Grid Connected Solar With Multilevel Inverter System

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Abstract: The main purpose for proposed work is to develop an inverter for AC module applications. The aim is to develop new and cost-effective solutions for injection of electrical power, generated by PV modules, into the grid. The proposed module must result in an inverter for use with a single PV module, approximately from 120 W to 160 W. The inverter should be made with economical specifications, high reliabilityand mass-production in mind. The project will end up with an inverter, which can be bulk-produced within short time. The proposed work lies in extracting maximum harvestable power from a Photovoltaic module and use the energy for a DC application as well as the grid connection of the generated power so that the surplus power unutilised in the load can be transferred to the grid. Maximum Power Point Tracking (MPPT), use of Boost converter and the importance of bridge inverter have been the main investigation in this project. Also, the grid connection along with supply to a three-phase load using bridge inverter and PWM has been shown. First SIMULINK software is used to model the photovoltaic cell. Then MPPT interfacing is done with a boost converter and resistive load and finally through an inverter connected to the 3-phase grid. All simulations have been done in SIMULINK software of MATLAB.

Keywords: Grid, PV module, Inverter, MPPT, Harmonics.

1. Introduction

In the near future, the demand for electric energy is expected to increase rapidly due to the global population growth and industrialization. This increase in the energy demand requires electric utilities to increase their generation. Recent studies predict that the world's net electricity generation is expected to rise from 17.3 trillion kilowatt-hours in 2005 to 24.4 trillion kilowatt-hours (an increase of 41%) in 2015 and 33.3 trillion kilowatt-hours (an increase of 92.5%) in 2030 [1]. Currently, a large share of electricity is generated from fossil fuels, especially coal due to its low prices. However, the increasing use of fossil fuels accounts for a significant portion of environmental pollution and greenhouse gas emissions, which are considered the main reason behind the global warming. To overcome the problems associated with generation of electricity from fossil fuels, renewable energy sources can be participated in the energy mix. One of the renewable energy sources that can be used for this purpose is the light received from the sun. This light can be converted to clean electricity through the photovoltaic process. The use of photovoltaic (PV) systems for electricity generation started in the seventies of the 20th century and is currently growing rapidly worldwide. In fact, many organizations expect a bright future for these systems. Grid-connected PV systems can be installed on the facades and rooftops of buildings, on the shades of parking lots. They can also be installed as power plants that aim to inject all their produced power into the grid. Despite the increasing use of PV systems, these systems still face a major obstacle due to their high capital cost, which is reflected in the cost per KWh of the energy produced by them. This obstacle can be overcome by utilizing the recent technology in developing low cost PV cells and by providing incentives to customers that tend to install these systems. Another major issue that faces the widespread of PV systems is that the increasing installation of grid-connected PV systems, especially large systems in the order of megawatts, might lead to some operational problems in the electric network.

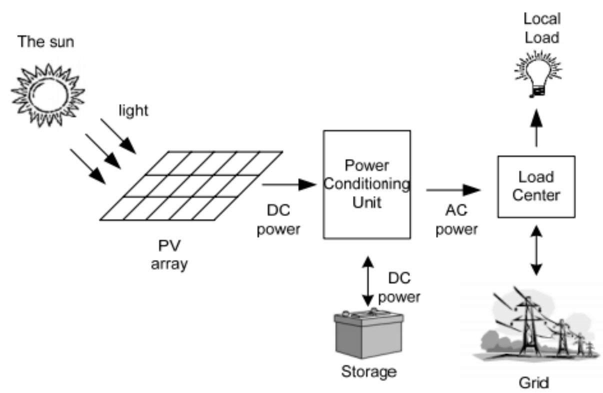

Figure 1: Components of grid connected photovoltaic system.

This issue, which is the main focus of the research presented in this thesis, can be tackled by accurately evaluating the impacts of installing PV systems on the performance of the grid and finding solutions that can reduce the operational problems that might arise due to their installation. While a solar panel has the capacity to convert only 30-40% of incident energy on it to useful electrical energy experiment show that the efficiencies of various types and makes of solar panel varies from 3% (amorphous grade silicon solar cells) to 25 % (single crystal silicon solar cells) [1][2]. Therefore, in order to increase the power output of the PV system there is aneed of various algorithms and tracking systems. There are different techniques for MPPT such as Hill climbing method (P&O), Fractional Short Circuit Current, Incremental conductance, Neural Network Control, Fractional Open Circuit Voltage, etc. The simplicityof implementation and short duration of operation makes Perturb and observe (P&O) andIncremental conductance algorithms popular.

2. Components of Grid-Connected PV Systems

The building blocks of a grid-connected photovoltaic system are shown in Figure 1. The system is mainly composed of a matrix of PV arrays, which converts the sunlight to DC power, and a power conditioning unit that converts the DC power to AC power. The generated AC power is injected into the grid and/or utilized by the local loads. In some cases, storage devices are used to improve the availability of the power generated by the PV system. In the following sub-sections, more details about different components of the PV system are presented and the recent related research activities are discussed.

3. Modelling of PV system

3.1 Photovoltaic System Components

Photovoltaic Cell: A photovoltaic cell or photoelectric cell is a semiconductor device basically a P-N junction diode that converts light to electrical energy by photovoltaic effect [1]. When photon particles of light having energy greater than the band gap of the valence electron is bombarded to the junction electron hole pairs are generated which when acted upon by internal electric field result in a photocurrent. PV cell is basically a current source [2] where current is produced by the variation of photons not the voltage.

PV module: It consists of a large number of P cells arranged in series or parallel or a mixture of both tomeet the consumption demand. PV modules of various materials and enhanced efficienciesand of desired size are available in the market.

PV modeling: Typically, a solar cell can be modelled by a current source and an inverted diode connected inparallel to it. The PV cell has its own series and shunt resistance. Series resistance is due to the diode resistance (of the bulk material) & resistance of metal contacts whereas parallelresistance represents the electron hole recombination before t reaches the load. A current source (I) along with a diode and series resistance (Rs) is considered. The shunt resistance (Rsh) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array can be given by

I=ISC – Id (1)

Id=I0(eqVd/kT-1) (2)

Operation of PV Cell

A PV cell is essentially a large silicon PN junction (diode), Figure 2. The incoming of a photon makes the current flow: the PN junction has become a PV cell. The silicon atom contains four electrons in the outer shell. The electrons are a part of the electron pairs binding with four other silicon atoms. By doping the silicon with boron (p-doped), which has only three electrons in the outer shell, the silicon becomes electron deficit. Thus, a 'hole' is present in the silicon lattice, and positive charges may move around in the network. When doped with phosphorus (n-doped), which have five electrons in the outer shell, the silicon become electron saturated. These additional electrons are also free to move around in the lattice. The PN junction, where the two alloys meet allows free electrons in the n-doped layer to move into the holes in the p-doped layer. An internal field is being build and the electrons can no longer force the junction, thus the layers have reach equilibrium. The amplitude of the built-in potential is:

$$\phi_i = \frac{k.T_{cell}}{q}.\ln\left(\frac{N_a.N_d}{n_i^2}\right) \quad (3)$$

Where N_a and N_d are the acceptor and donor doping densities correspondingly, and n_i is the intrinsic carrier density, which do not contain boron or phosphorus. The constant k is Boltzmann ($13.8x10^{-24}$ J/K), q is the electron charge ($160x10^{-19}$C), and T_{cell} is the absolute cell temperature.

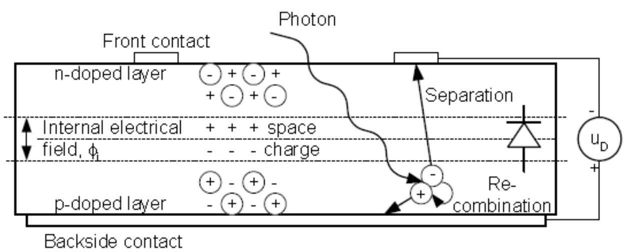

Figure 2: Cross section of an abrupt PN junction

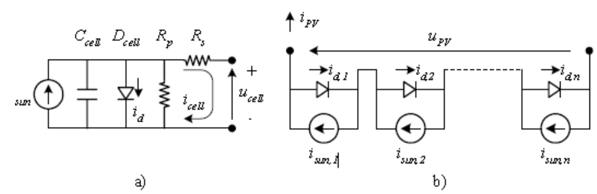

Figure 3: Electrical model of a PV cell (a) and of a PV module made up around n cells (b).

Model of PV Cell

An electrical model of the PV cell is shown in Figure.3(a). The PV module is collected of n of these cells in series, as shown in Figure.3 (b), in order to reach a high voltage at the terminal. The relationship of PV cells in series is named a string. From Figure 3(b) and the theory of superposition, it becomes clear that the current generated by the PV module is resolute by the lowest i_{sun}, this is the principle of the weakest link. Thus, mind must be taken when selecting the PV cells for a PV module, so that the cells are equal.

4. Inverter Topologies

The alternative of a proper inverter topology depends on many issues besides the electrical specifications, such as electrolytic capacitors cable; thermal enclosure demands; silicon devices, magnetic, and efficiency, etc. All the objects above must be evaluated cautiously for each system layout and inverter topology collection. Figure 4. depicts the blocks diagram for an inverter for PV system for protection and internal power supplies, energy buffer for power-decoupling between the PV system and the single-phase grid, Electro Magnetic Interference (EMI) filter for minimize conduct electrical noise, and finally; the power electronic circuit that inverts the generated DC voltage to an AC current. The study of some of the most regular technical solutions for inverters for AC modules up to 350 Watt. The analysis concludes with an evaluation of the different topologies, based on generation, components ratings, price, and efficiency.

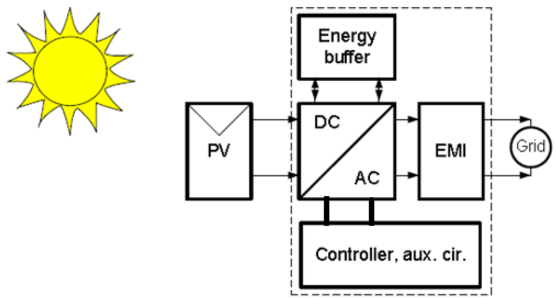

Figure 4: Block-diagram of an inverter for PV system.

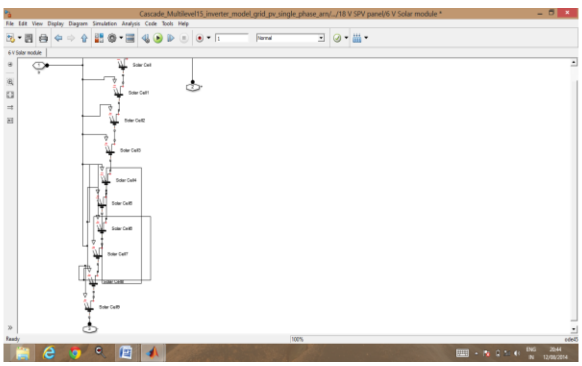

Figure 5. MATLAB connection of solar cells containing10 cells in parallel of 0.6V each

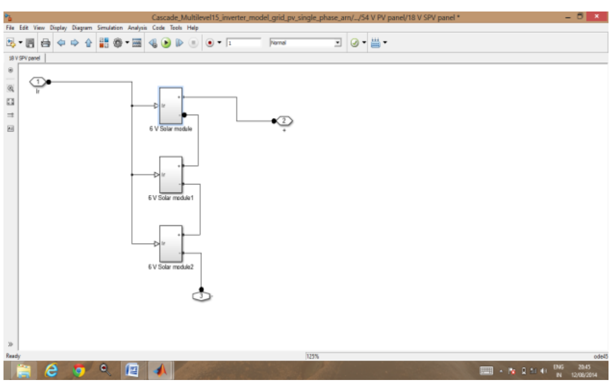

Figure 6: MATLAB connection of solar panel of 18V

5. Modelling of PV Module

The power source for each half bridge of MLI is a solar PV panel of 54V rating. The output of solar PV is considered at MPP with solar irradiance 1000 W/m^{2}and 25°C environment temperature. The nominal output voltage of solar PV module during run time is V = 54 volts, I = 4.8Amp. For this setup we use 10 solar cells of 0.6V each which are connected in parallel connected to produce 6V shown in Figure 5. combination of three6V solar modules make a 18V solar pannel shown in Figure6 and finally combination of three 18V solar panel make 54V solar pannel which is shown in Figure7.

5.1 Modelling of Multilevel Inverter

The half bridge is modelled using generic MOSFETs. Ratings of which can be observed in. Cascading of 7 half bridges form MLI to generate 15 level waveforms of 400V DC. This DC output is inverted into 15 level AC by the Full H bridge.

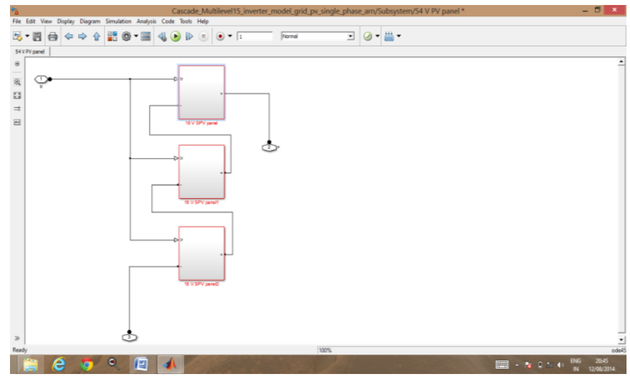

Figure 7: MATLAB connection of solar panel of 54V

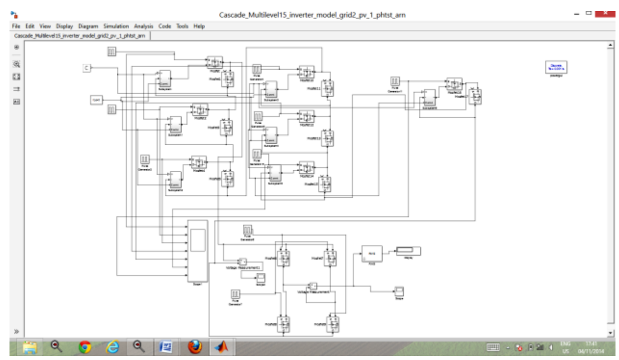

Figure 8: Simulation model of 15 level inverter

The DC output from the 15 level MLI is now fed to the inverter which is the interface between MLI and grid. The multilevel DC is synchronized with the grid using single phase inverter and PLL technique for transformer less grid synchronization. The final experimental setup is shown in Figure 9.

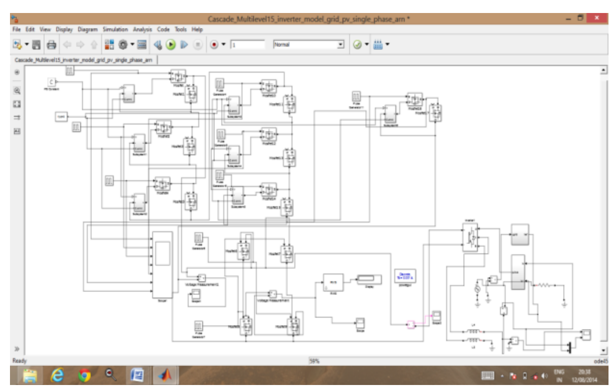

Figure 9: MATLAB Experment setup of solar inverter with grid syncronization

6. Experimental Results

The experimental model comprises of cascaded half bridge Multilevel Inverter of 15 levels, a Full H-bridge, Inverter, grid interfacing components and grid. Cascading of 7 half bridges form Multilevel Inverter to generate 15 level waveforms of 380 V DC. This DC output is inverted into 15 level AC by the Full H bridge. The output of MLI of given level is observed in Figure 6.1 showing all the levels, max voltage and timings. The DC output from the 15 level Multilevel Inverter is now fed to the inverter which is the interface between MLI and grid. The multilevel DC is synchronized with the grid using single phase inverter and PLL technique for transformer less grid synchronization. Figure 11 show synchronized output ac wave from grid interface. The peak voltage is 220 V AC and frequency is 50 Hz. The AC input in the grid is 11 level. The model is drawn on MATLAB platform SIMULINK tool version MATLAB R2012A.after opening the Simulink simulation can be started by RUN button on the menu. Simulation completes in 30 seconds. Output of each given waveforms can be observed on the scopes which automatically opens or can be opened during run time or after simulation time is over.

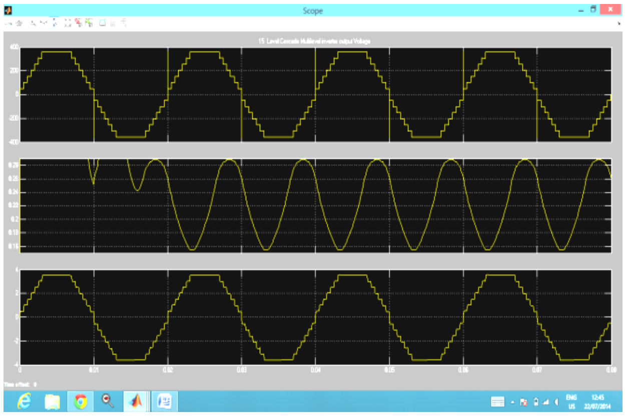

Figure10: 15 level waveform of solar inverter

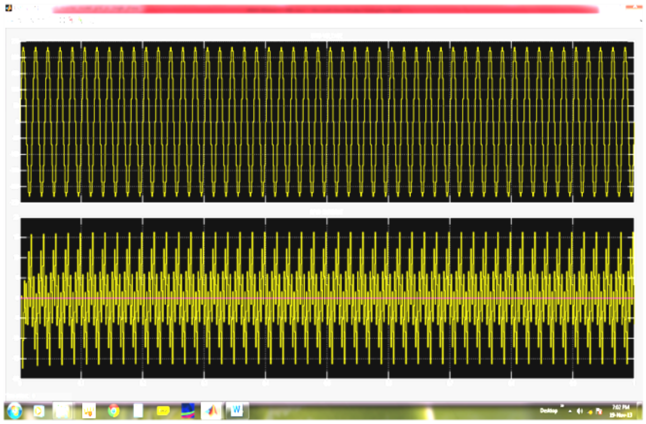

Figure11: 11 level waveform which injected in grid

7. Conclusions

In looking at the apparatus selected and the simulations formed before the authentic construction of the inverter, everything was built in mind for the reason of efficiency and keeping power losses to a minimum. The photovoltaic (PV) module is an all-electrical device that converts sunlight into electrical DC power. Solid-state power electronic inverters have been used to connect PV modules to the AC utility grid. The inverter has two main tasks: to inject a sinusoidal current into the grid, and convert solar DC voltage to AC voltage by using the solar inverter. The main objective for this thesis was to develop an inverter for the AC module, with special focus on cost, reliability, and efficiency.

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