POWER QUALITY ENHANCEMENT IN RENEWABLE ENERGY INTEGRATED MICROGRID SYSTEM USING DVR

Dr.S.Parthasarathy¹, R.M.Nimosini², R.Thangasankaran³

¹Professor, Department of EEE, K.L.N. College of Engineering, Pottapalyam
²PG Scholar, Department of EEE, K.L.N. College of Engineering, Pottapalyam
³JRF, Department of EEE, K.L.N. College of Engineering, Pottapalyam

Abstract— Micro grid plays an important role in power system. In recent years, renewable resources are becoming a most promising green energy sources all over the world for electricity production and for meeting out the today’s demands, hence micro-grids are becoming widespread. A micro grid is a local energy grid with control capability, which means it can detach from the traditional grid and operates autonomously. The integration of Micro grid to the utility or grid through power electronic converters has risen worried about the quality of supply voltage. In this proposed work, in order to compensate for voltage sag and swell in the Micro grid system Dynamic Voltage Restorer (DVR) is used to inject three phase voltage in series and it is in synchronism with the transmission line voltages. The main objective is to enhance the Power Quality by using Dynamic Voltage Restorer (DVR) in a Solar PV and Battery integrated Renewable Energy System (RES) and to compensate the voltage profile. The system is simulated using MATLAB Simulink.

Keywords— Solar Photovoltaic (PV), Battery, Boost converter, Buck-Boost converter, Inverter Injection Transformer, MATLAB – Simulink

I. INTRODUCTION

The term electric Power Quality (PQ) can be stated as maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency [1]. In addition, the energy supplied to a customer must be uninterrupted from the reliability point of view. It is to be noted that even though PQ is mainly a distribution system problem, power transmission systems may also have an impact on the quality of power.

PQ is a very important issue recently due to the impact on electricity suppliers, equipment manufacturers and customers. PQ is expressed as the variation of voltage, current and frequency and also injection of harmonics due to some non linear loads in a power system, which is measured in a indices namely Total harmonic Distortion (THD). It refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location in the power system. Nowadays, so many industries are using high technology for manufacturing and processing unit, requires high quality and high reliable power supply. PQ problems includes a wide range of disturbances such as voltage sags/swells, flicker, harmonic distortions, impulse transient, and interruptions. Voltage sag/swell can occur more frequently than other PQ phenomenon.

The integration of micro grid to the grid causes various power quality issues due to the use of inverters in the microgrid system. Inverter plays a very important role in the microgrid, because the power obtained from renewable energy sources like solar and battery are DC. So the DC power is
converted to AC using inverters. The inverters have large number of power electronic switches, which leads to power quality issues [4], [5]. Micro-grids offer clear financial advantages for low-income end-users, as access to electricity results from an ongoing service agreement, rather than ownership of a product (such as a solar home system or solar portable lighting device).

In this proposed work, the solar PV and battery is integrated with grid. Solar PV connected with boost converter to maintain the constant output. Battery is connected with Buck-Boost converter with a controller that will compare the reference and input from the battery, when there is low voltage or negative value, then boost converter acts and gives increased voltage if very high or positive value is obtained then buck converter acts and gives the constant output. Both converters produce DC power output, which is connected to the three phase inverter for DC to AC power conversion which is connected to the grid. Output of the inverter is connected to the injection transformer which helps to inject the voltage to the grid for compensation of sag and swell. The block diagram of the proposed microgrid system is shown in Figure 1.

![Image of block diagram](image)

*Figure 1: Block diagram of Renewable energy integrated micro grid system using DVR*

**II. PROPOSED PV AND BATTERY BASED DVR GRID INTEGRATED RENEWABLE ENERGY SYSTEM**

**2.1 Simulation model for Solar PV and Battery integration with Microgrid**

Solar energy has become a promising alternative renewable source due to the attractive features, such as direct energy conversion, ease of integration and low environmental impacts. A battery storage system has a significant role in all stand-alone hybrid systems. Batteries are the most promising units for renewable energies, since their energy density is high and have high performance. In all stand-alone systems, a battery backup is needed to get the continuous power supply [6-8]. The power obtained from both solar system and Battery system are DC supply. So Direct Current is converted into Alternating Current using Inverter. The converted AC voltage is
now ready to integrate with the grid. The energy from microgrid is supplied to the consumers through the main grid. Sometimes the power produced by microgrid can be used in remote areas where the supply of power is not possible and also DVR can be used for sag /swell compensation [8-10]. The simulation of integration of microgrid with DVR is shown in Figure 2.

Figure 2: Simulation model of solar and battery with DVR and grid integrated system

The reference voltage is set as desired 440 V/400 V/300 V and it is then compared with load voltage with a closed loop. It generates the desired pulse for an inverter that simulation of inverter is shown in Figure 3. The simulation of gate signal for the voltage source inverter is shown in Figure 4

Figure 3: Simulation of Pulse Generation for an inverter

Figure 4: Simulation output of Gate pulse
III. MITIGATION OF VOLTAGE SAG AND SWELL IN THE PROPOSED SYSTEM

3.1 Simulation Output of Compensation for Three Different Voltages

In case if a fault occurs in a system due to some electrical disturbances, there is a cause of sag / swell in a system. Here in the proposed system it is used for testing purpose and analyzing the performance by injecting a voltage from solar PV and Battery which is used here as a DC source. It is injected by means of an injection transformer in the grid in case of fault. The three cases are as follows:

Case 1: Grid voltage: 440 V

In this case, reference voltage is set 440 V and compared with load voltage to obtain desired output. Sag and swell occurs in the time between 0.5-0.7 seconds and 1.5-1.7 seconds respectively. The voltage Sag magnitude in grid is 260 V and Swell magnitude in grid is 500 V. The injected voltage from a Solar PV and Battery converted AC given to the injection transformer. The injected voltage is 180 V each for sag and swell magnitude. Hence, the load voltage is compensated for both Sag and Swell (440 V) after injection as shown in Figure 5 and its expanded form of waveform is shown in Figure 6.

Figure 5: Simulation output –Voltage Waveforms (440 V)  
Figure 6: Simulation of Grid voltage/Load Voltage /Injected Voltage at 440 V

Figure 7 shows the simulation for THD\(_V\) for Grid voltage 359.3 V has 0.0% THD\(_V\) and the Figure 8 shows the simulation of THD\(_V\) for load voltage 359.1 V has 0.68% of THD\(_V\). Figure 9 shows the injected voltage of 178.1 V with 1.22% of THD\(_V\).

Figure 7: Simulation of THD\(_V\) for Grid voltage (440 V)
Case 2: Grid voltage: 400 V

In this case, reference voltage is set 400 V and compared with load voltage to obtain desired output. Sag and swell occurs in the time of 0.5-0.7 seconds and 1.5-1.7 seconds respectively. The voltage Sag magnitude in grid is 260 V and Swell magnitude in grid is 500 V. The injected voltage from a Solar PV and Battery converted AC given to the injection transformer. The injected voltage is 70 V and 120 V for sag and swell magnitude respectively. Hence, in the load voltage swell alone is compensated (400 V) but sag time occurs as 0.5-0.7 secs after injection as shown in Figure 10.
Figure 11 shows the simulation for THD_V for Grid voltage 326.6 V has 0.0% THD_V and the Figure 12 shows the simulation of THD_V for load voltage 359.1 V has 0.93% of THD_V. Figure 13 shows the injected voltage of 359 V with 0.78% of THD_V.

Figure 11: Simulation of THD_V for Grid voltage (400 V)

Figure 12: Simulation of THDV for Load voltage (400 V)
Case 3: Grid voltage: 300 V

In this case, reference voltage is set 300 V and compared with load voltage to obtain desired output. Sag and swell occurs in the time of 0.5-0.7 seconds and 1.5-1.7 seconds respectively. The voltage Sag magnitude in grid is 220 V and Swell magnitude in grid is 500 V. The injected voltage from a Solar PV and Battery converted AC given to the injection transformer. The injected voltage is 70 V and 150 V for sag and swell magnitude respectively. Hence, in the load voltage, sag and swell both are not compensated after injection as shown in Figure 14.

Figure 15 shows the simulation for THD for Grid voltage 244.9 V has 0.0% THD and the Figure 16 shows the simulation of THD for load voltage 279.5 V has 4.72% of THD. Figure 17 shows the injected voltage of 153.3 V with 3.57 % of THD.
Figure 15: Simulation of THDv for Grid voltage (300 V)

Figure 16: Simulation of THDv for Load voltage (300 V)
Figure 17: Simulation of THD for Injected voltage (300 V)

IV. RESULTS AND DISCUSSIONS

4.1 Results and Discussion

In this paper, Solar PV with Battery is designed and kept as an DC source in DVR. It was then connected to Grid by means of an injection transformer. The DVR was tested under various grid voltages i.e 440V, 400V and 300V which was used to check the performance variation in Grid corresponding to an inverter. Inverter has a closed loop which compares the reference voltage and load voltage and hence it balances the Sag and Swell mainly in Grid system. The main objective here is to improve the voltage profile by compensation of Sag and Swell mainly in Grid system. The harmonics produced by the inverter is also reduced with the help of series active filter. The results are compared and tabulated in Table 1.

Table 1: Comparison of all three Grid voltages in correspondence with sag swell time and their respective magnitudes.

| DVR Reference voltage (V) | Sag time (sec) | Swell time (sec) | Sag Magnitude (V) | Swell magnitude (V) |
|---------------------------|----------------|------------------|-------------------|---------------------|
| Grid voltage (440 V)      | 0.5-0.7        | 1.5-1.7          | 260               | 500                 |
| Injected Voltage          | -              | -                | 180               | 60                  |
| Load voltage              | NIL            | NIL              | 440 (COMPENSATED) | 440 (COMPENSATED)   |
| Grid voltage (400 V)      | 0.5-0.7        | 1.5-1.7          | 260               | 500                 |
| Injected Voltage          | -              | -                | 140               | 100                 |
| Load voltage              | -              | NIL              | 400 (COMPENSATED) | 400 (COMPENSATED)   |
| Grid voltage (300 V)      | 0.5-0.7        | 1.5-1.7          | 220               | 500                 |
Table 2, 3 and 4 shows the harmonic profile of all three DVR Reference voltages (440 V, 400 V, and 300 V)

### Table 2 Harmonic profile at Grid voltage 440 V

| DVR Reference voltage | Voltage (V) | % THD$_V$ |
|-----------------------|-------------|-----------|
| Grid voltage          | 260         | 0.0       |
| Load voltage          | 440         | 0.68      |
| Injected voltage      | 180         | 0.78      |

### Table 3 Harmonic profile at Grid voltage 400 V

| DVR Reference voltage | Voltage (V) | % THD$_V$ |
|-----------------------|-------------|-----------|
| Grid voltage          | 260         | 0.0       |
| Load voltage          | 400         | 0.93      |
| Injected voltage      | 140         | 0.78      |

### Table 4 Harmonic profile at Grid voltage 300 V

| DVR Reference voltage | Voltage (V) | % THD$_V$ |
|-----------------------|-------------|-----------|
| Grid voltage          | 220         | 0.0       |
| Load voltage          | 300         | 4.72      |
| Injected voltage      | 90          | 3.5       |

V. CONCLUSION

It can be concluded that in all the test cases both the Sag and Swell were completely mitigated. The results of %THD$_V$ grid show that harmonic distortions are reduced for the proposed system according to IEEE 519-2014. DVR can be connected to PI controller and any other special advanced controller to improve the voltage profile. Thus the main objective of enhancing the PQ in all aspects like reducing THD and mitigation of Sag and Swell by using Dynamic Voltage Restorer (DVR) in a Solar PV and Battery integrated Renewable Energy System (RES) is achieved using MATLAB simulink model.

REFERENCES

I. Parthasarathy, S., S. Rahini, and SA Karthick Kumar. "Performance evaluation of Shunt Active Harmonic filter under different control techniques." In 2015 International Conference on Circuits, Power and Computing Technologies [ICCPCT-2015], pp. 1-8. IEEE, 2015.

II. AsitMohanty, Prakash K.Ray, “ Modelling, simulation and optimisation of robust PV based microgrid for mitigation of reactive power and voltage instability”, ELSEVIER, Electrical power and energy systems 8 (2016), 444-458, July 2016.

III. C.N.Bhende,A.Kalam, S.G. Malla, “Mitigation of power quality problems in Grid-Interactive Distributed Generation System”, International journal of emerging electrical power system, Jan 2016, DOI 10.1515/jeps-2015-0163

IV. Loganthurai, P., S. Parthasarathy, S. Selvakumaran, and V. Rajasekaran. "Energy conservation measures in a technical institutional building in Tamilnadu in India." Energy Procedia 14 (2012): 1181-1186.

V. P. Mohan, G. S. Suganya and T. Sivanandhan (2014), “PV/Battery to the Grid Integration of Hybrid Energy Conversion System with Power Quality Improvement Issues”, International Journal of Research in Engineering & Technology, vol. 2, pp. 173-184.
VI. Anita Pakharia, Manoj Gupta “Dynamic voltage restorer for compensation of voltage sag and swell: A literature review”, International Journal of Advances in Engineering and Technology, ISSN:2231-1963, July 2012

VII. Saravanan, S., M. Solaimanigandan, T. Tharaneetharan, V. Varunraj, and S. Parthasarathy. "Dynamic Voltage Restorer for Distribution System." International Journal of Engineering Research and Development e-ISSN: 2278-067X, p-ISSN: 2278-800X, 7, no. 1 (2013): 14-24.

VIII. Manorma Kushwah, Raginisaxena Optimization Of Voltage Sag/Swell Using Dynamic Voltage Restorer (DVR), International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) - 2016 978-1-4673-9939-5/16/$31.00 ©2016 IEEE

IX. Juan Manuel Carrasco, Leopoldo Garcia Franquelo and Jan T. Bialasiewicz (2006), “Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey”, IEEE Transactions on Industrial Electronics, vol. 53, pp. 1002-1016.

X. Parthasarathy, S., R. Thenmozhi, and V. Rajasekaran. "Current harmonic reduction using current Injection technique in a converter system." In 2012 International Conference on Computing, Electronics and Electrical Technologies (ICCEET), pp. 232-239. IEEE, 2012.

XI. Ganji Jhansi Rani1, Pavan Kumar, “Single Phase Inverter With Improved Power Quality Control Scheme For Distributed Generation System” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 9, September 2013

XII. Magesha G and Dr. Rashmi (2015), “Integration Of Battery Energy Storage System Based PV Power Plant into Grid”, International Journal of Emerging Technology in Computer Science & Electronics, vol. 14, pp. 56-62.

XIII. Parthasarathy, S., P. Loganthurai, S. Selvakumaran, and V. Rajasekaran. "Harmonic mitigation in UPS system using PLL.” Energy Procedia 14 (2012): 873-879.

XIV. Shashi Kala Kumari and Rekha Jha (2015), “Modeling Simulation and Performance Analysis of Hybrid Power Generation System”, International Journal of Innovative Research in Science, Engineering and Technology, vol. 4, pp. 5837-5844.

XV. T Appala Naidu, “The Role Of Dynamic Voltage Restorer(DVR) in Improving Power Quality” , International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB16) 978-1-4673-9745-2 ©2016 IEEE

XVI. Parthasarathy, S., V. Rajasekaran, and K. Gnanambal. "Optimal selection of harmonic filter branch parameters using PSO and differential evolution algorithm." International Transactions on Electrical Energy Systems 24, no. 10 (2014): 1434-1449.