



Investigating the Impact of PV System on Grid Connected Large Scale PV Systems of REWA Ultra Solar PV System

Swati Khare^{1*}, Anil Kurchania², Prateek Nigam³

Abstract

Renewable energy is gaining importance due to its inexhaustible nature and no GHG emissions. This paper deals with the investigation of voltage and current distortion on the grid side along with frequency distortion with variation in load when PV power is injected to grid. The simulation study is performed for the actual site of PV system at Rewa (M.P.). The total capacity of the PV system of considered location is 750 MW (3 unit of each 250 MW) with the load variation on the grid side. The reliability of the typical large scale grid connected system is investigated on 250 MW units for the selected site location performed in MATLAB software. The result shows the total harmonic distortion of voltage and current injected to grid along with the frequency deviation when the PV is injected to grid. The transient duration along with the harmonic profile of voltage is investigated in this work.

Key Words: PV system, Grid, Total Harmonic Distortion (THD), Frequency Deviation, Transient.

DOI Number: 10.14704/nq.2022.20.8.NQ44306

NeuroQuantology 2022; 20(8): 2758-2762

2758

Introduction

Grid connected PV systems in the world account for about 99% of the installed capacity compared to stand alone systems, which use batteries. Battery-fewer grids connected PV is cost effective and requires less maintenance. Batteries are not needed for grid connected PV, as the power generated is uploaded to the grid for direct transmission, distribution and consumption.[1,2,3] This eases the burden on other sources supplying power to the grid. In this paper, the impacts of connecting PV system to grid are studied. Further, the parameters investigated are Voltage distortion, current distortion and frequency deviation.

Impacts of Connecting PV System to the Grid

If the PV penetration is really high Photovoltaic systems can subject the grid to several negative impacts. They are i) Reverse power flow, ii) Overvoltage along Distribution feeders, iii) Voltage

control difficulty, iv) Phase unbalance, v) Power Quality problems, vi) Increased Reactive power and vii) Islanding detection difficulty. This paper considers the following three impacts.[4,5,6,7]

A. Power Quality Problems/Harmonics

The inverter forms the core of the grid connected PV system and is responsible for the quality of power injected into the grid. Inverters also introduce harmonics into the system in the presence of non-linear loads, during DC to AC conversion. Harmonic currents introduce voltage drop and result in distortion of supply voltage. Harmonics can also cause resonance in the supply system, resulting in malfunction, reduction in lifetime or permanent damage of electrical equipment [8,9].

Corresponding author: Swati Khare

Address: ¹Ph.D Scholar, Rabindranath Tagore University, Raisen (M.P.); ²Director, Centre for Renewable Energy, Rabindranath Tagore University, Raisen (M.P.); ³Associate Professor, Department of Electrical & Electronics Engineering, Rabindranath Tagore University, Raisen (M.P.).
E-mail: ¹*swatikhare2610@gmail.com



B. Increased Reactive Power

Photovoltaic inverters usually operate at unity power factor. The owners of small residential PV systems in an incentive based program are levied based on their kilowatt-hour yield and not on their kilovolt-ampere hour yield. Hence they prefer to operate PV inverters at unity power factor, maximizing the active power generation, and accordingly their returns. As a result the reactive power demand met by the PV system is minimal. Hence, the grid is responsible for supplying majority of reactive power, and it makes the distribution transformer operate at a low power factor [10,11,12].

C. Variation with Load Detection

The condition when the solar system continues to supply to the load even though grid power from the utility is not present is called islanding. Islanding can be dangerous to utility workers, who may not realize that a circuit is still energized while working on repairs or maintenance. Hence, the solar inverter must detect islanding and disconnect the PV system when the grid is down. This function of the PV system is known as ‘anti-islanding’ [13,14,15]. These impacts are dependent on the size and location of the PV system. According to the Solar America Board for Codes and Standards (Solar ABCs) PV systems are classified into three categories, based on the ratings of the system. Small-scale systems are rated at 10kW or less; Medium-scale systems are rated between 10kW and 500kW; and large-scale systems are rated above 500 kW [16,17,18]. This paper considers large-scale PV system for simulation.

System Description

A typical grid-connected Rewa ultrasolar PV project is considered for simulation, to study the impacts of connecting PV to the grid. Each PV array is connected to a DC/DC converter (average model). The outputs of the boost converters are connected to a common DC bus of 500 V. Each boost is controlled by individual Maximum Power Point Trackers (MPPT). The MPPTs use the "Perturb and Observe" technique to vary the voltage across the terminals of the PV array in order get the maximum possible power.

A three-phase Voltage Source Converter (VSC) converts the 500 V DC to 260 V AC and keeps unity power factor. A 400-kVA 260V/25kV three-phase

coupling transformer is used to connect the converter to the grid. The grid model consists of typical 25-kV distribution feeders and 120-kV equivalent transmission system.

In the average model the boost and VSC converters are represented by equivalent voltage sources generating the AC voltage averaged over one cycle of the switching frequency. Such a model does not represent harmonics, but the dynamics resulting from control system and power system interaction is preserved. This model allows using much larger time steps (50 us), resulting in a much faster simulation.

Simulation

The simulation of Rewa Ultra solar PV system pumping station PV System of 250 MW is shown in figure 1. The simulation parameters are shown in table 1. The simulation results will investigate the harmonic profile of voltage, current and frequency deviation along with the Active and reactive power when the PV system power is injected to grid. The two PV system of 300kW and 250 kW are used to inject power to the grid. The output of the PV system is fed to the VSI converter to convert DC power to the AC power through common mode operation. A simple inverter control is adopted to generate the pulse for the inverter. The output of the inverter is fed to the filter and then to the Step-up transformer 440kVA, 260V/25kVA. Three loads of 100 kW, 2 MW and 30 MW are connected to grid. The simulation study investigates the variation of voltage and current injected to grid with the variation of load on the grid side. The power injected to grid is also observed and presented in the result section.

Table 1. Simulation parameters of Grid connected PV system (Gaurighat Pumping Station)

S.No.	System	Rating
1.	PV System	250 MW
2.	Inverter	500 V DC to 260 V AC
3.	Load 1,2,3	100KW, 2 MW, 30MW
4.	Distribution feeders	25-kV
5.	Equivalent transmission system	120-kV
6.	Transformer connected to grid	400-kVA 260V/25kV



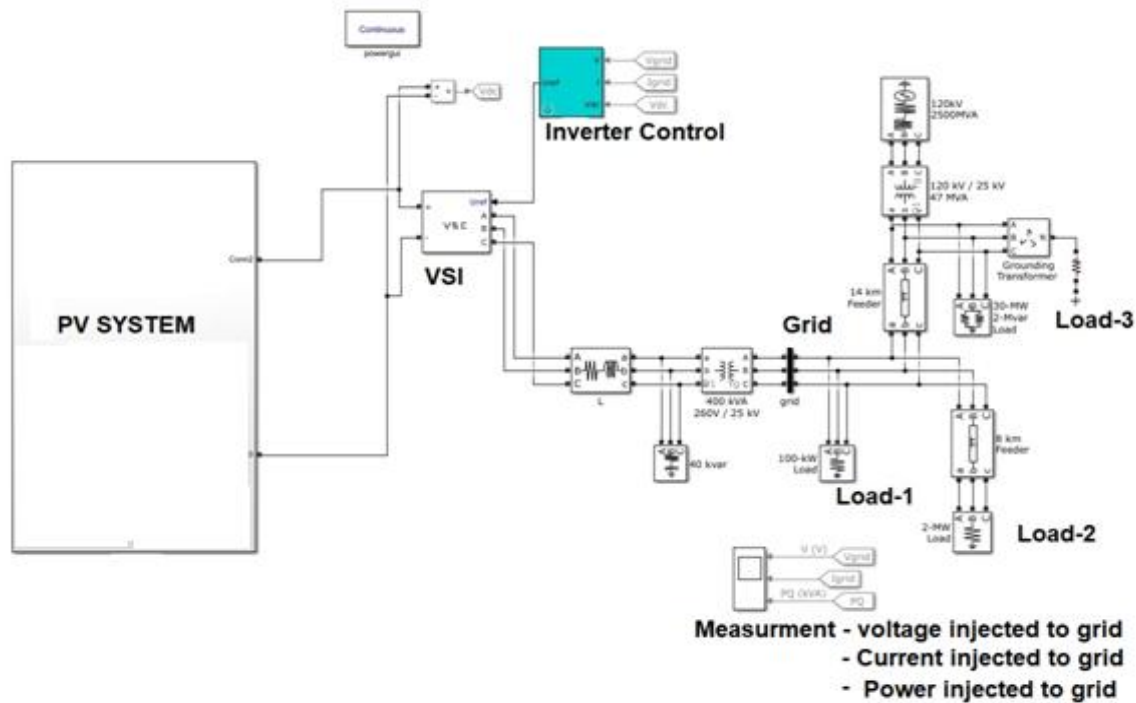


Figure1.Simulation of 250 MW Rewa Ultra Solar PV System connected to Grid

Results and Discussion

The simulations results are discussed in this section, the three phase voltage injected to grid waveform are presented in figure 2. The current injected to grid is shown in figure 3 at time t=0 sec

to t=0.05 sec some transient is observed while after t=0.05 sec the constant current for load-1 is injected to grid. With the change in load from load-2 and load-3 the magnitude of current varies. 2760

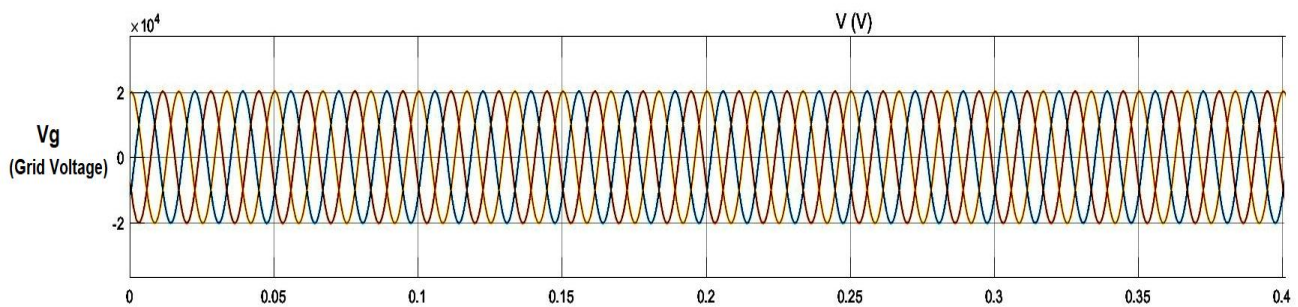


Figure2.Three phase voltage injected to grid

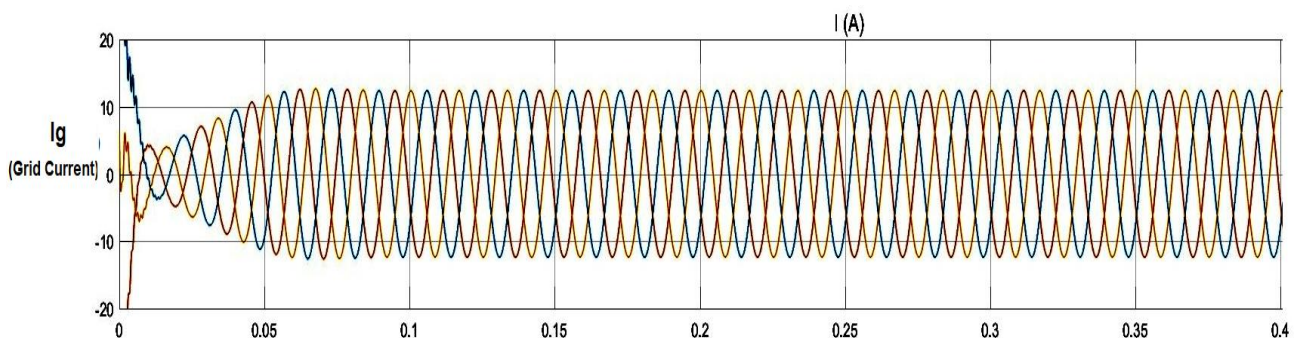


Figure3.Three phase current injected to grid



Figure 4 shows the active and reactive power active power (P) and reactive power (Q) is nearly injected to grid and it is observed to be 225 MW negligible.

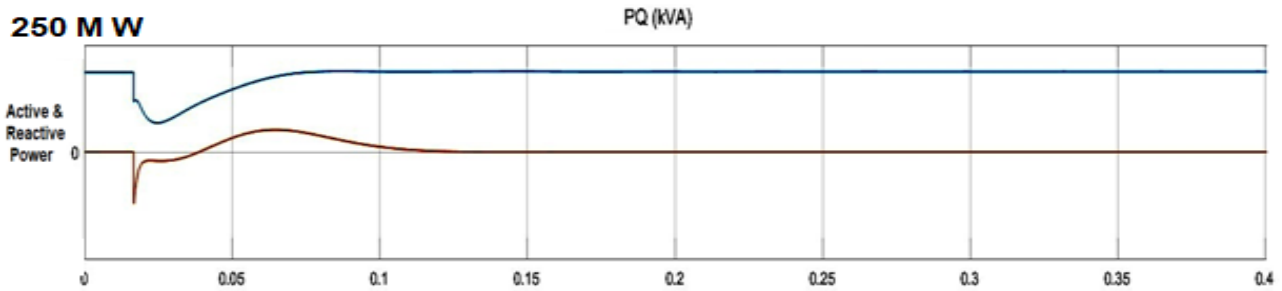


Figure4.Active and Reactive power drawn from the Grid

The harmonic profile of Voltage & current injected to grid is also investigated and presented in figure 5 and figure 6 respectively. It is observed that the voltage THD is 1.13% of fundamental frequency and current THD is 0.49% of fundamental frequency.

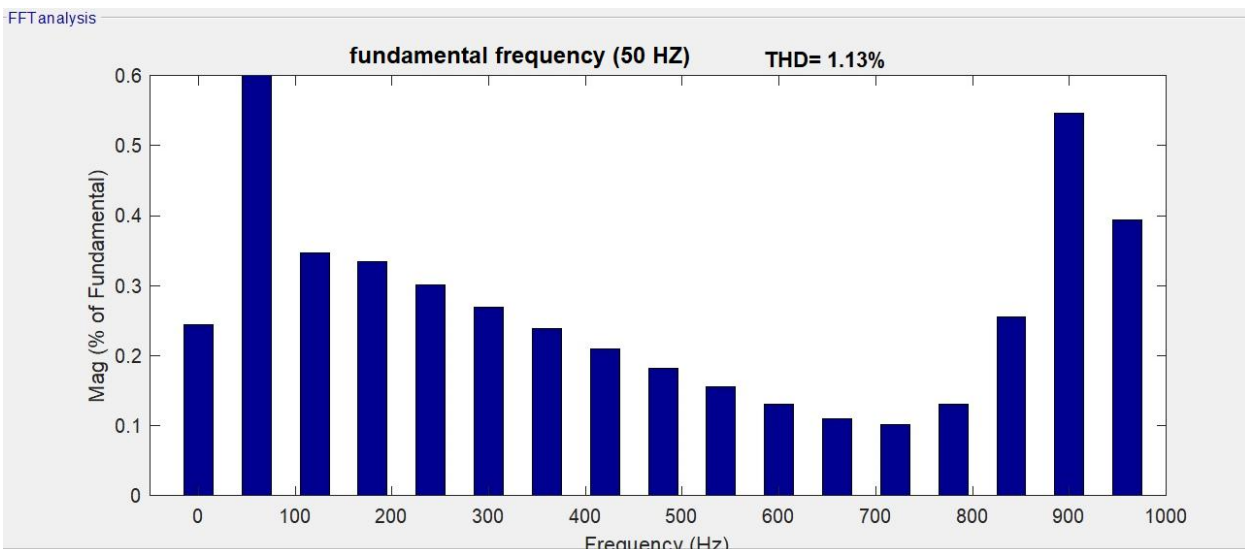


Figure 5.THd of Voltage injected to grid

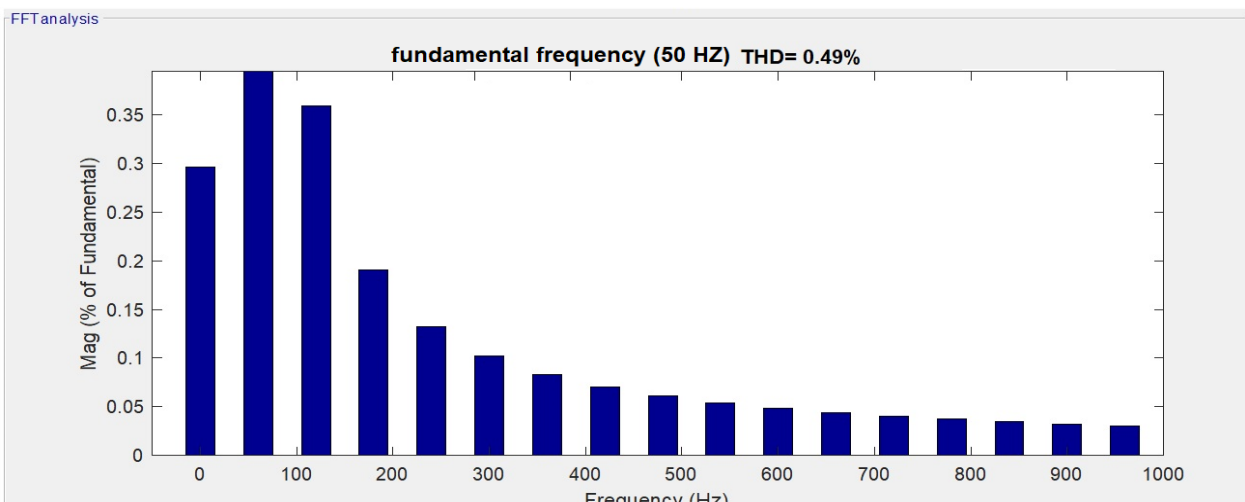


Figure6.THd of current injected to grid



Conclusion

Photovoltaic Systems have developed into a mature technology used for mainstream electricity generation. However, they introduce numerous negative impacts into the electrical networks. Investigation of three impact is been provided. A grid-connected 250MW PV system was considered and simulated in MATLAB software. Harmonic content introduced by PVsystem with a 3-phase DC/AC inverter, at grid side was found to be within the limits. Reactive power support with regards to varying load power factor and varying PV penetration levels was studied. The studies carried out will help PV power generators and utilities the issues to be studied for a grid connected PV system.

References

- D.M. Tobnaghi, "A Review on Impacts of Grid-Connected PV System on Distribution Network," *International Journal of Electrical, Computer, Energetic, Electronic and Communication Engg.*, Vol. 10, No.1, 2016.
- B.K. Perera, P. Ciufu, S. Perera, "Point of Common Coupling (PCC) voltage control of a grid-connected solar Photovoltaic (PV) system," *39th Annual Conference of the IEEE Industrial Electronics Society (IECON 2013)*, 2013, pp.7475-7480.
- R. Sabzehgar, "A review of AC/DC microgrid-developments, technologies, and challenges," *2015 IEEE Green Energy and Systems Conference, IGESC 2015*, pp. 11-17, 2015.
- M. Lede, M.G. Molina, M. Martinez, and P.E. Mercado, "Microgrid architectures for distributed generation: A brief review," *2017 IEEE PES Innovative Smart Grid Technologies Conference - Latin America, ISGT Latin America 2017*, vol. 2017-Janua, pp. 1-6, 2017.
- Dwivedi, A., Pahariya, Y. Design and Analysis of Hybrid Multilevel Inverter for Asymmetrical Input Voltages. *J. Electr. Eng. Technol.*, 16, 3025-3036 (2021). <https://doi.org/10.1007/s42835-021-00814-5>.
- F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, "Overview of control and grid synchronization for distributed power generation systems," 2006.
- P. Rodríguez, R. Teodorescu, I. Candela, A. V. Timbus, M. Liserre, and F. Blaabjerg, "New positive-sequence voltage detector for grid synchronization of power converters under faulty grid conditions," *PESC Record - IEEE Annual Power Electronics Specialists Conference*, 2006.
- P. Rodriguez, A.V. Timbus, R. Teodorescu, M. Liserre, and F. Blaabjerg, "Flexible Active Power Control of Distributed Power Generation Systems During Grid Faults," *IEEE Transactions on Industrial Electronics*, vol. 54, no. 5, pp. 2583-2592, 2007.
- H.S. Song and K. Nam, "Dual current control scheme for PWM converter under unbalanced input voltage conditions," *IEEE Transactions on Industrial Electronics*, vol. 46, no. 5, pp. 953-959, 1999.
- J. Rocabert, A. Luna, F. Blaabjerg, and I. Paper, "Control of Power Converters in AC Microgrids.pdf," *IEEE Transactions on Power Electronics*, vol. 27, no. 11, pp. 4734-4749, 2012.
- J.M. Guerrero, J.C. Vasquez, J. Matas, L.G. DeVicuña, and M. Castilla, "Hierarchical control of droop-controlled AC and DC microgrids - A general approach toward standardization," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 1, pp. 158- 172, 2011.
- E. Afshari, "A Low-Voltage Ride-Through Control Strategy for Three-Phase Grid- Connected PV Systems," *2017 IEEE Power and Energy Conference at Illinois (PECI)*, no. 1, pp. 1 - 6, 2017.
- D.E. Olivares, A. Mehrizi-Sani, A.H. Etemadi, C.A. Cañizares, R. Iravani, M. Kazerani, A.H. Hajimiragha, O. Gomis-Bellmunt, M. Saeedifard, R. Palma-Behnke, G.A. Jiménez-Estévez, and N.D. Hatziargyriou, "Trends in microgrid control," *IEEE Transactions on Smart Grid*, vol. 5, no. 4, pp. 1905-1919, 2014.
- M. Villalva, J. Gazoli, and E. Filho, "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays," *IEEE Transactions on Power Electronics*, vol. 24, no. 5, pp. 1198-1208, 2009.
- N.E. Zakzouk, A.K. Abdelsalam, A.A. Helal, and B.W. Williams, "PV Single-Phase Grid-Connected Converter: DC-Link Voltage Sensorless Perspective," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 1, pp. 526-546, 2017.
- T. Huang, X. Shi, Y. Sun, and D. Wang, "Three-phase photovoltaic grid-connected inverter based on feed forward decoupling control," *ICMREE 2013 - Proceedings: 2013 International Conference on Materials for Renewable Energy and Environment*, vol. 2, pp. 476-480, 2013.
- J. Guerrero, F. Blaabjerg, T. Zhelev, K. Hemmes, E. Monmasson, S. Jemei, M. P. Comech, R. Granadino, and J. I. Frau, "Distributed generation: Toward a new energy paradigm," *IEEE Industrial Electronics Magazine*, vol. 4, no. 1, pp. 52-64, 2010.
- J. Svensson and A. Sannino, "Improving Voltage Disturbance Rejection for Variable-Speed Wind Turbines," *IEEE Power Engineering Review*, vol. 22, no. 7, p. 53, 2002.

