm with fault

The validation for voltage and current sag is done by applying the fault in the load. Case 3 represents the enhancement of the PQ in this proposed method by applying fault. In order for the system to run reliably and consistently, the voltage drop needs to be fixed. PQ issues are sustained by using UPQC, and it provides the power required to meet the load. *Fig. 16* shows the sag generation in the signals of voltage. This sag is managed by the UPQC and proposed controller with optimization. The proposed method shows the voltage drop in standalone MGs. Voltage swell should be solved to run the system steadily and linearly.

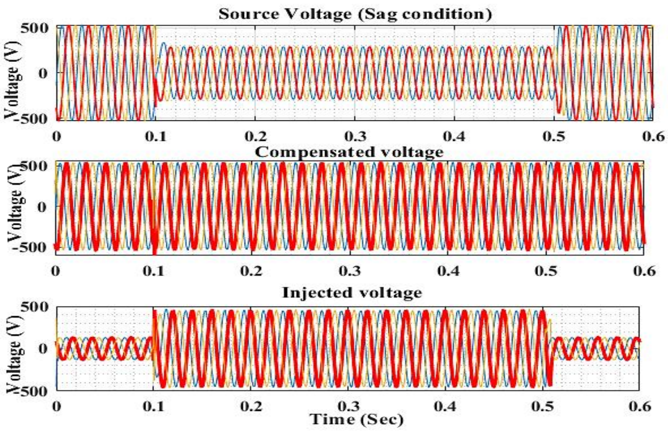


Figure 16. Analysis of voltage sag condition in standalone MG system

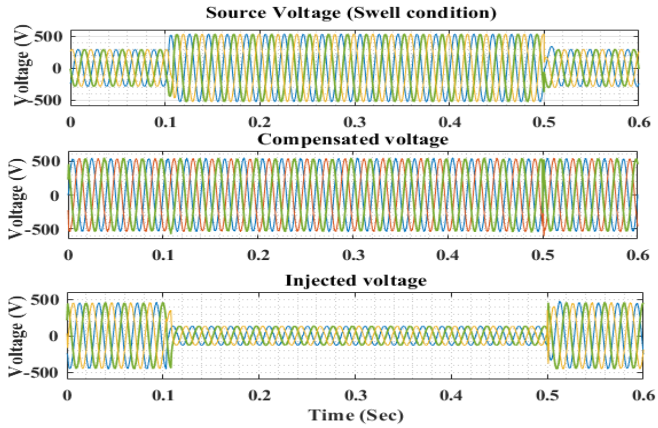
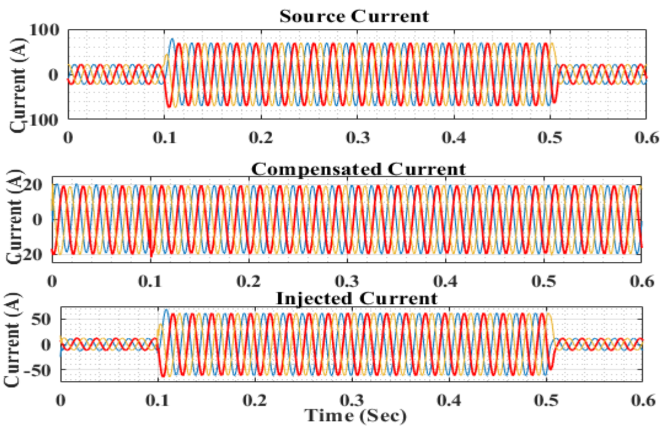


Figure 17. Analysis of voltage swells condition in standalone MG system

Figure 17 shows how the voltage swell evolved. By combining the suggested controller with an optimization technique, the mitigation is accomplished. The threshold conditions are uncontrollable due to power grid damage. When the reported voltage goes up or down by certain criteria, the program isolates the system. The active power filters receive the necessary power, and the suggested way decreases swell. This method's output is unaffected by this swell and sag situation. Therefore, PQ problems, such as voltage and current sags and bulges, are addressed using this technology.



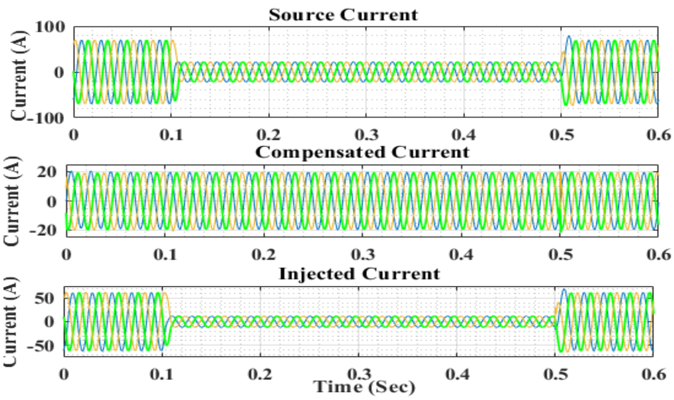


Figure 18. Simulation result for Current while applying the fault

Fig. 18 indicates the current after applying fault in the proposed method. But the current will not affect by these faults because of the proposed method with TLBO. Thus, the PQ enhancement is achieved by using this method. The THD of the proposed method is reduced to 10.56%, while without optimization method achieved 14.21% and 10.56%. UPQC and PRc-PID controller with optimization theory provide reliability and dependability of the system. The proper control pulses of shunt and series APF completely eliminate PQ concerns in a standalone microgrid system using the controller and algorithm. This method is used to reduce PQ issues, including disruption, interruption swell, harmonics, and sag. The suggested controller with optimization method can help by creating the right control pulses for series and shunt APF. It is used to reduce current and voltage oscillations in linked standalone microgrid systems. The PQ is measured using UPQC device with controller and optimization method. Output power with less harmonics represents the enhanced PQ. PQ is also measured by using applying fault in the input side, by this fault sag and swell may occurred. Proposed controller and optimization method connected with UPQC will prevent these flickering and generate the output voltage with no distortions.

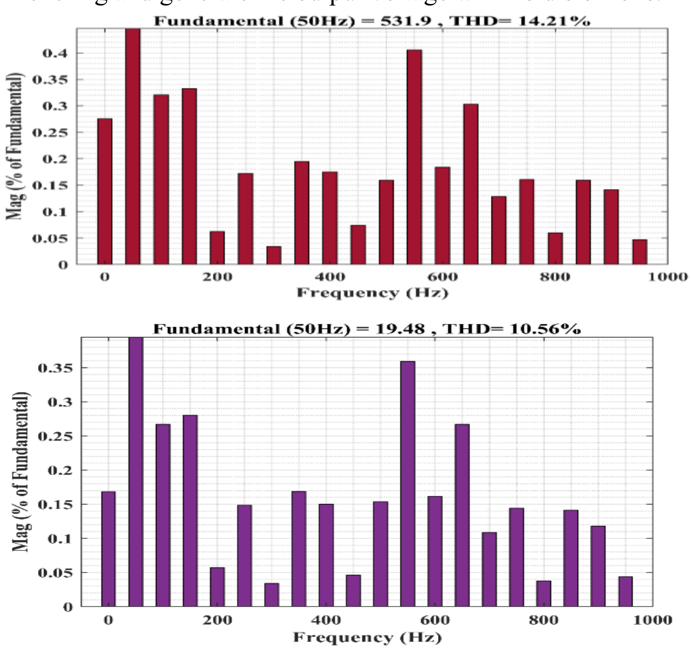


Figure 19. *THD for current in case 3*

Table 1. Comparison of THDs with Proposed Controllers

Controllers	THD for Voltage (%)	THD for Current (%)
With PI controller	**25.26**	**21.56**
PRc-PID Controller	22.11	18.56
PRc-PID with TLBO	18.21	13.56
PRc-PIDwith TLBO(Fault)	14.21	10.56

Table 2 shows the parameters utilized for standalone MG and TLBO implementation.

Table 2. Implementation Parameters

S. No	Description	Parameters	Values
1		Irradiance	1000
2	PV	Temperature	25 C
3		Generated power	50 KW
4		Base Torque	200/0.9 N/m
5		Base rotational speed	1.2 m/s
6	WT	Nominal mechanical output power	20 KW
7		Armature inductance	0.000835
8		Base wind speed	12 m/s
9		Number of iterations	100
10		Upper bond	100
11	TLBO	Lower bond	100
12		Number of Population	30
13		Dimension	30

4. CONCLUSION

For a standalone MG system, this research suggests TLBO based UPQC to minimize PQ problems. In the design of the freestanding MG are the WT and PV systems integrated. Renewable energy technologies are employed on the load side to meet the required demand. Concerns about power quality might affect the integration of renewable energy sources into linked load networks. To resolve PQ issues in MG, the UPQC with TLBO approach was employed. The PQ problem in the standalone MG can be improved using this suggested solution. By selecting optimal pulses, an algorithm based on TLBO enhances the PRc-PID controller's performance. Suggested controller testing for interruption, sag, sale, and disturbance PQ problems. The PRc-PID with TLBO controller, as well as PRc-PID controllers, underwent THD study. The suggested solution enhanced PQ and had a THD value of 10.56% when compared to the two controllers. Research indicates that the most effective method for reducing PQ is the UPQC system that incorporates TLBO and the PRc-PID controller. A more efficient system will be possible with three-phase UPQCs in the future thanks to clever control algorithms.

Conflicts of Interest: The authors declare no conflict of interest.

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