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Control of Grid-Connected Photovoltaic Systems to Improve the Voltage Profile of a Distribution Feeder

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***Abstract*: This paper presents a photovoltaic system interconnecting 15 bus radial distribution feeder for the finding the variation of bus voltage and line current. It consists of a PV array in addition to a power conditioning system for grid interfacing purposes. The power conditioning system is composed of a DC-DC boost converter, followed by a current controlled Voltage Source Inverter (VSI)). An analysis of bus voltage and line current is made with the simulated model. By connecting PV to the loaded line its voltage profile can be improved.**

Index terms: **MPPT, Voltage source inverter, photovoltaic, reverse saturation current**

I. INTRODUCTION

The present energy production has mainly been based on energy sources like oil, gas and coal, which until today was looked upon as close to inexhaustible. As the global energy consumption is growing with a drastically high rate and the fossil fuels reserves are shrinking, the urge for renewable energy resources has attained more focus [1]. Both renewable and non-renewable energy resources are mostly created by the sun rays hitting the surface of the earth. The sun is a non-polluting resource responsible for the sustained life on earth. Among the renewable energy resources are hydro power, wind power and solar energy. While hydro power has been a well-known technology for a long time, there is a lot of research going on with wind and solar power today. Solar energy as a source of energy has a large theoretical potential, and can be utilized both directly and indirectly. In a grid connected Photovoltaic (PV) inverter system the PV system utilize the solar energy as the power source and transfer the power into the grid through power electronics conditioning.

The strategy behind Maximum Power Point Tracking (MPPT) results in appreciable increase in the efficiency of the Photovoltaic System. The MPPT algorithm thus proposed identifies the suitable duty ratio in which the DC/DC converter should be operated to obtain maximum power output. However the solar radiation never remains constant. The main objective is to track the maximum power point (MPP) of the solar array by modulating the DC-DC converter's duty cycle, thereby, optimizing the power output of the panel. The Perturb and Observe (P&O) algorithm is utilized here which performed with a higher overall efficiency capable of tracking the MPP quickly[2].

II. EVALUATION OF THE BASIC BLOCKS

The major components of a grid connected PV system are shown in figure 1. It consists of a PV array, DC–DC Boost converter, and a voltage source inverter. The module making solar array converts sun's energy to direct current (DC). This output has to be converted to AC for interfacing with the grid. The mounting system supports the solar array at different angles to the sun. Output of a PV array varies with temperature and irradiation. Irradiation is the amount of radiation both direct and diffused that can be received at any given location. MPPT method is used to track maximum power from the solar array. The switching of DC-DC converter is based on MPPT.

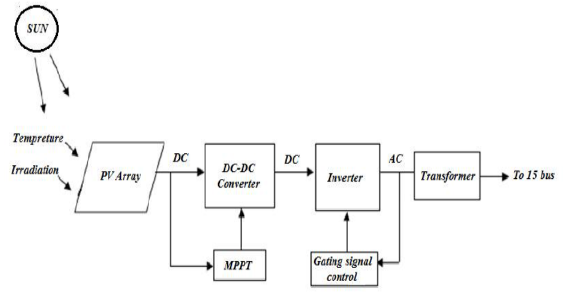

Fig.1. Block diagram of grid connected photovoltaic system

The DC–DC boost converter extracts maximum power from the solar array and increases the terminal voltage to a level suitable for interfacing with the 15 bus.The voltage source inverter converts DC to AC. For the switching of inverter gating signals are provided. The transformer increases the voltage and the system is interfaced to the 15 bus.

The equivalent circuit model of a PV cell is needed in order to simulate its real behavior. Using the physics of p-n junctions, a PV cell can be modeled as a DC current source in parallel with a diode that represents currents escaping due to diffusion. Two resistances, R_s and R_p, are included to model which are the contact resistances and the internal PV cell resistance respectively. PV cell equivalent circuit model is shown in Fig.2.

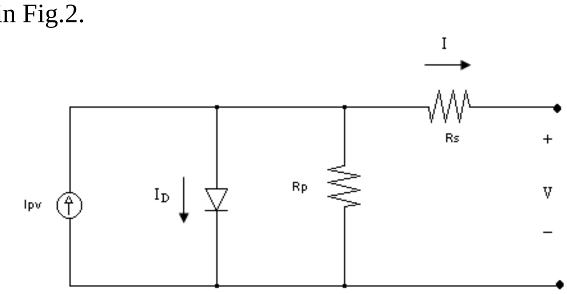

Fig 2. PV Cell Circuit Model

$$I = I_{PV} - I_D - \frac{V+IR_S}{R_P} \qquad (1)$$

$$I_D = I_0 \left[\exp\left(\frac{(V+IR_S)}{\alpha KT}\right) - 1\right] \qquad (2)$$

Where I_{pvc} is the PV cell internal generated photocurrent, I_D is the currents passing through diode *D*, '*a*' isthe diode ideality factor, *k* is the Boltzmann constant(1.3806503 × 10^{-23} J/K), *T* is the PV cell temperature in Kelvin, *q* is the electron charge (1.60217646 × 10^{-19} C), $I_0$is the reverse saturation currents of each diode respectively.

A number of MPPT techniques have been developed for PV systems, and for all conventional MPPT techniques the main problem is how to obtain optimal operating points (voltage and current) automatically at maximum PV output power under variable atmospheric conditions. The majority of MPPT control strategies depend on characteristics of PV panels in real time, such as the duty cycle ratio control and using a look-up table.

The perturb-and-observe method, also known as perturbation method, is the most commonly used MPPT algorithm. Here we are using perturb-and-observe method for the switching of DC-DC boost converter.The PV array was connected at the input side of the converter while the DC link capacitor was connected at the output. The power and voltage from the PV array is measured and the difference between the present power and the previous power is measured, also the difference between the present voltage and previous voltage is measured and it is compared to zero and is given to a switch which switches according to the set condition.The power, voltage and current at maximum power point of the PV array is tracked by the MPPT. The gating signals obtained from the MPPT controller controls the switching of MOSFET of the boost converter.

The voltage source inverter was used to convert the DC output of the PV array to AC power. The aim of the control strategy in this work is to regulate the current output from the inverter to follow a specified reference signal. A possible way of doing so is to convert the three phase output current of the inverter to a rotating reference frame (*dq0*) and then shape the output current as desired.

III. BASIC STRUCTURE OF 15 BUS DISTRIBUTION SYSTEM

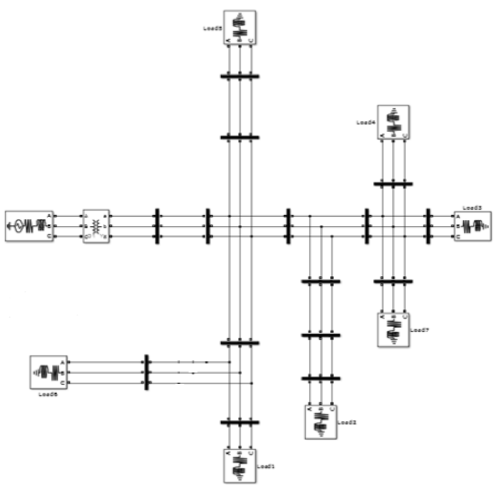

Figure 3: 15 bus radial distribution system without DG

In this work, 15 bus, 11KV radial distribution system Connected with substation is taken as the test system as shown in Fig. 1. This system consists of 4 main feeders and 10 lateral. Loads represented as constant power and shunt capacitances are neglected. It is assumed that the three phase radial distribution networks are balanced and loads are assumed to be constant. The substation consists of a step down transformer with voltages 230/11kV.The substation is taken as the slack bus and its voltage is taken as 1 pu. It is assumed that slack bus generates real and reactive power required for transmission losses.

The designed PV system is interfaced to the model of 15 bus radial distribution feeder using a circuit breaker. The opening time of the circuit breaker is set from 0.066 to 0.1666 seconds. The interconnected PV and 15 bus distribution system model is shown in the figure 4,

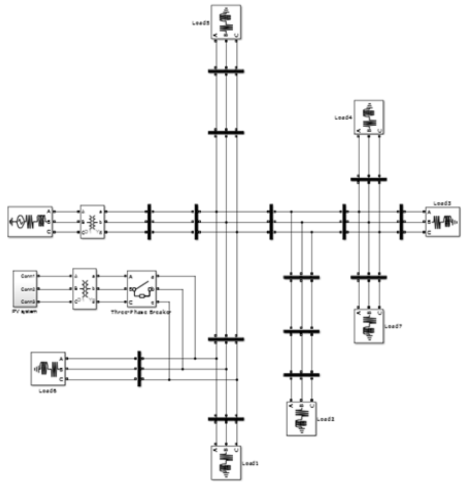

Figure 4: 15 bus radial distribution system with PV system

The main advantages of PV connecting to the distribution feeders are comparatively easier to install as they do not require a battery system.Grid interconnection of photovoltaic (PV) power generation systems has the advantage of effective utilization of generated power because there are no storage losses involved. A photovoltaic power system is carbon negative over its lifespan, as any energy produced over and above that to build the panel initially offsets the need for burning fossil fuels. Even though the sun doesn't always shine, any installation gives a reasonably predictable average reduction in carbon consumption. Also PV panels have no mechanically moving parts. So they are totally silent and producing no noise pollutions.

IV. SIMULATION RESULTS

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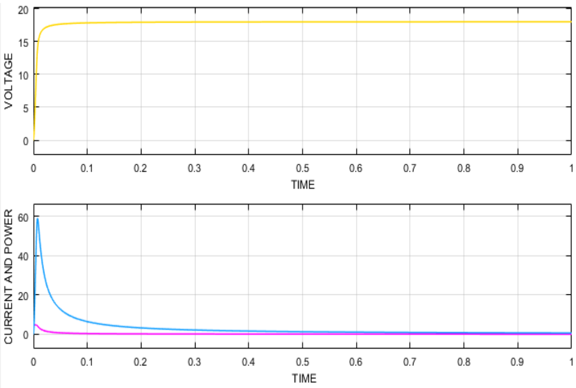
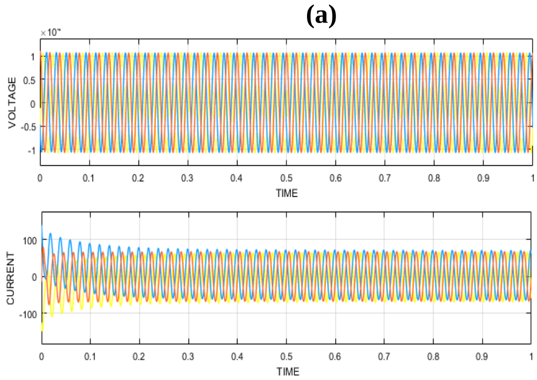
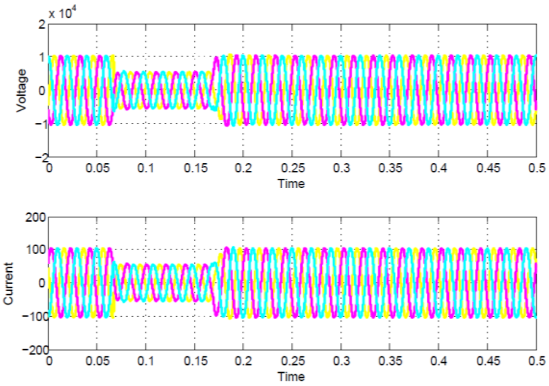
The simulation result of photovoltaic system is shown below:



(a)





(b)

(c)

Figure 5: (a)simulation result of PV module,(b)simulation result of PV system (c) simulation result of PV interfaced 15 bus distribution feeder.

The voltage, current and power waveform of the PV module simulation is shown in figure (a). From this we can easily point out the maximum power point. The figure (b) shows the simulation result of a PV system consist of a PV array, DC–DC Boost converter, and a voltage source inverter. The output voltage of pv system is in the range 11KV and initially the current is high due to switching then settles around 80 amps. The figure (c) shows the simulation result of the PV interfaced to the 15 bus distribution network.The opening time of the circuit breaker is set from 0.066 to 0.1666 second, from the simulation result it can be seen that during the opening time there is low voltage in the feeder .And while connecting PV the voltage profile is improved.

CONCLUSION

Grid interconnection of solar powered inverter is presented with 15 bus system model using Matlab simulation.The main objectives were to improve the voltage profile of the radial distribution feeder and reduce voltage variations.An analysis of bus voltage and line current is made with the simulated model.By connecting PV to the loaded line its voltage profile can be improved.

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