Single Stage Renewable Energy Source to Grid Interface with Multilevel Current Source Inverter

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Abstract - Renewable energy sources can be used for electric power generation to supply specific devices in distributed systems like smart grids. Solar power based on the technology of grid-connected photovoltaic power has become the fastest growing and most widely application in the view of solar energy application. A single stage solution to interconnect a solar panel with a low voltage distribution system is proposed in this paper. The traditional Boost DC/DC converter plus Voltage Source Inverter is replaced by a Single Stage Multilevel Current Source Inverter (MCSI). The MCSI can both interconnect to the grid and perform the Maximum Power Point Tracking (MPPT) algorithm (dI/dV incremental conductance method). This novel single stage converter approach provides active power to the grid, power factor compensation and reduction of the line current harmonics content. The synchronization, modulation and control scheme are implemented on MATLAB/Simulink using a fast-prototype high-level synthesis tool to reduce design time. Both simulation and experimental results show excellent behaviour and fast dynamics, while complying with IEEE and IEC harmonic content regulations.

Keywords - *Multilevel Current Source Inverter, Solar Cells, MPPT, Grid Interface.*

I. INTRODUCTION

Renewable energy sources are one of the focal points of research in distributed power generation, attracting a significant amount of resources worldwide in the quest for new methods of energy generation and storage. Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect. Recent developments in super capacitors can be used to respond to rapid load changes or to start operation as soon as it is needed, compensating for the fact that solar cells do not have the capability to respond immediately. Solar panel built with a Multilevel Current Source Inverter (MCSI). Since MCSIs can boost the input voltage and Maximum Power Point Tracking (MPPT) is also achieved by controlling the reference signals of the MCSI. This solution reduces the complexity and power losses while increasing power density, efficiency and reliability of the system.

II. SYSTEM DESCRIPTION

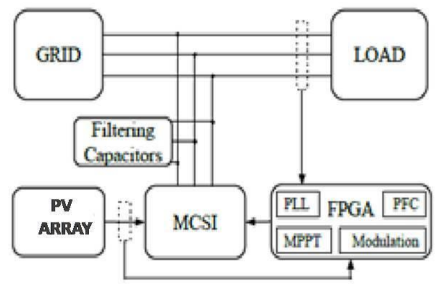


Fig.1 System lay out

A three phase MCSI is used to inject the current provided by a to a3x190VLL, 50Hz, three phase utility grid. An MCSI has three main advantages. Firstly it can be connected directly to the grid utility without any coupling inductors. Secondly, it can drain constant current from the solar cell. Thirdly, it requires smaller input voltage compared to traditional voltage inverters. Current source inverters have a large inductor on the DC side, this means that the current drained from the energy source has a low ripple. At the output a small capacitor bank is required to smooth commutation currents, avoiding over voltages due to inductances in the current path.

Shifted Carrier Sinusoidal Pulse Width Modulation:

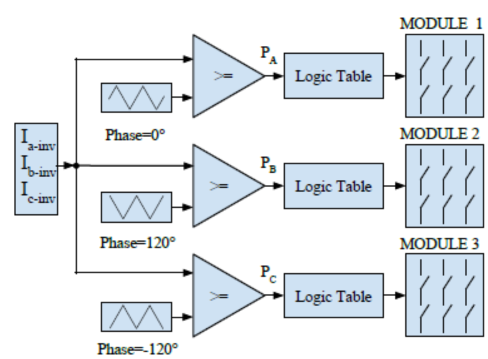


Fig. 2. Shifted carrier SPWM.

A. MCSI

The schematic diagram of the inverter is shown

Multilevel current source inverter connected to grid:

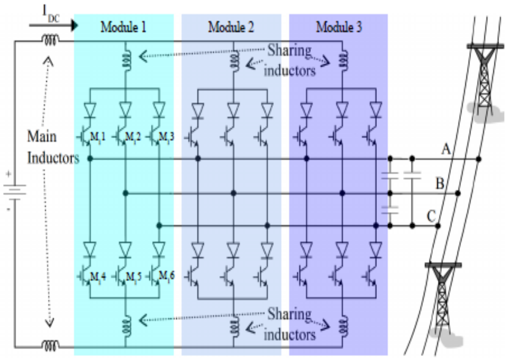


Fig. 3. Schematic of the MCSI.

It consists of three identical modules with the capability of producing seven levels in the output current, each module has six switches with bidirectional voltage blocking capabilities and two inductors to balance the current through them. All the balance inductors are identical

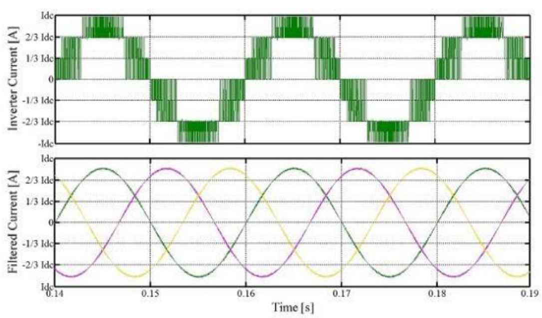


Fig. 4. Output current of the inverter. (Top) Phase-A unfiltered. (Bottom) Three phases filtered by the coupling capacitor bank.

and carry the same average current, simplifying the design, construction, operation and maintenance of the inverter. The current of each module can be balanced by the use of the well known Phase Shifted Carrier Sinusoidal Pulse Width Modulation (PSC-SPWM) in which gate signals are calculated comparing the reference signals with three equally phase shifted triangular waveforms.

B. Solar panel

A 36 solar cells PV panel used as a source. A solar panel works by allowing photons, or particles of light, to knock electrons free from atoms, generating a flow of electricity. Solar panels actually comprise many, smaller units called photovoltaic cells. (Photovoltaic simply means they convert sunlight into electricity.) Many cells linked together make up a solar panel. Each photovoltaic cell is basically a sandwich made up of two slices of semi-conducting material, usually silicon used in microelectronics. To work, photovoltaic cells need to establish an electric field. Much like a magnetic field, which occurs due to opposite poles, an electric field occurs when opposite charges are separated. To get this field, manufacturers "dope" silicon with other materials, giving each slice of the sandwich a positive or negative electrical charge.

C. Control

The control block must fulfill five coordinated functions:

_ set the current drained from the cell to track the maximum power point of the cell stack (MPPT algorithm).

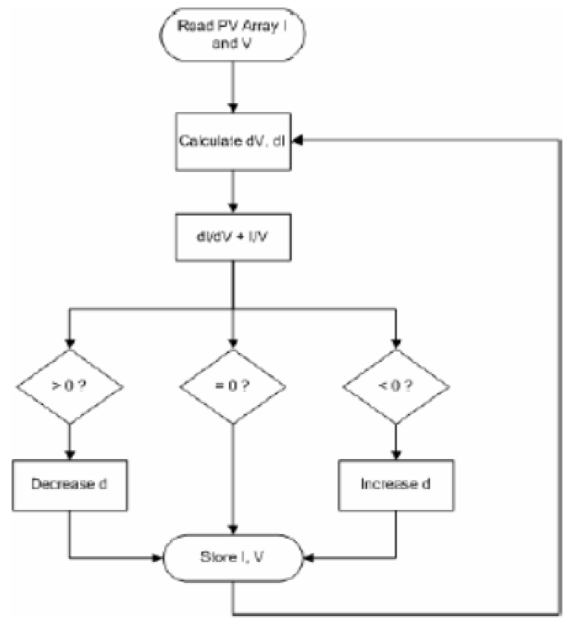


Fig 5.incremental conductance method

_ synchronize the MCSI with the grid,

_ generate the reference signals used for the modulation of the inverter .

adjust the active power delivered to the grid, and compensate reactive power and harmonics in the grid.

III. PROPOSED SYSTEM

A photovoltaic system is a system which uses one or more solar panels to convert solar energy into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output

PHOTOVOLTAIC ARRANGEMENTS

PHOTOVOLTAIC CELL

PV cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current - that is, electricity. This electricity can then be used to power a load. A PV cell can either be circular or square in construction.

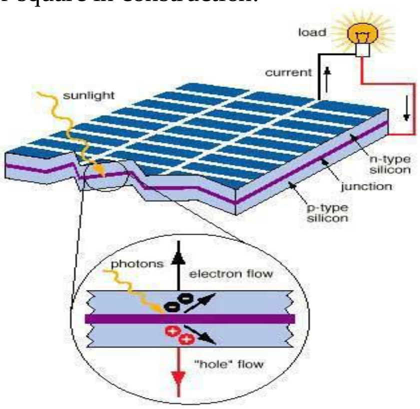
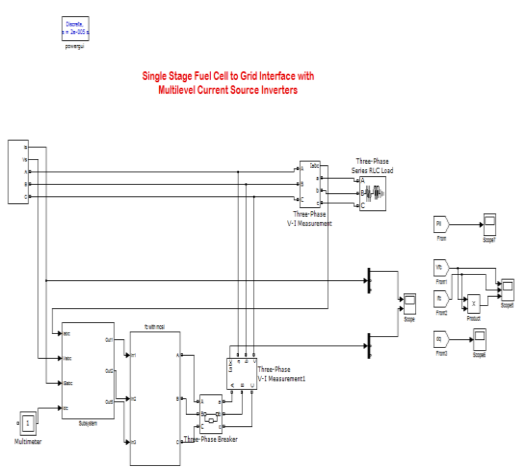


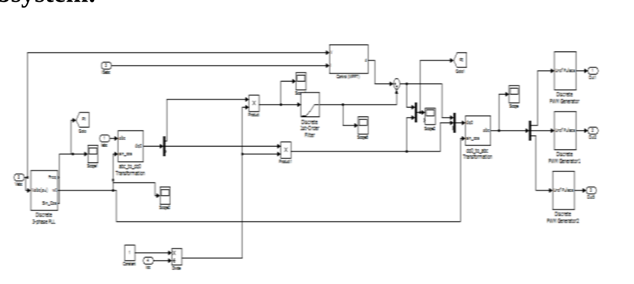
Fig 6 .Photovoltaic Module

Due to the low voltage generated in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. Separate diodes may be needed to avoid reverse currents, in case of partial or total shading, and at night. The p-n junctions of mono-crystalline silicon cells may have adequate reverse current characteristics and these are not necessary. Reverse currents waste power and can also lead to overheating of shaded cells. Solar cells become less efficient at higher temperatures and installers try to provide good ventilation behind solar panels.

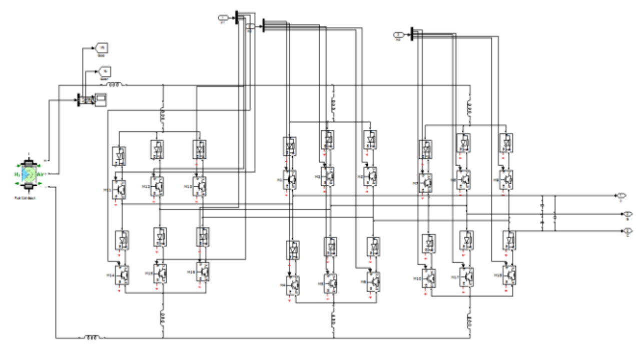
Existing Simulation circuit:



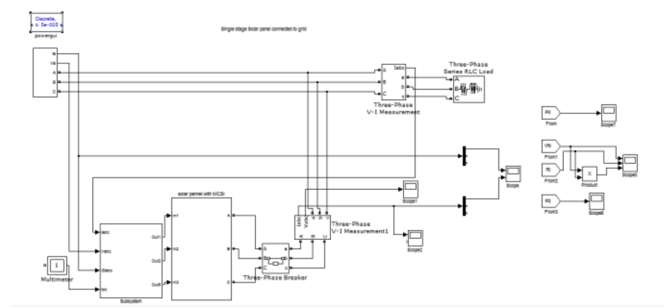
Subsystem:



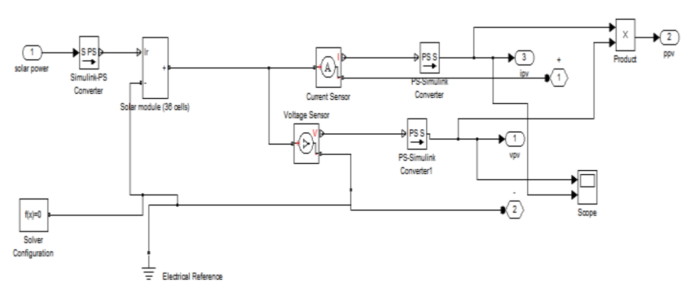
Fc with mcsi:



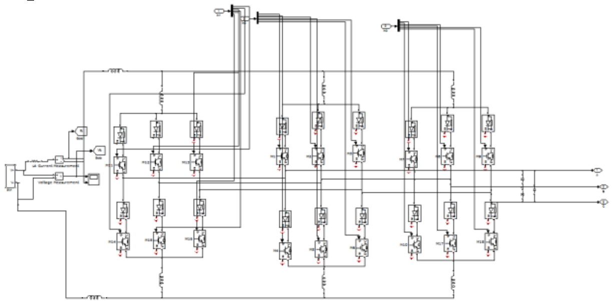
Proposed simulation circuit:



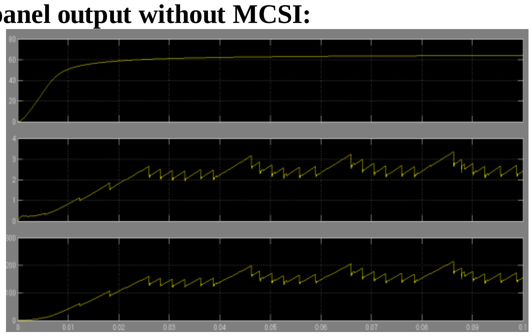
Solar Subsystem:



Solar panel with MCSI:



Solar panel output without MCSI:



Output waveforms:

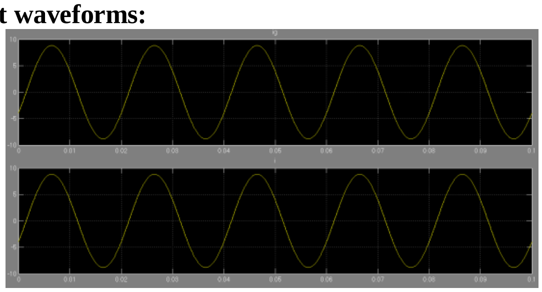


Fig 5 Solar panel output current with MCSI compared to grid current

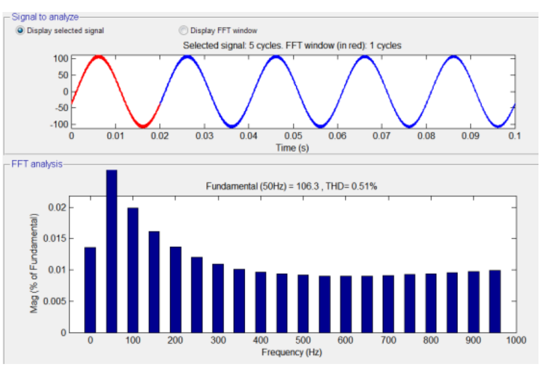


Fig.6 THD of output current with MCSI

IV. CONCLUSIONS

The integration of a MCSI and a renewable energy to provide energy and increase power quality in the electric grid is presented. A system to deliver energy from a Renewable energy to the electric grid using a 7 level MCSI power converter has been designed, evaluated through simulations and implemented on a reduced scale model based on a 200W renewable energy. The whole system shows an excellent behaviour, both in simulation and experimental results. The MCSI outputs fulfill the IEEE Standard 519 and the IEC 61000-4-7 standard regarding harmonics distortion. All the experimental results demonstrate that the experimental setup has a good correlation compared to the simulation counterpart, allowing extrapolating the results obtained to much higher power systems. The proposed system is a good choice in distributed generation systems or smart grids as it can provide active power while compensating power factor and harmonic distortion on the grid current. The proposed energy integration system is also suitable to integrate different energy sources such as wind or solar using the same layout, requiring only minimal changes in the control

V. REFERENCES

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