CONSTRUCTION AND PERFORMANCE INVESTIGATION OF THREE-PHASE SOLAR PV AND BATTERY ENERGY STORAGE SYSTEM INTEGRATED UPQC

GADAPA NIKHILA[1], V.PRASHANTH[2]

[1]M.Tech Student, Department Electrical and Electronics Engineering, Vinuthna Institute of Technology & Science, Hasanparthy (Mdl), Warangal, Dist, Hasanparthy, Telangana 506371

[2]Assistant professor, Department Electrical and Electronics Engineering, Vinuthna Institute of Technology & Science, Hasanparthy (Mdl), Warangal, Dist, Hasanparthy, Telangana 506371

Abstract This study examines the use of Unified Power Quality Conditioner (UPQC) to mitigate the power quality problems existed in the grid and the harmonics penetrated by the non-linear loads. The UPQC is supported by the Photovoltaic (PV) and Battery Energy Storage System (BESS) in this work. Generally, the PV system supplies the active power to the load. However, if the PV is unable to supply the power then the BESS activates and provides power especially during the longer-term voltage interruption. The standalone PV-UPQC system is less reliable compared to a hybrid PV-BESS system because of its instability and high environment-dependency. Therefore, BESS will improve the voltage support capability continuously in the longer-term, reduce the complexity of the DC-link voltage regulation algorithm, and keep producing clean energy. The phase synchronization operation of the UPQC controller is directed by a self-tuning filter (STF) integrated with the unit vector generator (UVG) technique. Implementation of STF will make sure the UPQC can successfully operate under unbalanced and distorted grid voltage conditions. Thus, the requirement of a phase-locked loop (PLL) is omitted and the STF-UVG is utilized to produce the synchronization phases for the series and shunt active power filter (APF) compensator in UPQC controller. Finally, the proposed STF-UVG method is compared with the conventional synchronous references frame (SRF-PLL) method based UPQC to show the significance of the proposed technique. Several case studies are further considered to validate the study in MATLAB-Simulink software.

1. INTRODUCTION

Energy is the basic input of life. Electricity is one of the significant energy among the different forms of energy. It ensures the flexibility of life and the demand for this energy is increasing rapidly. In recent decades, the ‘Power Quality’ term has achieved remarkable responses from the researchers, most importantly in the electrical engineering sector. Energy efficiency is maintained by compensating the power quality problems which ensures a smooth generation of electrical energy and to encourage decarbonization of the grid.

Under different environmental conditions and requirements, the definition of power quality can have several interpretations and significances.

For instance, the network can be affected by the harmonics created by non-linear loads which is a great concern for the utility and the disturbances existed in the supplied voltage is a great concern for the consumers. Power losses, undesirable and abnormal characteristics of equipment due to power quality problems can cause interference in neighboring communication lines, and disruption to different consumers. IEEE-1159 [1] stated the behavior of a standard waveform and categorized a different kind of disturbances.

A complex power quality scenario is a specific disturbance that consists of an amalgamation of two or more individual disturbances, Energy is the basic input of life. Electricity is one of the significant energy among the different forms of energy. It ensures the flexibility of life and the demand for this energy is increasing rapidly. In recent decades, the 'Power Quality' term has achieved remarkable responses from the researchers, most importantly in the electrical engineering sector.

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A complex power quality scenario is a specific disturbance that consists of an amalgamation of two or more individual disturbances, In this paper, PV and BESS connected parallelly with UPQC is proposed to solve the complex power quality problems specifically in case of long voltage interruption. Various case study is applied to validate the dynamic performance of the suggested UPQC integrated with PV and BESS.

The comparison between the performance of UPQC with only DC-link capacitor and the UPQC integrated with PV and BESS is also shown. In addition, the STF integrated with the UVG technique (STF-UVG) is utilized to produce the synchronization phases for the UPQC controller to address the drawbacks of the conventional PLL.

The performance comparison of the STF-UVG and a standard SRF-PLL to validate the superiority of the proposed technique. Finally, the performance of the suggested UPQC system is investigated utilizing MATLAB-Simulink software under dynamic condition.

Photovoltaic (PV) power systems and solar power Generation

Solar power generation:

When sunlight strikes on photovoltaic solar panels solar electricity is produced. That is why this is also referred to as photovoltaic solar, or PV solar.

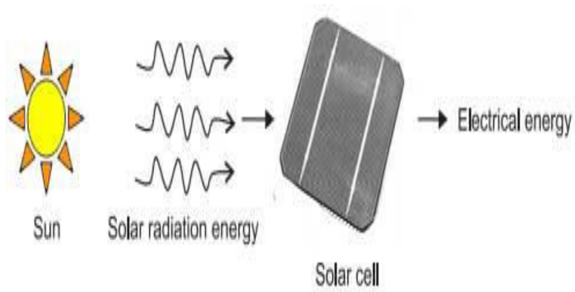

Fig 1: Solar power

II SYSTEM CONSTRUCTION

The construction of PV-BESS-UPQC is displayed in Fig. 1. The three-phase system is designed for the PV-BESS-UPQC model. The PV-BESS-UPQC comprises of series and shunt APF compensator linked with DC-link split capacitor. The battery and the PV array are linked parallelly to the DC-link. The PV is linked through a boost converter to the DC-link.

Moreover, the BESS is linked through a buck-boost converter to the DC-link. The series compensator works like a controlled voltage source manner and mitigates for the supply voltage sags, swells, interruption, and voltage harmonic. On the other hand, the shunt compensator mitigates the current harmonics for the load. Both the series and shunt APF compensator are attached through interfacing inductors.

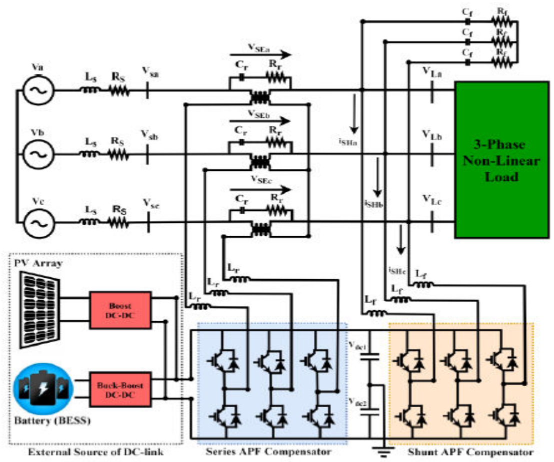

Fig 2:UPQC system configuration

Due to the converter switching action harmonics are generated and therefore, ripple filter is utilized to filter out harmonics. The series compensator uses a series injection transformer to insert voltage to the grid. In this work, a three-phase non-linear load is utilized. The PV-BESS-UPQC design procedure starts with the accurate measurement of PV array, split capacitor, reference voltage of DC-link etc. The design of the shunt compensator follows the way that apart from mitigating current harmonics it controls the peak output power from PV array.

Since the PV array is connected to the UPQC DC-link directly, the PV array is constructed in a way such that the maximum power point (MPP) voltage is equivalent to the reference DC-link voltage. During nominal conditions, the rating of PV array ensures that the load active power is delivered by the PV array and power is supplied to the grid and charging BESS by the PV array as well. Besides, the BESS is designed in a way that, when the PV array generate less power than the DC-link load demand, the BESS provides the insufficient power equivalent to the decrease in DC-link voltage. Moreover, when there is no power produced by PV array, the BESS will supply the total load demand.

III SIMULATION RESULTS

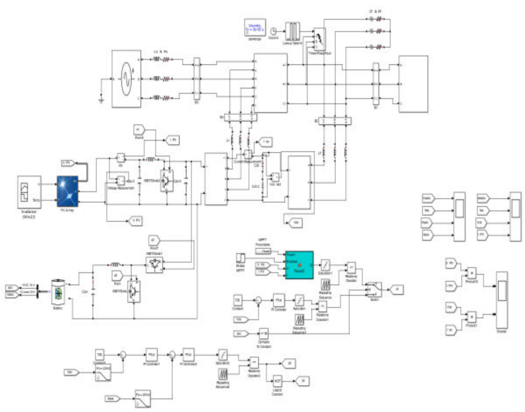

Fig 3: Simulink model

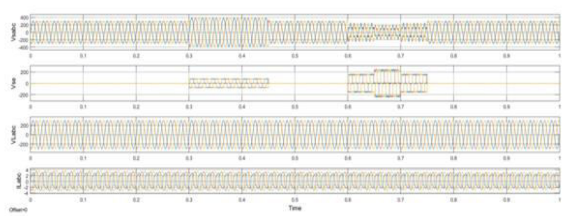

Fig 4: Three-phase load currents and load voltages

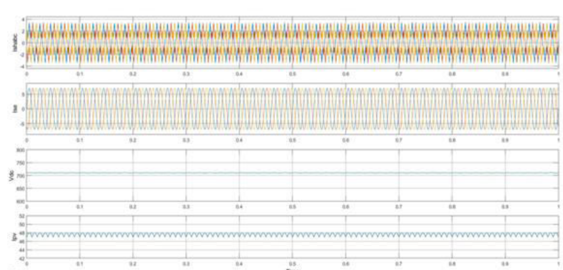

Fig 5: Current at PV and voltage DC OUTPUT voltage

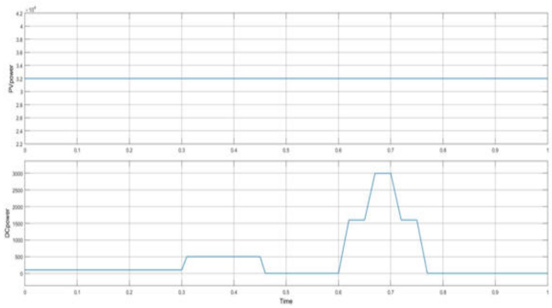

Fig 6: PV power and DC power

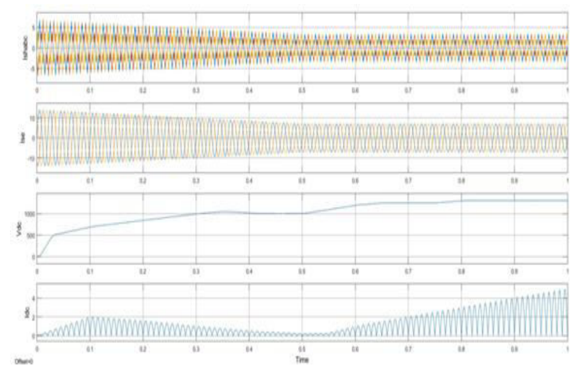

Fig 7: DC voltage and current

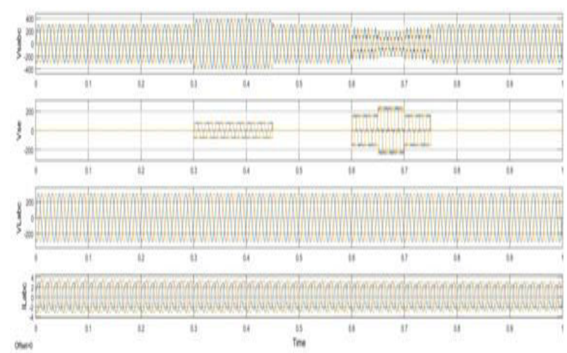

Fig 8: Load currents and load voltages

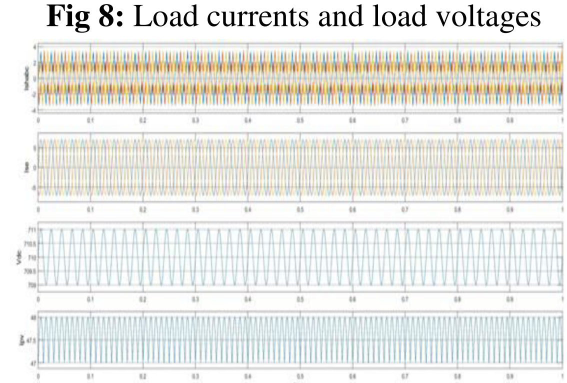

Fig 9: PV currents and DC voltages

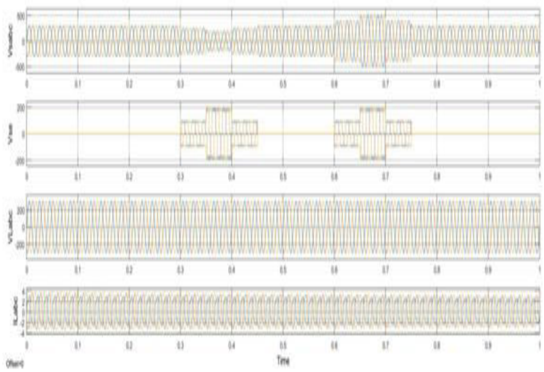

Fig 10: Load currents and load voltages

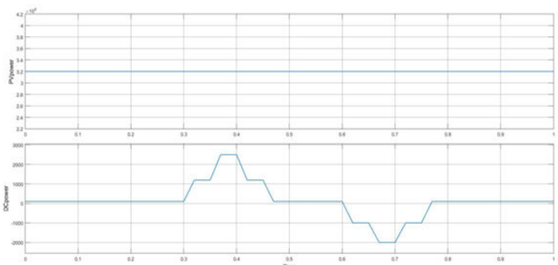

Fig 11:DC power and PV power

IV CONCLUSIONS

The construction of three-phase UPQC has been investigated considering the condition of complex power quality problems which are an amalgamation of harmonics, voltage swell, and sags, and voltage interruption under unbalanced and distorted voltage grid condition. Integrating the BESS and PV with the UPQC provides active power capability to the network. The main benefit of BESS integrated with UPQC is that it makes the system capable of supplying and absorbing active power from the PV. Since renewable energy is not completely reliable because of its environment-dependent feature, integrating a BESS will solve the lack of renewable energy resources.

Finally, it can be figured that the BESS and PV attached with UPQC can be a good alternative in the distributed generation to upgrade the power quality of the contemporary distribution system. The DC-link voltage is stable because of the continuous supply from the PV-BESS system. Therefore, it can reduce the complexity of the DC-link voltage regulation algorithm.

The STF-UVG technique for synchronization phases is applied successfully in the shunt and series APF compensator to generate reference current and voltage. Thus, the UPQC is designed without relying on the PLL components, and mitigation of current and voltage are achieved successfully following the grid condition to ensure the system stability and to achieve almost unity power factor. The implementation of the proposed technique has confirmed that the grid current harmonics follow the IEEE-519 standard. Finally, it is worth mentioning that the proposed system can enhance the overall efficiency of the grid power system.

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