Battery Storage Photovoltaic Grid-Interconnected System: Part-IV

Ritesh Dash and S.C. Swain

Abstract This paper basically describes about the phenomena of off-grid and on-grid electrification of renewable energy sources like photovoltaic and wind system. The main objective of the paper is to find some grid standard for interconnection of these renewable sources to the existing grid. To study the behavior of the system a matlab based model has been designed by taking solar PV, wind and a conventional grid. The simulation of the system focuses on maximum power extraction from the grid, grid code prediction, real and reactive control of power.

Keywords Grid interconnection · Solar PV system · Storage system · Maximum power point tracking · Real and reactive power control · Wind turbine

1 Introduction

A clean, green, and zero-pollution emission concept drives us to think for harvesting renewable energy. As the people demand for more and continuous supply of energy we cannot simply rely on thermal power plant. Therefore, both the wind and solar can be used together for a better performance and also can increase the system reliability. The research-based development of solar PV and wind make it possible to design a stand-alone system or a grid-interconnected system. If some other sources like biogas, biodiesel, or a storage device are interconnected then it may be treated as a hybrid system. However, the control of hybrid system is more difficult than the control of simple wind or solar system.

The integration of renewable sources requires a full bridge inverter which always creates a problem in real-time implementation. The inverter must be designed in such a way that it should not affect the voltage magnitude at the grid side or inject any reactive power of more than 5 % and this value is not fixed generally and vary

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L.P. Suresh and B.K. Panigrahi (eds.), *Proceedings of the International Conference on Soft Computing Systems*, Advances in Intelligent Systems and Computing 397, DOI 10.1007/978-81-322-2671-0_75

from country to country. Under transient conditions, the inverter may sense a low voltage at its output terminal and isolates itself from the grid. So inverters must be designed to withstand these small voltage fluctuations. Under voltage sag conditions, if islanding occurs then the whole performance is affected and collapse of grid may occur. So it is very important to predict a control strategy which can operate the system safely under such adverse condition.

In a renewable-based grid-interconnected system, it is always assumed that the grid voltage is constant. However, in a practical system it is always fluctuating. So this paper tries to find the problems associated with a dynamic system where the parameters are variables.

This also allows large penetration of solar PV system into the existing grid. Here a battery storage system is also provided for increasing the performance under the absence of PV system.

This paper investigated the performance of a hybrid system under different power quality condition. The solar photovoltaic system is connected near the load end which is again located in a remote area. The load is connected through a doubly fed transmission line with the grid. The coupling capacitor which is used for the interconnection purpose may affect the grid voltage. Therefore series compensation to the system is applied to increase the performance.

2 Hybrid System

2.1 Annual Energy Consumption

According to Indian electricity rule, each consumer in an urban area is supplied with a 2 kW of load. However, the average energy consumption by a customer is 1200 W. So in this regard the total monthly average may be 36,000 W or 36 kW. So here an average of 40 kh is considered for operation.

2.2 Solar Panel Calculation

Harvesting the solar energy is a very difficult task, because of its weather-dependent property. The average efficiency of a solar photovoltaic system is only 19 %. So it requires a lot of photovoltaic panel to meet the load demand. From estimation the average solar energy that a panel receives is about 2.2 MWh. So if the entire earth surface is covered with the solar panel then it can supply the entire world demand. But it is not possible because of its low efficiency. So, considering a polycrystalline solar cell of annual producing capacity of 316 kwh of energy, the number of panels required is 68 (Fig. 1).

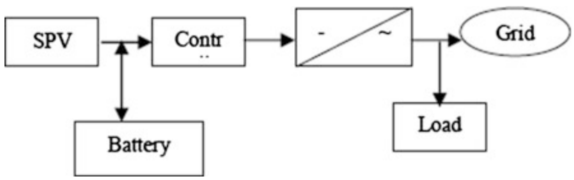

Fig. 1 Overall line diagram

2.3 Solar Panel Operating Condition

Photovoltaic system produces energy from 8 a.m. to 4 p.m. The total energy produced by the system throughout the whole day may be more than the required energy. So after utilizing the energy the surplus can be stored for future. Another advantage of storing the energy is in sudden cloudy condition the photovoltaic system may not produce the energy to withstand the peak load and it will affect the system stability. So to avoid unintentional islanding the help of battery can be taken. However, it increases the overall cost (Fig. 2).

2.4 Controller

One of the most important problems in the renewable grid interconnection is maintaining the DC the bus. There are basically two topologies like droop control method and master control method. Droop control method does not require any grid converter communication. Therefore it is the simplest method of controlling the DC voltage over the DC bus than the master control method, which requires a continuous communication between the converter and grid. Therefore, it requires a lot of control action which is complex and also it generates error during online monitoring system.

Master control can be achieved by two methods like inner loop control and outer loop control method. Inner control method provides the current control where as outer loop provides the voltage control. In a general sense, the voltage control

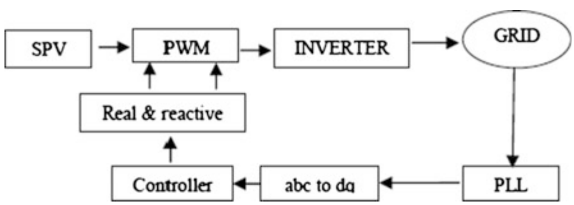

Fig. 2 Controller diagram

provides the reactive power control and the current provides control of real power. It is because in a renewable grid interconnection system the inverter should not inject any reactive power into the grid. To achieve this, different types of controllers like linear and nonlinear controllers are used. The improvement in nonlinear controller such as deadbeat-type controller, resonant controller makes it possible for a variable source grid interconnection.

3 Results and Analysis

In our earlier paper, we have simulated the grid-connected system to use it to supply a load which is located in a remote area at a distance of 15 km. Here the same system is again modeled with a storage device. The proposed storage device is a nickel–cadmium battery. The number of batteries exactly required to withstand fluctuation can be calculated through a proper simulation. The below-shown Fig. 3 shows the state of charge of the battery. Each battery in the system has a full load voltage of 12 V and has a maximum capacity of 14.856 V. The typical capacity of the entire battery system is 2000 A. The simulation for the proposed system has been tested under different solar irradiance condition like 1000, 800 and 400 W/m^2. The system consist of a radial bus system having four number of alternator each of 2500 MVA. The grid is supposed to supply a load of 1 MW located at a remote location. Figure 1 shows the daily load profile of the load (Fig. 4).

Table 1 shows the different parameters used in the simulation. Based on the different simulation results, the maximum penetration label can be determined. Figure 5 shows the charging and discharging conditions of the battery.

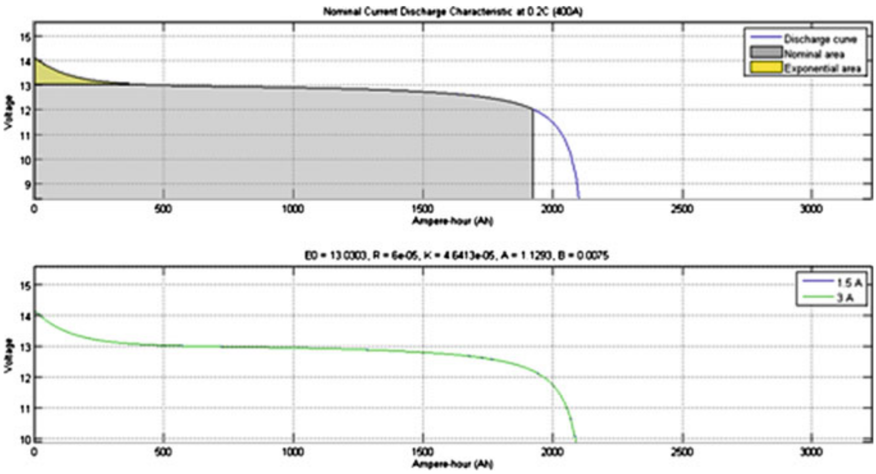

Fig. 3 Battery discharging characteristics

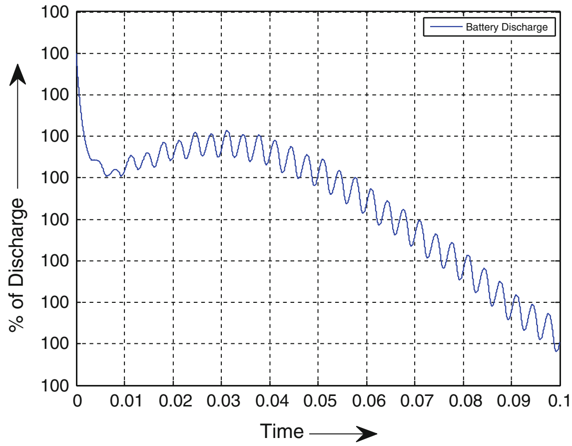

Fig. 4 State of discharge of battery

Table 1 System parameters under consideration

Bus no.	Generator (MW)	Voltage (kV)	Load (MW)	Transformer
Solar bus	1	0.4	1	400 V/33 kV, 55 MVA
1	250	11	–	11 kV/33 kV 47 MVA
2	250	11	–	11 kV/33 kV 47 MVA
3	160	11	–	11 kV/33 kV 25 MVA
4	85	13.8	–	11 kV/33 kV 25 MVA
5	–	33	45	–
6	–	33	40	–

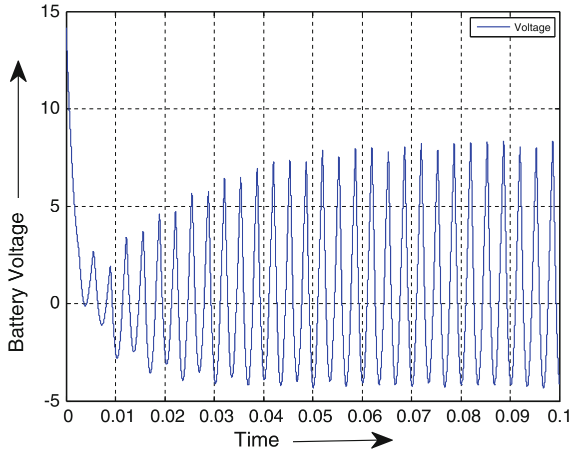

Fig. 5 Battery charging and discharging condition

Figure 6 shows the flowchart of the proposed model. The algorithm first reads the output power of the solar photovoltaic system and the grid. Based on the measured value, it checks for power over flow. If the PV power is sufficient then it will directly connect the PV to the load after proper control of the real and reactive power of the system. For control of real and reactive power, it applies the park's transformation and calculates the phase angle. It then fed the phase angle to the

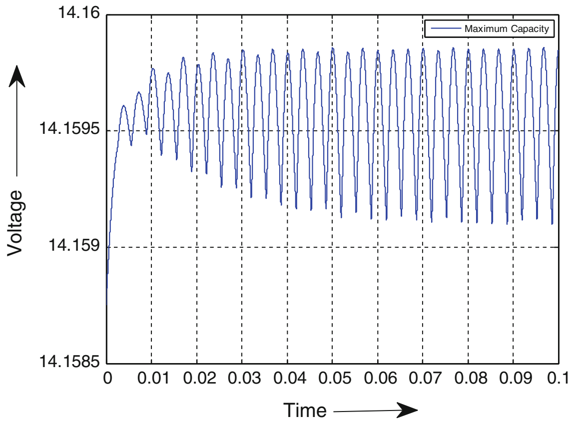

Fig. 6 Battery maximum charging and discharging condition

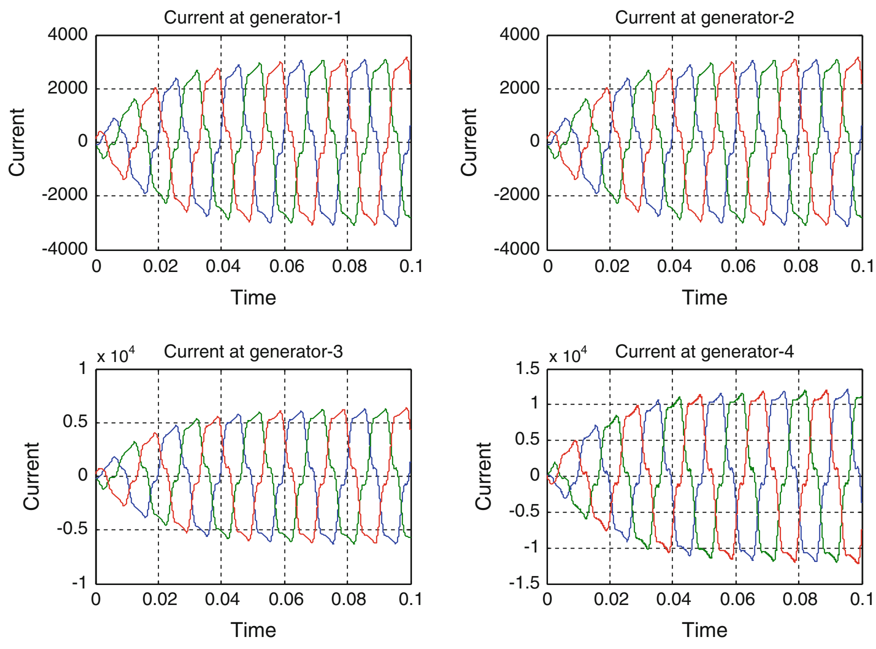

Fig. 7 Current at different generators

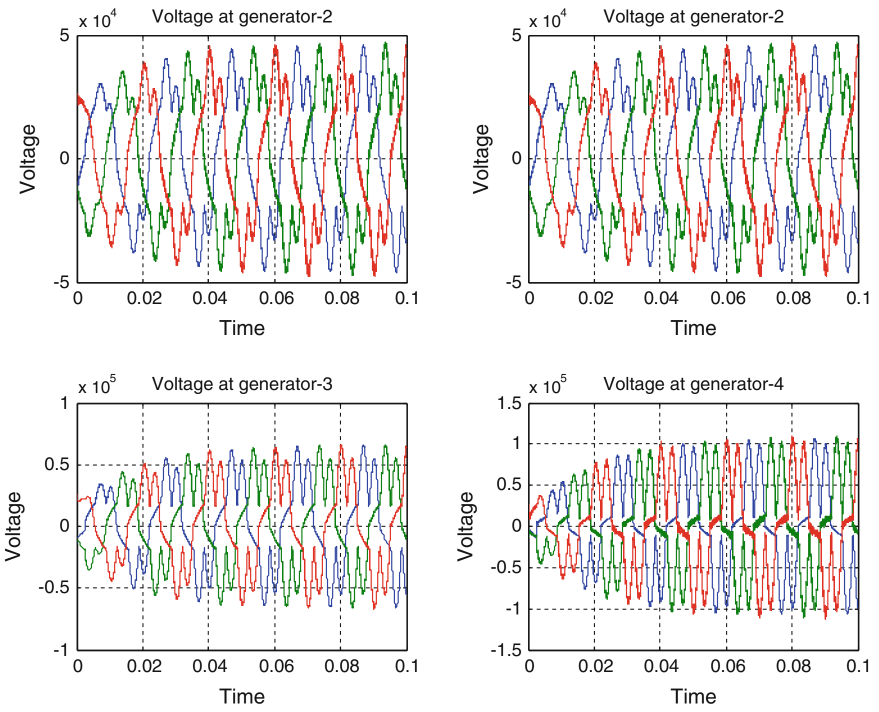

Fig. 8 Voltage at different generators

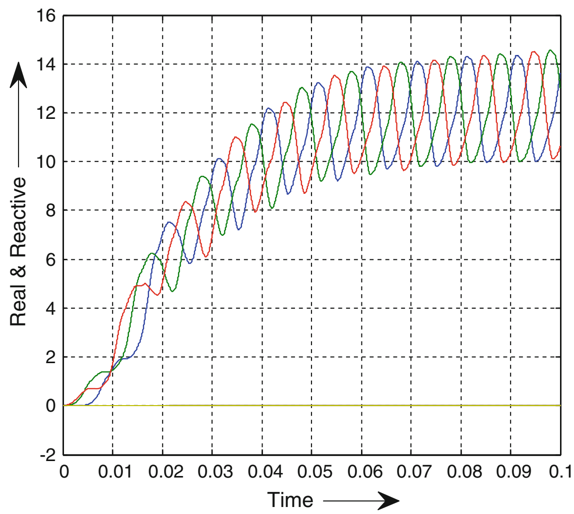

Fig. 9 Real and reactive at load-1

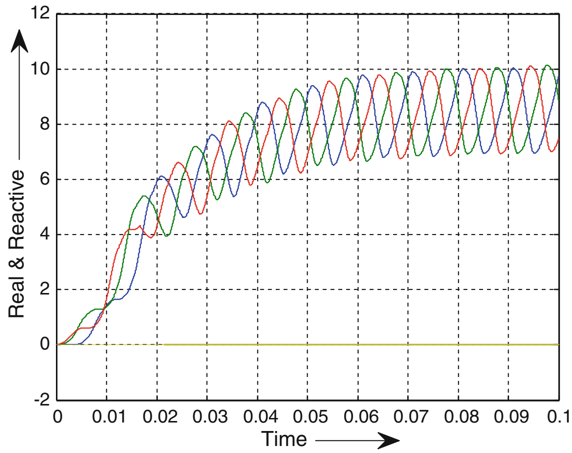

Fig. 10 Real and reactive at load-2

PWM converter for further calculation of required power factor and corresponding firing angle. Upon receiving the boosted voltage it again compare power with the load power, if the two quantities match with each other, then synchronization is done. If the hybrid system is sufficient to meet the load demand, then system will run smoothly or will be completely isolated from the grid (Figs. 7, 8, 9, and 10).

4 Conclusion

The result presented in this paper depicts about different problems associated with a grid-connected hybrid system. The simulation can be taken as a reference for stand-alone system design. However, the problem of grid integration and two-way metering system can be eliminated through proper system modeling and design. For increasing the stability of the system, wind mills can also be incorporated. However, their variable speeds with respect to wind may create instability problem. Both PI and deadbeat controller can be employed for achieving the system stability. This also reduces the complexity of the system.

Acknowledgments The authors would like to thank the school of electrical engineering for providing necessary laboratory facility throughout the project work.

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