

POWER QUALITY IMPROVEMENT FOR A GRID CONNECTED PV SYSTEM USING POWER CONVERTER

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Abstract: Renewable energy sources are spreading due to environmental and energetic shortcomings. These systems are usually grid connected, and a power converter is the key item to connect the renewable energy sources to the grid. The power converter must be accurately designed in order to comply with grid requirements in terms of power quality and safety. This paper focuses on the design, modeling and control of power converters for power quality improvement in a grid connected distributed generators system. Control action of power converters are designed such that they can figure out with a transformer coupled grid connected system with different voltage levels of the grid. The Grid connected photovoltaic system in which a low voltage based PV generation system tied to grid of 25 k V and 125 k V along with the effect of irradiance on active power tied to grid is demonstrated. The simulations are carried out in MATLAB/Simulink environment and the results with priggish analysis are exhibited.

1. Introduction

The exclusion of transformer, and hence its isolation capability, has to be considered carefully. Because of the parasitic capacitance between the PV module and the ground, the fluctuating common mode (CM) voltage that depends on the topology structure and switching scheme can inject a capacitive leakage current. The existence of leakage current increases grid current harmonics and system losses, deteriorates the electromagnetic compatibility and, more significantly, lead to a safety threat. In order to solve the problem of leakage current, many dc-ac inverter topologies have been proposed. Most of the inverter topologies described in literature and commercially available show the European efficiency in the range of 96%-98%. Therefore, to boost the efficiency, some transformer less topologies use MOSFET switches because of its low switching and conduction losses the most attractive transformer less topology is the Highly Efficient and Reliable Concept (HERIC) topology.

2. Proposed System

In our proposed system, the DC output voltage from the solar panel is given to the boost converter to maintain the constant voltage irrespective of the irradiation of the sun. As the voltage to be given to the grid is AC voltage, the output of the boost converter is given to the inverter which converts the input DC voltage to AC voltage. The output of the inverter is given to LC filter to remove the harmonics present in the AC voltage.

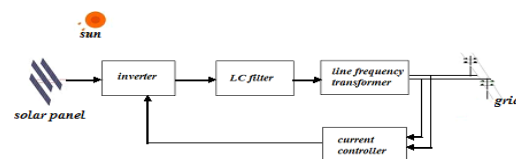


Figure 1. Block Diagram of Proposed System

3. Circuit Diagram of the Proposed Methodology

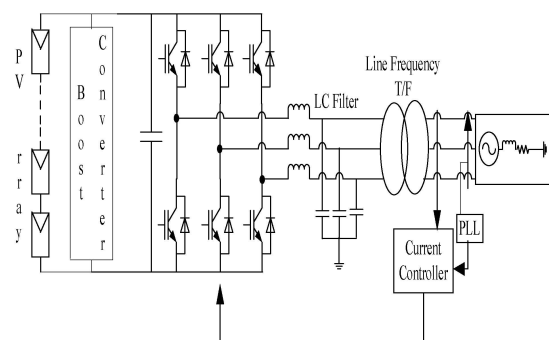


Figure 2. Circuit Diagram of Proposed System

The PV array is designed at voltage level of 270 V and capable of producing 100 kW at constant irradiation of 1000W/m². This 270 V PV voltage is boosted to 500 V by using a DC-DC boost converter. A 3-level bridge inverter is used to convert this dc power

into ac power, which is filtered by an LC filter before being fed to line frequency transformer. Source Converter (V SC) control block. Since voltage has been taken as reference the controller is termed as Voltage Source Converter. The VSC control block is a subsystem.

The following considerations are made for designing DC Fed Grid:

- DC voltage: 270 V
- Boost converter Frequency: 5 kHz
- Duty ratio: 0.48
- Transformer rating: 260V /25 kV 100 kV A
- Grid Voltage: 25 Kv

3.1 Hardware Used for the Proposed Methodology

- Power Supply
- Rectifier
- Filter
- Regulator
- Three Phase Inverter
- Driver Circuit
- PIC 16F877A Microcontroller

3.1.1 Power Supply

Since all electronics circuits work only with low DC voltage, a power supply unit is needed to provide the approximate voltage supply. This unit consists of transformer, receiver, filter and regulator. AC voltage typically 230 V is connected to a step down transformer. The output of transformer is given to the bridge rectifier and then a simple capacitor filter to produce a DC voltage initially filters it. This DC voltage is given to regulator, which gives a constant DC voltage.

3.1.2 Rectifier

Rectifier to be used is bridge rectifier. It is now available in a single entity. It is IRBR 6840. Here IR stands for INTERNATIONAL RECTIFIER that is the company manufacturing the product. BR stands for the bridge rectifier. 6 stands for its rating that is 600V,6A. Rectifier is used for converting AC into pulsating DC. Here instead of using the DC source such as battery we are using the rectifier because those sources have less life time.

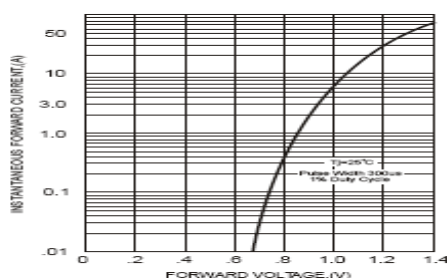


Figure 3. Forward Characteristics of IRBR6840

Forward characteristics of IRBR6840, here we find that minimum voltage for rectifier to respond is 0.7V. From that forward current increases till 1.4 V after which it becomes constant.

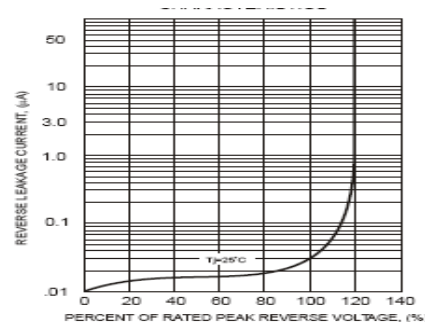


Figure 4. Reverse Characteristics of IRBR6840

Reverse characteristics of IRBR6840, As reverse voltage increase beyond 120% of rated voltage reverse current shoots through a high value.

3.1.3 Filter

Filtering should be done in order to reduce the harmonics and ripples. For this purpose we use capacitors for the filtering. They are rated at 100 V. Here output voltage from rectifier is 100V. The capacitors are used in two arms. They share this voltage equally. The capacitors are therefore rated at 1000 µf/100V. Each of the capacitors share 50V. The capacitors are electrolytic in nature.

3.1.4 Regulator

Regulator IC units contains the circuitry for reference source, comparator amplifier, control device and overload protection in a single IC. Although the internal construction of the IC is somewhat different from that described one, the external operation is the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage or an adjustable set voltage. A power supply can be built using a transformer connected to the AC supply line to step the AC voltage to the desired amplitude. It is then rectified filtered with the capacitor and finally regulating the DC voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milli-amperes to tones of amperes, corresponding to power rating from milli watts to tens of watts.

3.1.5 Three Phase Inverter

Three phase Inverter are designed by using Mosfets. IGBT can be used but it is of high cost. Same is the case with special devices such as GTO, SITH, IGT etc. SCR can also be used but it has commutation problem. Also it requires commutating circuit which is complex in nature. BJT has the problem of second breakdown. Hence we have the MOSFET as optimal device for this application.

3.1.5.1 MOSFET

MOSFET used is IRF P250. Its voltage rating is 250V, current rating is 20A. It has following advantages:

- Extremely high dv/dt capability
- Very low intrinsic capacitances
- Gate charge is minimized.
- Fast switching is possible.
- Ease of paralleling with other MOSFET

The distance between the pins of IRFP460 is optimal and hence it meets the safety requirements. Certain absolute maximum ratings of various parameters are given below:

Drain current at $V_{GS} = 10V$ is 20A

Gate to Source voltage $V_{GS} = 20V$

dv/dt of IRFP6840 is $3.5V/ns$

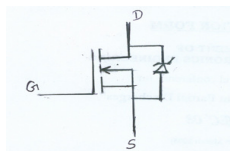


Figure 5. Internal Schematic Diagram of IRFP460

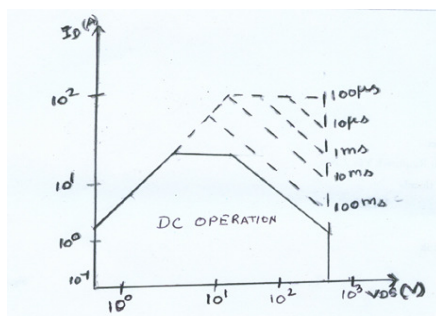


Figure 6. Safe Operating Area (Soa) of IRFP460

From the above curve we find that safe operating area falls within 100A.

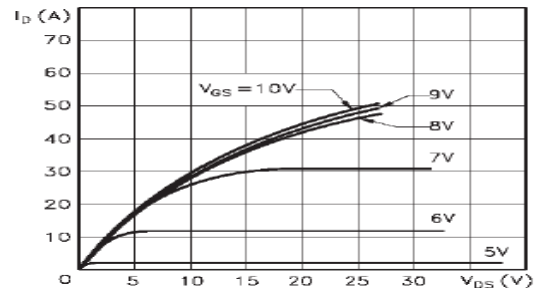


Figure 7. Output Characteristics of the MOSFET

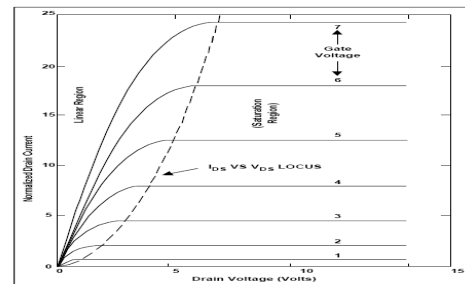


Figure 8. General Output Characteristics of MOSFET

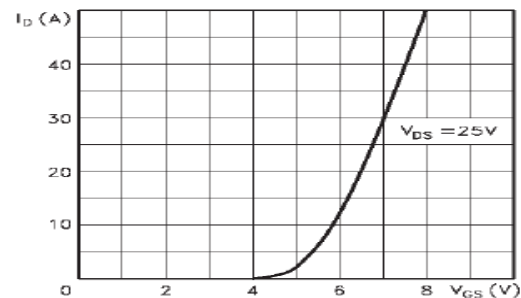


Figure 9. Transfer Characteristics of IRFP460

It shows that minimum voltage for this MOSFET to respond is 4V after which drain current increases parabolic ally.

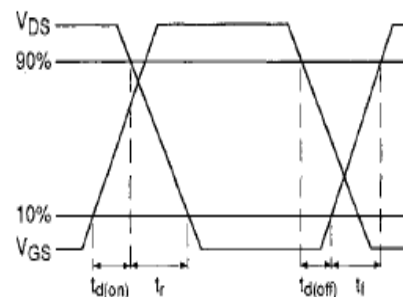


Figure 10. Switching Characteristics of IRFP 6840

Without any gate signal MOSFET may be considered as two diodes connected back to back otherwise as a NPN transistor. The MOSFET has parasitic capacitances as

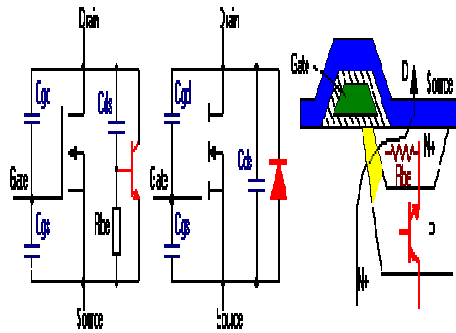


Figure 11. Parasitic Elements In MOSFET

The gate structure has capacitances with source C_{gs} and also with drain. C_{gd} . Also NPN transistor has a reverse bias junction from drain to source. This junction offers a Drain to Source capacitance C_{ds} . The figure has a parasitic bipolar transistor in parallel with the MOSFET. The Base-to-Emitter region of the transistor is shorted at the chip by metalizing the source terminal and the impedance from the base to emitter due to bulk resistance of n and p-regions, R_{be} is small. Hence MOSFE may be considered as having an internal diode. Such an equivalent circuit of the MOSFET with an internal diode. Parasitic capacitances are dependent on respective voltages.

Following are various terms related to it:

- Turn-on delay($t_{d(on)}$): t is the time that is required to charge the input capacitance to threshold level.
- Rise time(t_r): It is the time required to charge the gate from threshold level to full gate voltage.
- Turn-off delay time: It is the time required to discharge the input capacitance from overdrive voltage to pinch-off voltage. V_{GS} should decrease significantly before V_{DS} begins to rise.
- Fall Time: It is the time required for input capacitance to discharge from pinch off voltage to threshold voltage. If $V_{GS} < V_T$ transistor turns off. When MOSFET is used as a switch it's main function is to control the drain current by gate voltage.

3.1.6 Driver Circuit

Driver is nothing but an optoisolator. This is used to prevent the 100V directly affecting the PIC micro controller. Here we are using opto isolator MCT2E. It is a six pin device.



Figure 12. Three Dimensional View of MCT2E

It consists of Gallium arsenide infrared emitting diode driving a silicon photo transistor in a 6-pin dual in line package. It is used in following applications:

- Isolating applications
- Power supply regulators.
- Digital logic inputs

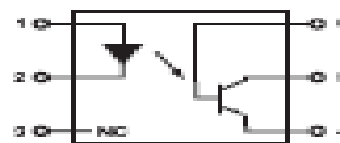


Figure 13. Schematic Diagram of MCT2E

- Pin Configurations:
1. Anode
 2. Cathode
 3. No connection
 4. Emitter
 5. Collector
 6. Base

Certain technical details of this MCT 2E is given below:

DC average input current of emitter	: 60mA
Reverse input voltage	: 3V
Forward input current	: 3A
Collector current	: 50mA
Collector –Emitter Voltage	: 30V
Emitter input voltage	: 1.5V
Reverse leakage current	: 10A
Emitter-Collector breakdown voltage	: 100V

Collector-Base breakdown voltage : 120V

Turn-on, Turn off and rise time : 2s

Fall time : 1.5s

From this we find that on increase in temperature for the same forward voltage the forward current increases.

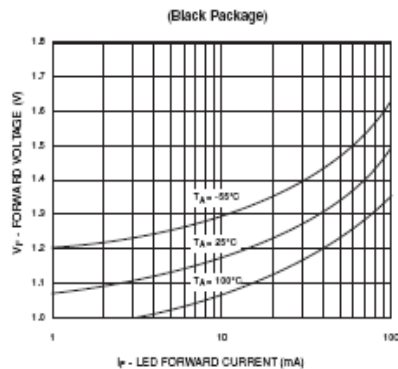


Figure 14. Forward Characteristics of MCT2E

From this we find that turn on or turn off is obtained at 1.5V.

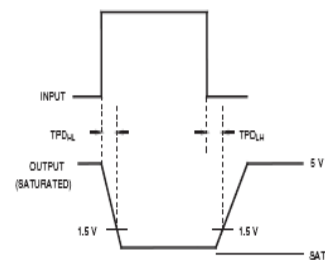


Figure 15. Switching Characteristics MCT2E

3.1.7 High-Performance Risc CPU

- Only 35 single- word instructions to learn .Hence it is user friendly. easy to use
- All single - cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory. It is huge one

It has following features:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

4. Simulink Blocks Used In Simulation of Proposed System

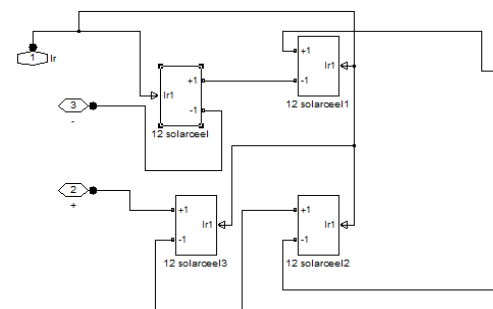


Figure 16. Simulink of Solar Modules

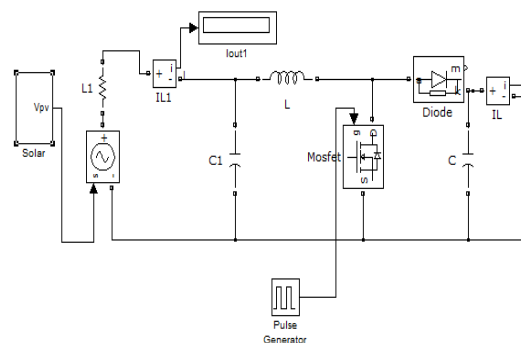


Figure 17. Simulink Model of Boost Converter

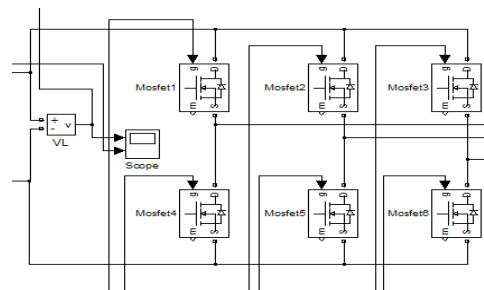


Figure 18. Simulink Model of Three Phase Inverter

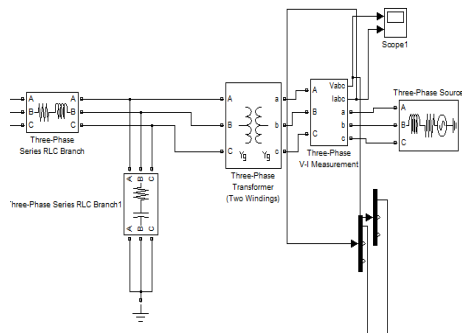


Figure 19. Simulink Model of Filter Circuit And Grid System

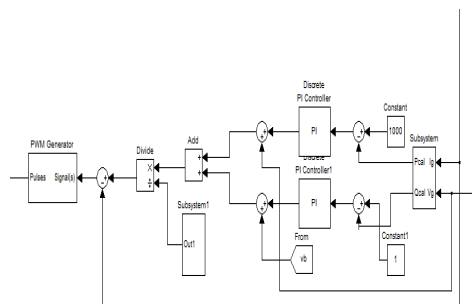


Figure 20. Simulink Model of Controller Circuit For Inverter Switching Devices

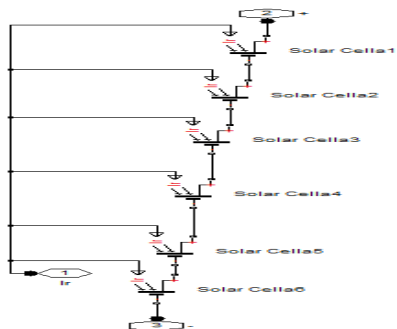


Figure 21. Solar Cells Connected In Series

5. Results and Discussions

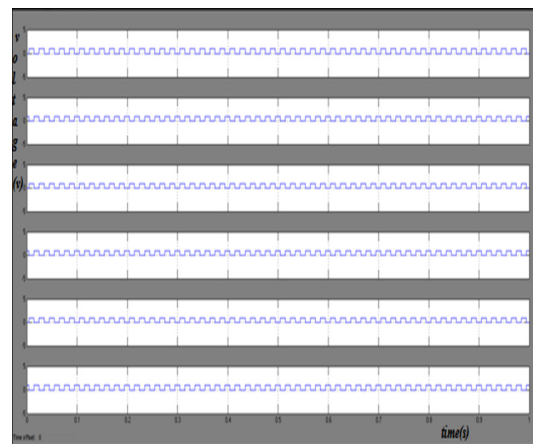


Figure 22. Pulses From the Controller to the Inverter Switches

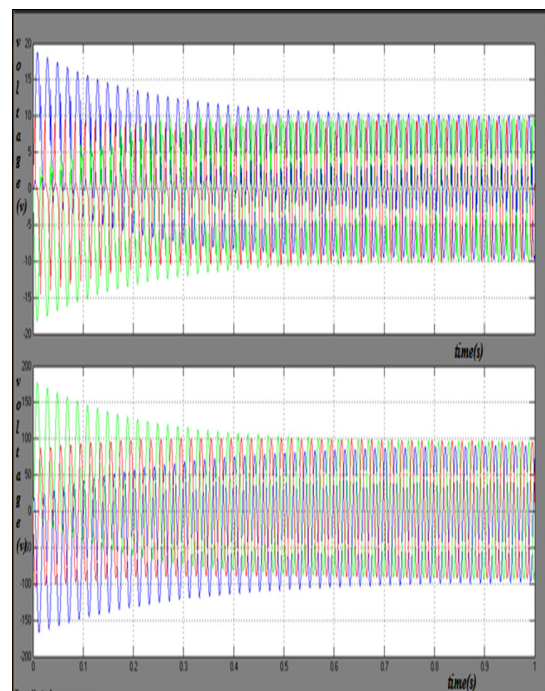


Figure 23. Output Filtered Output Voltage Waveform From Rc Filter

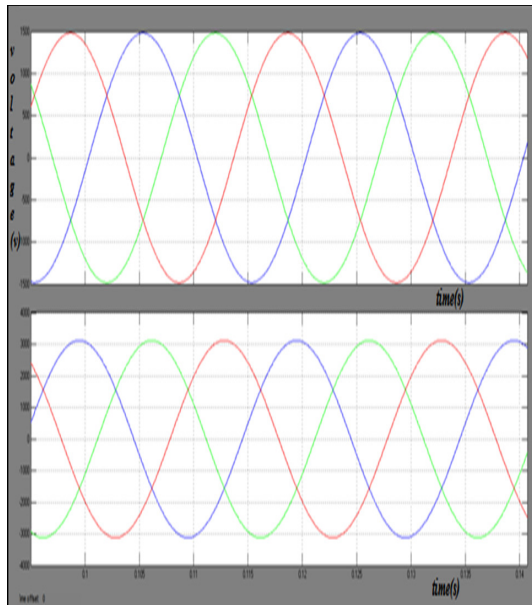


Figure 24. Output Voltage Waveform From Line Transformer

6. Conclusion

The simulation of the DC fed to Grid and PV fed to Grid were evidenced that the modeled power converter is controlled effectively to feed power to the 25 kV Grid without any PQ problems. Similarly, the simulation of PV fed 125 kV Utility Grid also proved that power quality in any GPV system can be improved by controlling the power converter.

In addition, the effect of irradiation on PV power generation and PV power fed to Grid are simulated and the results are presented.

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