Analysis of SPWM Technique for Solar Inverter

Mr.R.Ashokkumar, Raajeshwar Elangovan, Vinoth K, Vijayakumar S

Abstract— **Reactive power control is necessary to maintain power system stable. In a three phase grid connected PV system, the inverter should regulate the reactive power. Low Voltage Ride Through has to be done to ensure the system stability in fault conditions. Fault current has to be limited. In this paper, we propose a control strategy for grid connected solar PV inverter. The system study is done under LVRT condition. The strategy is based on current loop under single axis dq rotating coordinate system. Grid connected PV systems has a three phase inverter fed by DC-DC converter which will take care of maximum power point. In this project, a 100kW PV system is studied. The entire system is simulated and analysed using MATLAB Simulink software.**

Index Terms— **LVRT, MPPT, PWM, Reactive power control, Three Phase Inverter**

I. INTRODUCTION

In recent days, in addition to generating power and distributing a quality power, need for green power has also grown. Carbon emission being high in various countries, environmental safety is equally important in power generation. This made the mankind to move towards renewable energy sources like solar, wind and the like. Though the efficiency is low in solar, it has its own advantages as it deals with free solar energy from the ultimate energy source. To get maximum power from the solar PV system, various control techniques are used which are discussed in this paper. PV panels are installed as PV arrays and connected to a DC-DC converter to regulate the DC power output from the panel. DC-DC converter is employed with Maximum Power Point Tracking algorithm to extract more power. Then the regulated DC is converted to AC and supplied to the grid using AC-DC inverter. Block diagram for the system is given in Fig.1. In this paper, the inverter part with LVRT is discussed in detail.
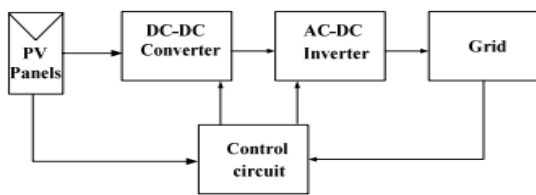

Fig.1. Block diagram of typical grid connected PV systems

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II. PV SYSTEM MODELLING

The study is done for 100kW system. PV modelling in MATLAB can be done by deriving the function from the equivalent circuit of the PV cell. PV equivalent circuit is shown in Fig.2.
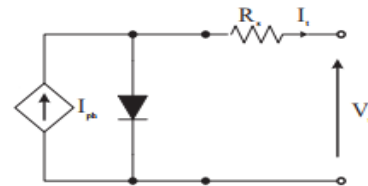

Fig.2. Equivalent Circuit of Photovoltaic cell

The relation between the terminal current I_t and voltage V_t is given by the equation (1).

$$It = Iph - Io(e^{\frac{Vt+IRs}{Vth}} - 1) \ \dots\dots (1)$$

Where, I_o, I_{ph}, I and V are saturation current, photo current, current and voltage of the module respectively. $V_{th} = nN_skT/q$ is thermal voltage of the module; n, Ns, K, T and q are ideality factor, number of cells in series, man constant and electron charge respectively. Expressing in terms of Short circuit Current and Voltage, the equation will be as shown below (2). Where, M_{ss} and N_{ss} are number of shunt and series connected modules respectively.

$$Ipv = Mss\ Isc\ (1 - \exp(\frac{Vpv - Nss\ Voc + \frac{Nss\ Ipv\ Rs}{Mss}}{Nss\ Vth})) \ \dots\dots (2)$$

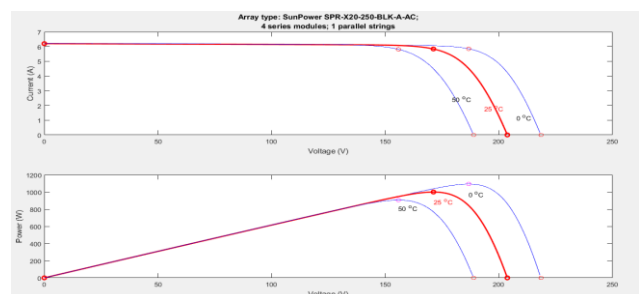IV characteristics and PV characteristics of solar PV module used is given in Fig.3.

Fig.3. I-V and P-V Characteristics of 1kW PV Panel

III. DC-DC BOOST CONVERTER AND THE MPPT

DC-DC boost converters are used in PV systems, to boost the unregulated, constantly varying, PV output to a required voltage level. MPPT control technique is commonly used in all DC-DC converters. Maximum Power Point Tracking algorithm can be derived from the expression that relates generated power and voltage, which is given below in equation (3).

$$\frac{dPpv}{dvpv} = Ipv + Vpv\frac{dIpv}{dvpv} \quad \dots\dots\dots (3)$$

As far as DC-DC converter is concerned, it may be any of the maximum power point tracking (MPPT) algorithms, which extracts maximum power from the PV array. MPPT controller can be used to generate switching pulse for DC-DC converter and a constant terminal voltage can be maintained up to certain level of fluctuation in input. It is necessary to maintain a constant output voltage irrespective of input irradiance and temperature. MPPT techniques have been discussed in [1]-[5] in detail. In this paper, the simulations followed Perturb and Observe (P&O) Algorithm [6]. Flow chart of P&O algorithm is given in Fig.3.
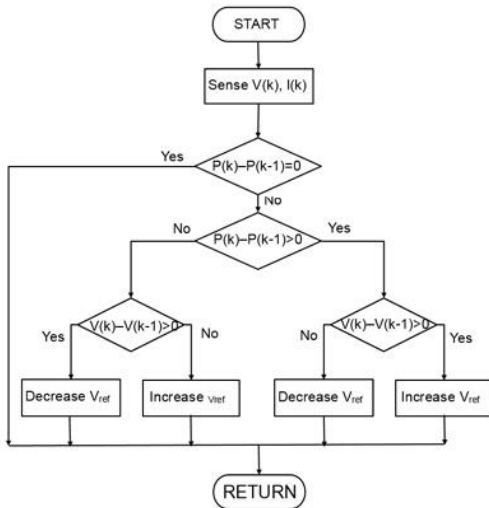

Fig.3. Perturb & Observe algorithm

IV. SINUSOIDAL PULSE WIDTH MODULATION

PWM techniques are adopted in inverters to maintain constant output voltage irrespective of load. PWM is the process of modifying the width of pulse with respect to carrier wave or control wave. But, in order to reduce harmonic content of the inverter output, various types of PWM is tested and adopted [7]. In this study, we adopted Sinusoidal PWM.

When voltage source inverter is switched in either 120 degree or 180 degree mode of operation, the output waveform obtained will be a square wave. Hence, to acquire a sine wave, sinusoidal PWM is simple and efficient method. In this method, a sine wave and triangular wave which acts as carrier are compared with comparator. The resultant pulse generated is the required PWM signal. Basic principle of SPWM is shown in Fig.4.
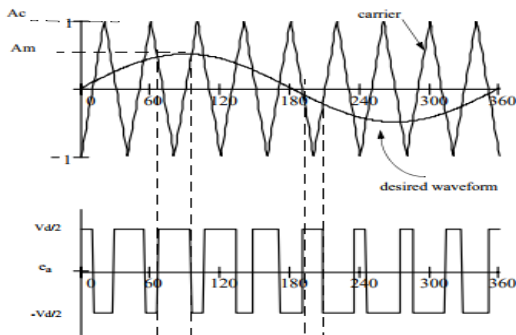

Fig.4. Sinusoidal PWM wave generation

There are certain considerations to be made, before going for SPWM. Let the amplitude of sine wave to be modulated is A_m and the triangular carrier be A_c (refer Fig. 1). The modulation index (A_m/A_c) has a greater impact on output voltage. Very high carrier frequency has an advantage of reducing harmonic components due to the inductive nature. High frequency switching also increases the switching losses in power electronic switches used in the inverter. For this reason, the carrier frequency is chosen between 2 kHz to 15 kHz which is optimum to use. Similarly, for three phase inverters, it is mandatory to maintain all three waveforms symmetrical. So, the ratio of sine wave frequency f_m to the carrier frequency f_c is chosen in integral multiples of 3 (f_m/f_c= 3n, n ∈ N).

V. AMPLITUDE MODULATION

Consider a three phase system with line to line voltage of 415V rms. Its peak value will be 590V. Let the carrier wave of frequency 2 kHz is chosen. Amplitude of carrier is same as that of system voltage, the waveform obtained will be as shown in Fig.5.
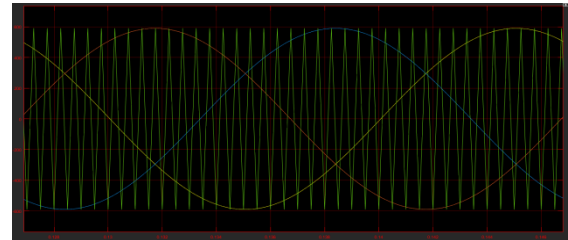

Fig.5. Amplitude modulation with 2 kHz carrier and 590V peak voltage

After generating the carrier wave, a comparator is used to obtain desired PWM signal. The comparator compares the amplitude of carrier and voltage of each phase. Wherever the carrier amplitude is high, the output from comparator is high. The resultant waveform will be as shown in Fig.6.
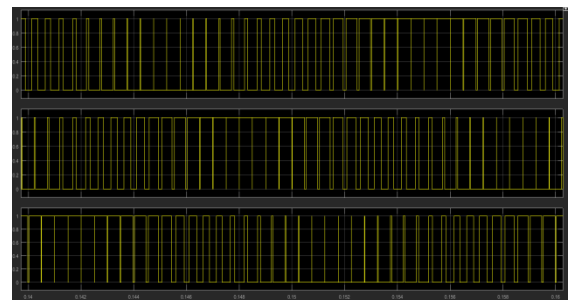

Fig.6. PWM wave for 590V carrier

VI. OVERMODULATION ERRORS

In the above results, we find many pulses have very small width, which contribute to more switching losses rather than smoothing the waveform. If we choose modulation index of 1, (ie., A_m/A_c = 1 or $A_m = A_c$) width of the pulses will be low. If carrier amplitude is lower than the modulation wave, then the modulation index goes beyond 1. In this case, some triangular spikes will not intersect with sine wave. So, very high pulse width is possible and an uneven distribution will be followed. It is illustrated in Fig.7.
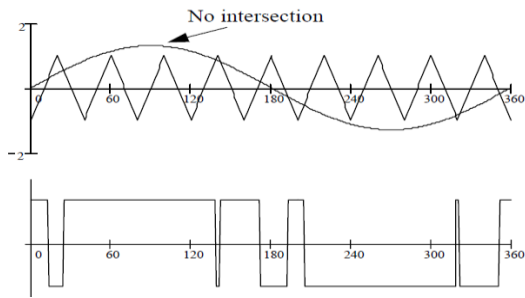
Fig.7. Over modulation error

Fig.10. Grid Voltage with inverter under LVRT

VII. VOLTAGE SOURCE INVERTER (VSI)

In this study, a universal bridge type three-phase voltage source inverter (VSI) is used for the DC to AC conversion. The VSI maintains a constant DC link voltage of 2kV. This inverter is responsible for providing active and reactive power to the grid. Inverter is controlled by Current Loop under Single Axis dq Rotating Coordinate System. In certain cases, if fault arises in power system, the system voltage drops to a lower limit. This increases the fault current beyond limit. Protection devices employed in the system trips the circuit to prevent the system from this high fault current. But, this may result in adverse effects in case of momentary faults in a grid connected system. This may get generators out of synchronization. So, momentary low voltages should be allowed upto tolerable limit. This is Low Voltage Ride Through control which is possible in our proposed control strategy.
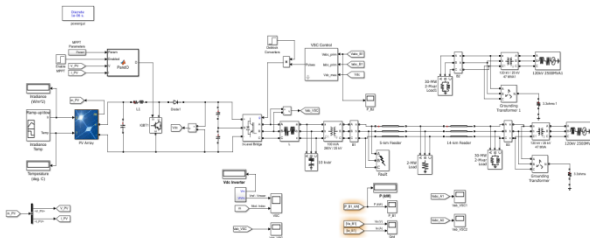
VIII. SIMULATION RESULTS AND DISCUSSION

Fig.8. Simulation model of 100kW grid connected solar PV system

A 100kW grid connected system is simulated. Input parameters for solar PV are temperature and irradiance. PV module is followed by 500kV DC-DC boost converter. Closed loop control is fed back from the grid to the inverter controller. The grid voltage under fault condition without LVRT control is shown in Fig,9. The grid voltage after including the LVRT control, get regulated and the output is shown in Fig.10.
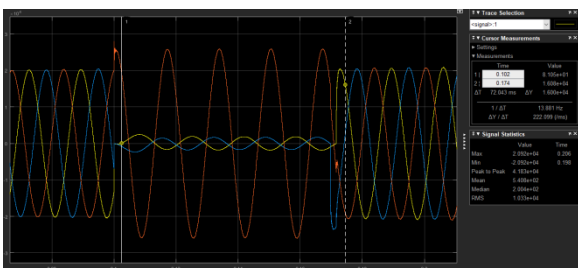

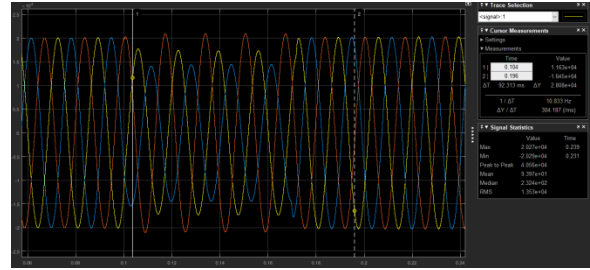Fig.9. Grid Voltage under Double line to ground fault

IX. CONCLUSIONS

In this paper, control strategies that can enhance the performance of three phase grid connected inverter have been discussed. Whenever a momentary voltage drop occurs, this technique prevents the system from isolation. Necessary reactive power compensation is done to manage the low voltage under grid faults. The simulation results show that the new grid objectives are satisfied for a 20 kVA, 100kW system successfully.

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