

Mitigation of power quality problems in independent micro-grid using intelligent controller based STATCOM

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ABSTRACT

A Reactive power divergence has created a major power quality issue in the micro grid system which in turn results in voltage fluctuation. This fluctuation has impact on both steady state and transient stability. Hence, this work is mainly developed to compensate the reactive power and to overcome the problems of maintaining a constant voltage profile of a micro grid system. Therefore, this study employs a fuzzy Controller along with a Static Synchronous Compensator (STATCOM). Thus the obtained result reveals that this proposed system maintains stability and power quality improvement in micro grids.

Keywords

STATCOM, FLC, Grid.

Introduction

The scarcity of fossil fuel has lead to the development of new energy infrastructure called “Smart Grid”. Thus the smart grid design is based on green energy technologies such as PV, wind, biomass, hydro etc. While, implementing this as an alternative energy generation, this will benefit in lower transmission losses and improved reliability. Instead of using an individual energy generation, the combination of two or more systems will yield better reliable power. As wind and solar are the more prominent sources, this work formulated a hybrid system using wind and solar.

However, the output of both the systems depends upon the environmental condition. So energy back up should be implemented to increase the security level of energy available. Hence, Battery/ Fuel Cell can be employed as a storage device. Thus, the designed microgrid can be operated in either grid connected / islanded mode.

Apart from this pollution free environment, microgrid can create power quality problems due to its random output nature. In a standalone system, when the load is changed, the voltage profile of the system gets affected owing to power variations. If Non-linear loads are introduced, current harmonics are injected into the system. Thus these power quality issues can be eliminated by introducing a filter combination or by FACTS devices.

Conventional LC filter technique utilized for power quality issue results in resonance with the impedance of the system [3]. Hence, STATCOM can be incorporated to mitigate power quality issues in MG. It can either absorb / inject reactive power into the network. This regulates power flow and improves power quality aspects of the system. Simultaneously, it will remove the stress imposed by wind energy generator also [4]. In order to regulate the operation of STATCOM, controllers are implemented. As the PI controller exhibits wide range of stability margin, they are not suitable for nonlinear variations of microgrid [11, 12]. Hence, various controllers were used for smooth operation of STATCOM. Icos ϕ controller was introduced to reduce

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power quality problems in a hybrid power system connected to grid [5]. Fuzzy and PI controller was introduced for STATCOM and their performances were studied over PV-Wind-Diesel-BESS based hybrid energy system [7]. Battery energy source (BESS) in conjunction with static compensator was proposed [8] to mitigate power quality related problems [9]. The performance analysis of hybrid wind-diesel system with FPID and ANFIS-PID controller based STATCOM was investigated [10,15, 16]. However, no standard method is available for rule base formation. Hence, the membership functions have to be tuned properly to minimize the error. Hence, to disregard the limitations of conventional and AI controllers, a AI controller called FIS controller is proposed in this work. FIS controllers are easy to implement [17, 18, 21].

Thus in this work, a hybrid RES which comprises PV and wind system along with battery backup is modeled. Here, the reactive power compensation is carried using fuzzy controlled STATCOM.

Solar PV system

System description

The equivalent circuit PV cell (figure 1) is made of semiconductor materials which converts incident solar light energy into electrical energy.

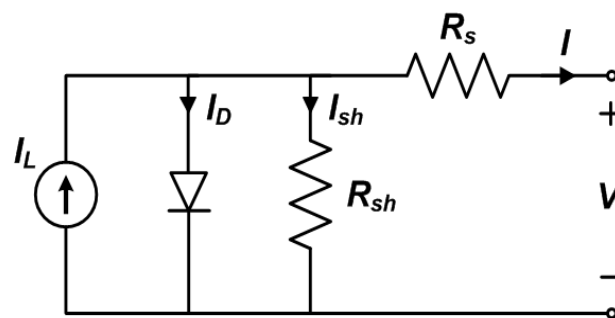


Figure 1: Solar cell -Model

The current /voltage characteristic of PV cell can be expressed as

$$I = I_L - I_0 \exp\left(\frac{V + IR_s}{nV_T} - 1\right) - \frac{V + IR_s}{R_{sh}} \quad (1)$$

Where

I and V - Current and Voltage of solar panel.

$I_L = N_p I_{L \text{ cell}}$,

N_p - Number of parallel cells.

Figure 2 depicts the IV / PV characteristics of the PV array utilized in this work.

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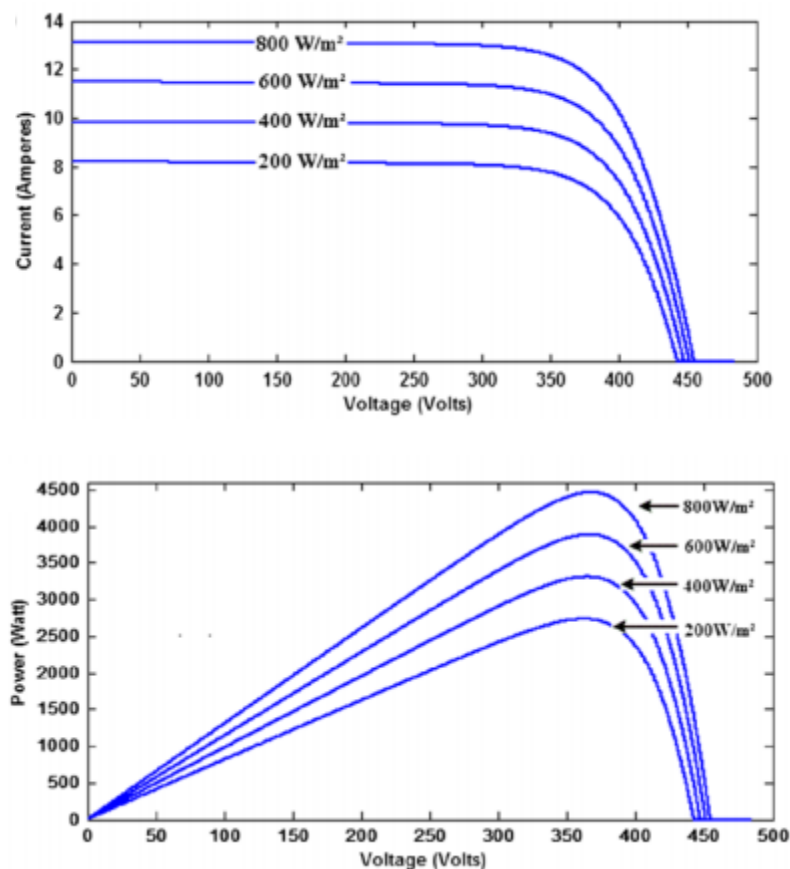


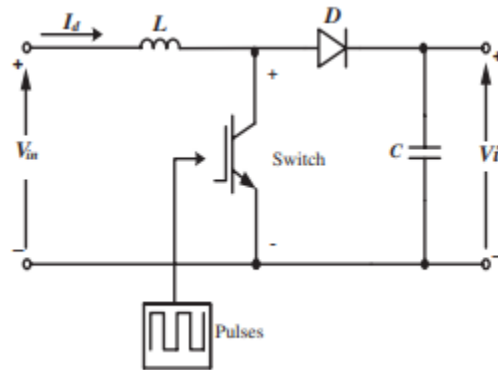
Figure 2:(a)IV and (b) PV characteristics of a proposed PV array.

It is found that when at the lower irradiance value, there will be a small change in the maximum output voltage whereas output current changes in drastic nature. Hence, there will be drop in MPP.

Power Conditioning Unit Arrangement

Powerconditioning scheme comprises a boost converter with MPPT, a 3 Φ VSI and a LC filter. Thus, the DC voltage acquired from the PV array is fed into the boost converter. Thus, to obtain the maximumpower from the system, P&O technique is employed.

Figure 3represents the flowchart of P&O topology.The boost converter implemented in this work is shown in Figure 4.

**Figure 3:**Boost Converter

Its operation is as follows:

During ($0 < t \leq t_{on}$):

Switch remains 'ON' and the voltage across L is V_i .

During ($t_{on} < t \leq T$):

Switch remains 'OFF' and the voltage across L becomes $V_i - V_o$

Wind Energy conversion system

The basic idea is to convert the kinetic energy available in the wind into mechanical energy which in turn rotates the turbine of an electrical generator to produce electrical power. Bernoulli's equation gives us the power available from a wind turbine

$$P_w = \frac{1}{2} \rho A V^3 \quad (2)$$

Where ρ = air density, V = wind density, A = area swept by rotor respectively. However practically power extracted from a wind turbine generator is fraction of power P_w . Generators rotor speed and pitch angle are determining factors for the amount of power extracted (P_T).

$$P_T = \frac{1}{2} C_p \rho A V^3 \quad (3)$$

Where C_p is called power coefficients whose value normally ranges around 0.593. This is generally referred as Betz limit. Value of C_p can be controlled using two factors such as β and tip TSR.

Finally, the output of the wind system and PV system is integrated and fed to VSI.

STATCOM

STATCOM is a compensating device which can be implemented to control the flow of reactive power in a network and thereby enhances the stability of a network. The function of capacitor in a STATCOM circuit is only to maintain dc voltage at constant level to aid inverter operation. The capacitor does not produce any reactive power.

By having control over the phase angle difference between voltage source converter and line voltage, the dc capacitor voltage can be controlled. If the bus angle is advanced beyond the phase angle (α), the static compensator increases the injected voltage, reactive power thus flows into

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the bus. Hence, in order to provide a continuous voltage regulation in the microgrid, STATCOM should be controlled using controller.

Design of fuzzy controller for STATCOM

The flow chart representation of proposed Fuzzy logic controller is established in Fig.4.

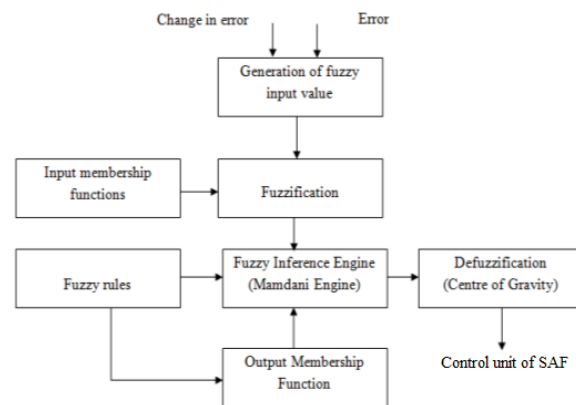


Figure 4.Flowchart representation of FLC

The FLC utilized in this topology is characterized with

- Seven triangular MF for all inputs and outputs.
- continuousUoD
- Implications are carried using Mamdani’s ‘min’ operator.
- Centroid Method is adopted for Defuzzification.

Figure 5Depicts MF adopted for both input and output.

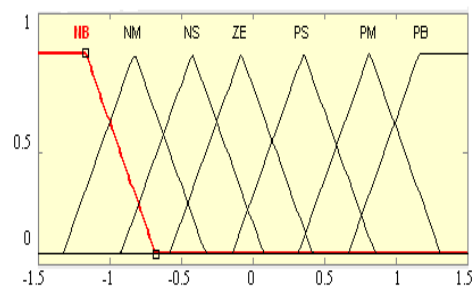


Figure 5a.MF-e

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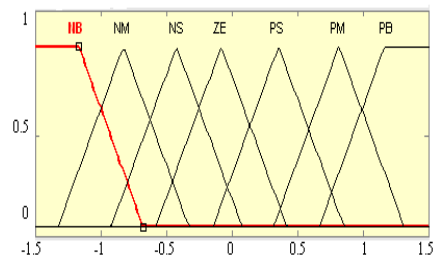


Figure 5b.MF - Δe

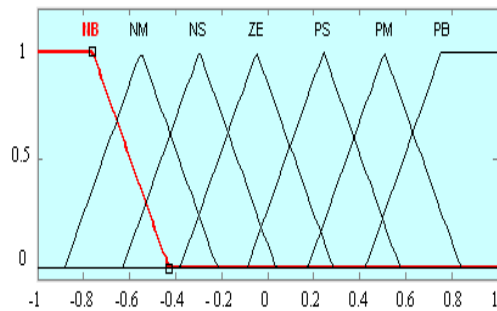


Figure 5c.MF - Δu

The 3D surface view of the rule base of FLC is shown in Fig. 5d.

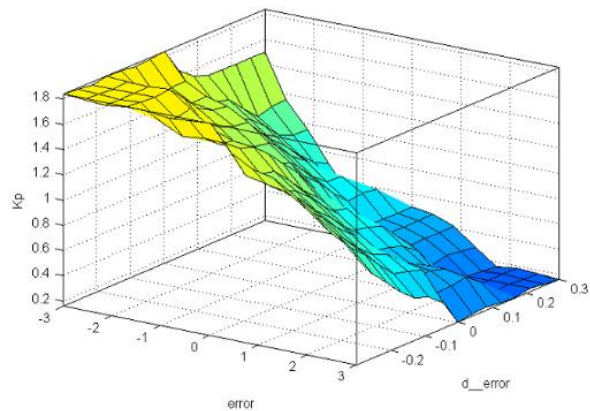


Figure5d. 3D surface view of proposed FLC

Results and Discussion

Thus, the performance evaluation of proposed topology in MATLAB platform is discussed below. Thus the topology of proposed methodology is represented in the Figure6.

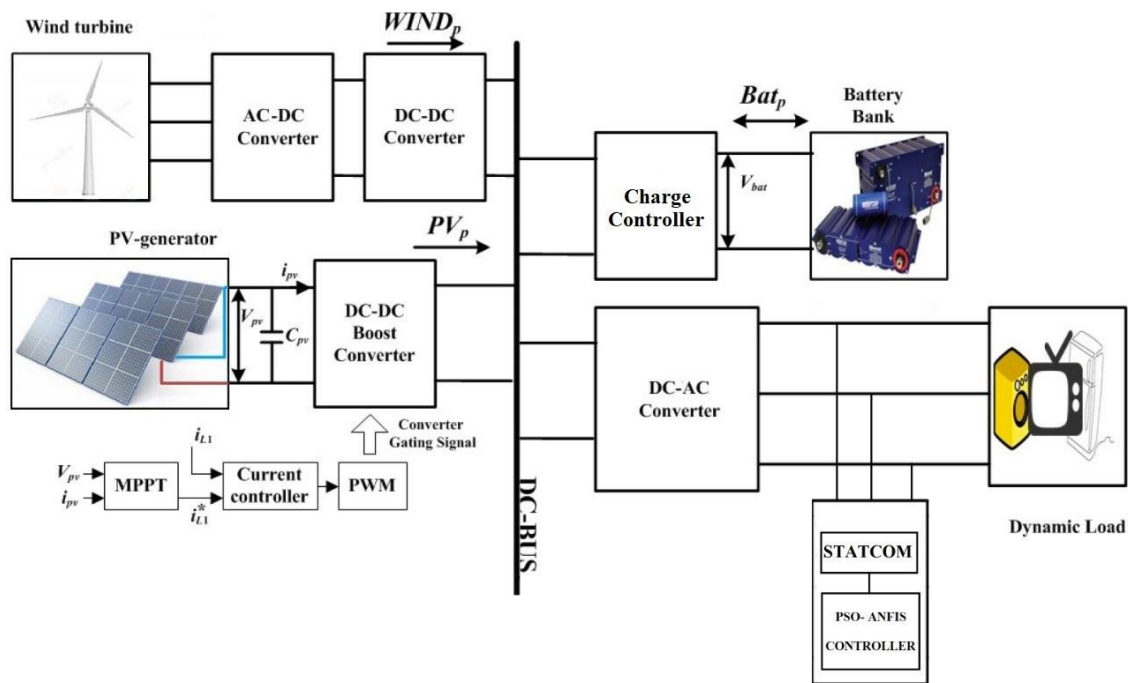


Figure 6.Topology of proposed methodology

The proposed method's effectiveness is verified under different parameter analysis.

Improvement in Voltage stability

The operation of microgrid without STATCOM is reflected in Figure7.

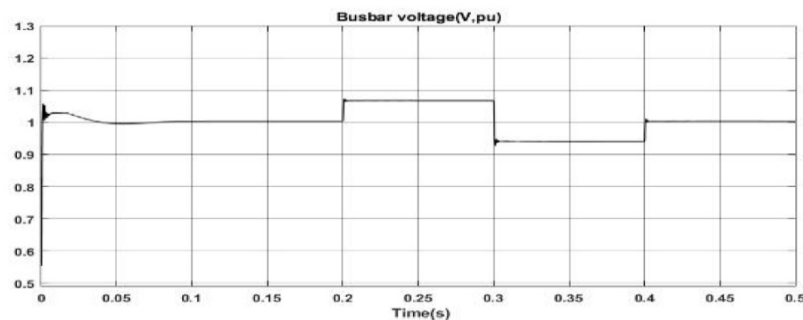


Figure 7.Bus bar voltage profile without STATCOM

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Thus, it is found that the voltage across the bus varies with time and results in fluctuation which is about $\pm 10\%$.

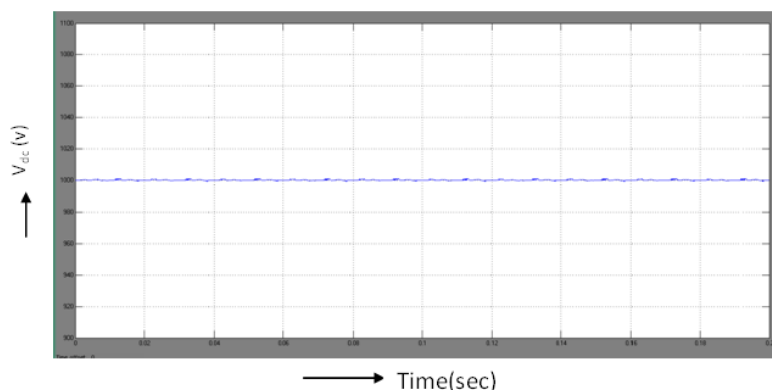


Figure 8.Bus bar voltage profile with STATCOM

However, when the STATCOM is inserted, the voltage remains constant as shown in figure 8 and there is no fluctuation in voltage. Hence, STATCOM with proposed controller exhibits lower overshoot and minimized voltage fluctuation

THD calculation and FFT analysis

Figure 9 depicts the current and voltage waveforms of system before STATCOM injection.

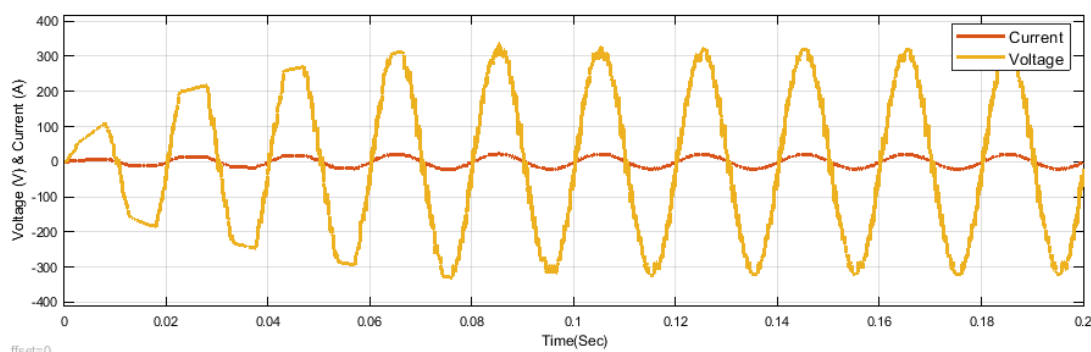


Figure 9.Voltage / current waveform of the system (without STATCOM)

Figure 9 depicts the current and voltage waveforms of system without STATCOM. From the figure, it is clearly understood there will be more non linearity in voltage and current waveforms.

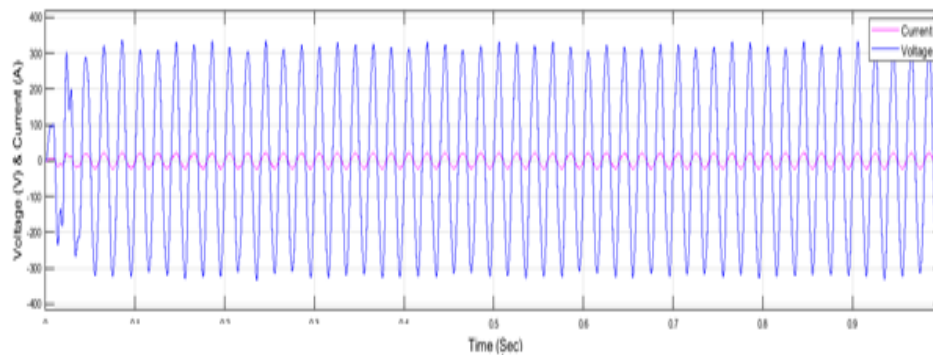


Figure 10. Voltage /current waveform of the system (With STATCOM)

Figure 10 depicts the current and voltage waveforms of FL controlled STATCOM. From that figure, it can be clearly understood that static compensator removes the non-linearity to a great extent. Figure 11 and figure 12 represents THD of the system obtained at the load terminal.

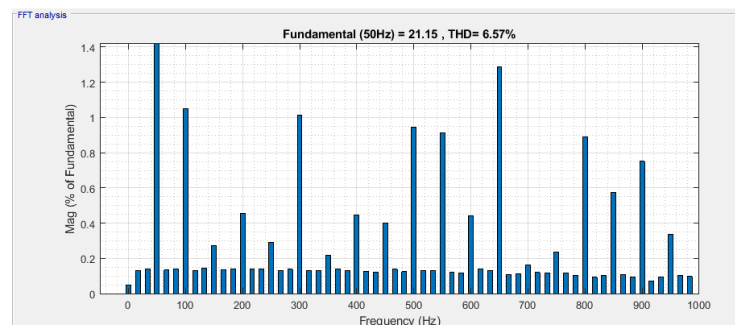


Figure 11.FFT analysis without STATCOM

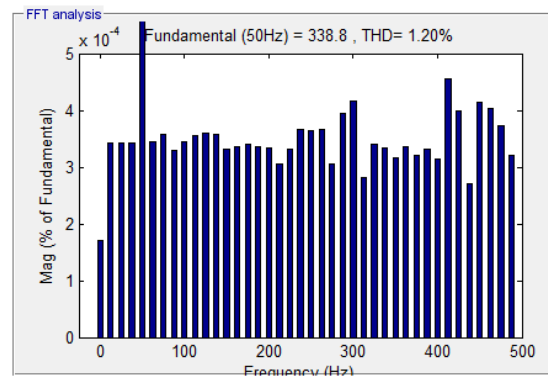


Figure 12.FFT analysis with proposed controller

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From the figures, the total harmonic distortion (THD) considering the maximum frequency as 500 Hz is found out to be 6.50% before compensation, After compensation, it was about 1.20% for the load voltage, i.e. well within the IEEE-519 prescribed limits.

Battery Performance

Here the Battery complements the part of the total power when the RES failed to supply the demand. Figure 13 portrays the SOC and output voltage of the battery.

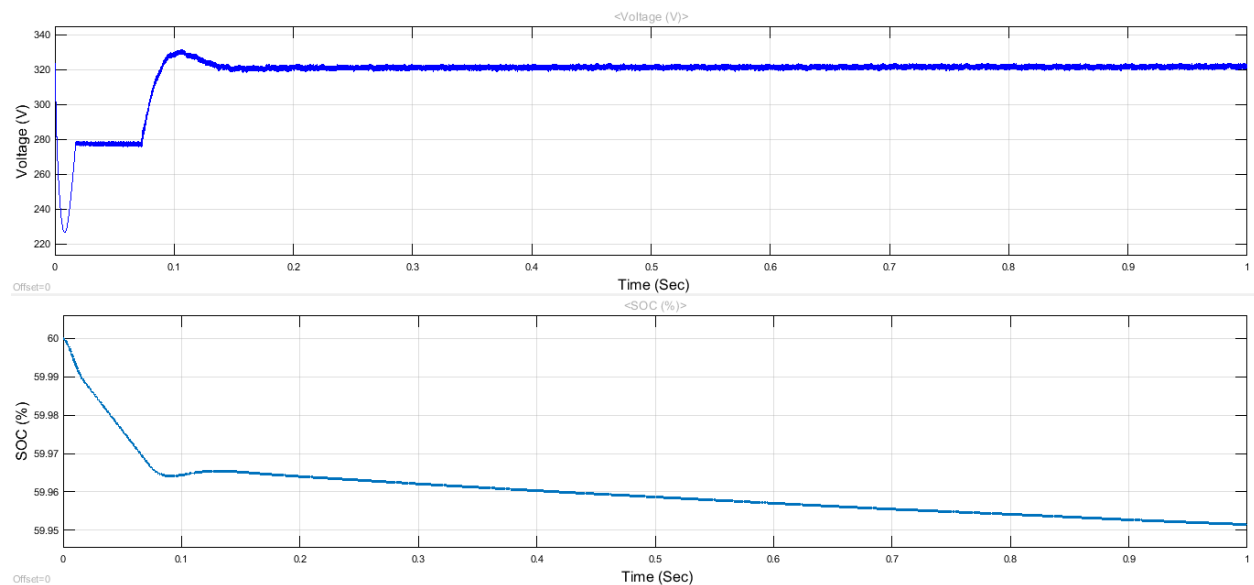


Figure 13.Output voltage /SOC of battery

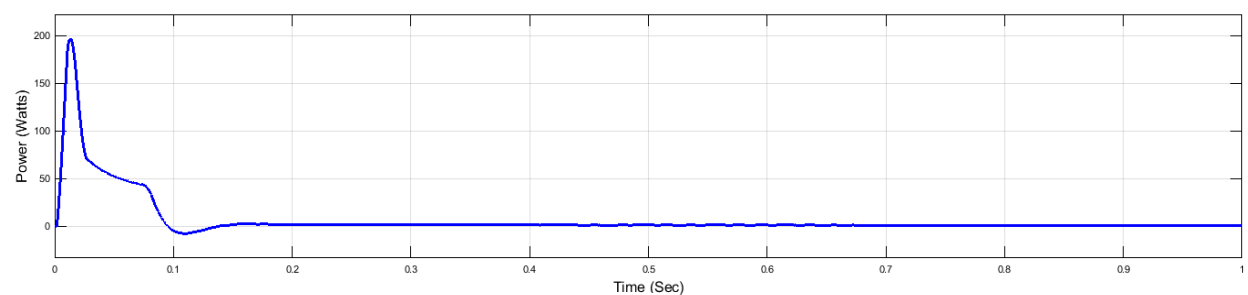


Figure 14.BatteryPower

The power delivered by the proposed battery is depicted in figure 14.

Conclusion

This work mainly focused on the PQ issues occurred in MG, In this work ,the formulated MG comprises both PV and wind sources together to supply power to the end user. STATCOM is tailored to mitigate the power quality issues present in the MG, In this, FLC is implemented to control the STATCOM's dc link voltage at a constant level. With the help of

this FLC based STATCOM, the proposed work mitigates the harmonics present in the system along with reactive power compensation.

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