DESIGN, SIMULATION AND PERFORMANCE ANALYSIS OF GRID CONNECTED HYBRID INVERTER WITH DECOUPLED CURRENT CONTROL

Swarna Soni [1], Lumesh Kumar Sahu [2]

Assistant Professor , Department of Electrical Engineering[2]

Department of Electrical Engineering [1]

Kalinga University, Raipur ,Chhattisgarh., India[1]

Abstract: **Solar energy is the most prominent source of electrical energy in today's world. Many research works are going on to increase the efficiency and for reducing the complexity of the system. This paper presents the simulation model of grid connected hybrid inverter with decoupled current control. While studying the simulation of grid connected models allows to understand that how these system performs with the grid. In this paper hybrid inverter is used which reduces the complexity of the system and increase the efficiency and also the implemented control strategy helps to separately regulate the active and reactive power.**

*Keywords - **PLL, Decoupled Current Control , alpha-beta transformation, hybrid inverter***.

I. INTRODUCTION

The worlds demand for energy is increasing and non Renewable sources are fast depleting the only option is to use non renewable energy sources and solar PV energy system is one of them. The installation of PV is done according to their function and requirements of operation named as grid connected system or stand alone system. Remote areas are supplied by using stand alone system with the use of converter and energy storage device; on the other hand in grid connected system the power generated is directly fed to transmission line and distributed[2].

To integrate the PV system with grid the basic requirements are - (i) the PV system should withstand rise and fall in voltage for a short time.(ii) desired control scheme should be there to synchronize it with the grid.(iii) there should be less harmonic distortion.

The aim of this paper is to simulate the grid connected PV system using hybrid inverter (closed loop). The control strategy used in this paper is voltage oriented control(VOC) for separately controlling the active and reactive power flow[1].

As we need to control active and reactive power separately decoupling is necessary and this can be achieved by the transformation of stationary reference to a rotating reference frame i.e.($\alpha\beta$-dq). Phase locked loop has been used to synchronize the rotating reference frame with the grid[6].

The Simulated results and advantages of using hybrid inverter instead of basic inverters are discussed in this paper.

In this paper, Grid connected PV system is simulated and analyzed. Section-I provide introduction of the subject, section-II contains theoretical base for grid connected PV system and section-III gives analysis of grid connected PV System and its operation in varying irradiation condition in detail.

II. GRID CONNECTED PV SYSTEM

A. hybrid Inverter -

As shown in below figure hybrid inverter includes internal boosting circuit and H-Bridge inverter. Inductor (L) and lower switches of H-Bridge inverter provide voltage boosting and charge capacitor(C) at voltage higher than supply voltage. This eliminate requirement of external DC/DC stage or AC/AC Stage for voltage boosting.
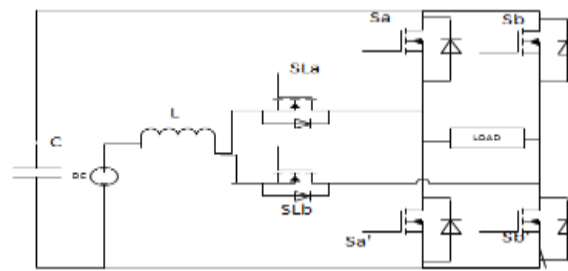
Figure 1 Hybrid Inverter

To introduce the voltage-boosting capability, this work advocates the integration of an inductor *L* and a dc-link capacitor *C* into a full-bridge inverter by means of two MOSFETs, S_{La} and S_{Lb} in the single-stage topology. This work, on the other hand, attempts to adopt MOSFETs in lieu of diodes to smooth out the undesirable high frequency current commutation and high forward voltage drop, so that better efficiency with less switching loss and conduction losses is guaranteed. Besides, the adoption of MOSFETs provides an added advantage such that bidirectional power flow is enabled. It provides extended capability to resolve the high frequency current commutation problem existing in the earlier SSI while enabling bidirectional power flow so that the proposed SSI can operate in rectification mode or inversion mode. This refinement is made feasible by the proposed hybrid quasi-sinusoidal and constant PWM.

It is worth pointing out that between the two legs of the full bridge inverter, it is essential for one leg to operate at constant duty cycle (for dc–dc boost conversion) while the other leg operates at sinusoidally varying duty cycle (for dc–ac sinusoidal output). The complementary switches S_{La} and S_{Lb}, which operate at fundamental frequency, play their role in clamping the leg which operates at constant duty cycle to the inductor and dc source, so as to boost the dc voltage across the dc link.
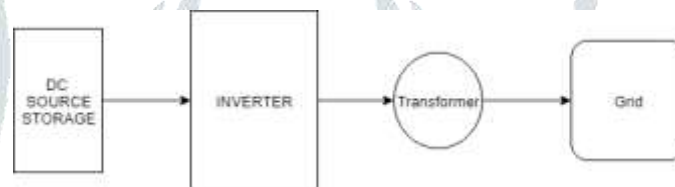
B. *Grid connected pv system*
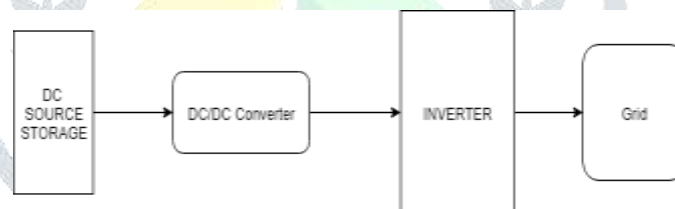

Fig.2 Grid Connected PV System Topology-1

Fig.3 Grid Connected Topology-2

Two different structures for injecting energy into AC grid from DC Source are shown in above figures. Topology-1 considered to be single stage conversion from DC/AC. In this case transformer is essential to boost the injected voltage up to the grid level. Efficiency of this kind of structure mostly depends on transformer as the inverter is highly efficient. Beside the losses in the transformer, it also makes this system bulky and costly. Toplogy-2 eliminate transformer and introduce voltage boosting at the source side by means of power electronics converter. Efficiency of this two stage topology depends on both the converter. Control logic of this topology also need to take care of that DC side conversion and hence become complex than Topology-1.
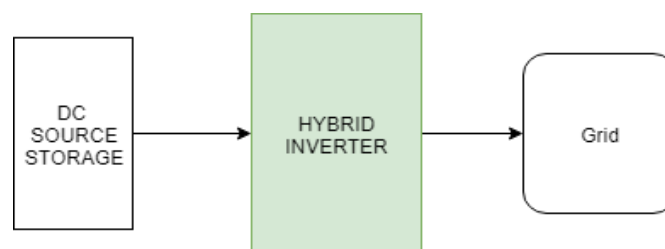

Figure 4 Proposed Grid Connected System

In figure 4 hybrid inverter has been utilized to convert DC into AC. As hybrid inverter provides internal boosting for the source voltage, the conversion becomes single stage from lower DC voltage to higher AC voltage.

Inverter control includes grid synchronization, DC link voltage control and Active/Reactive power control. Generally, inverter current is controlled for active and reactive power control. For current control, Voltage Oriented Control (VOC) is widely used in inverter based distributed generation system . VOC require dq reference frame orientation with grid voltage. dq Reference frame orientation also provides DC transformation of AC quantity which can be easily controlled with PI controller. Grid current in dq reference frame decomposed in two parts active current (I_d) and reactive current (I_q) as grid voltage is oriented with d axis. DC link voltage controller is cascaded with Active power (I_d) control loop and both I_{dq} controlled with PI controller which generate references for sine pulse width modulation (SPWM) switching.

The grid-side voltage equation can be written as,

$$v_s = i_s R_s + L_s \frac{di_s}{dt} + j\omega_s L_s i_s + v_c \qquad \ldots \ldots (5)$$

Then, decomposing equation-5 into the d and $c$omponents yields as follows,

$$V_{sd} = i_{sd} R_s + L_s \frac{di_{sd}}{dt} - j\omega_s L_s i_{sq} + v_{cd} \qquad \ldots \ldots (6)$$

$$v_{sq} = i_{sq} R_s + L_s \frac{di_{sq}}{dt} + j\omega_s L_s i_{sd} + v_{cq} \qquad \ldots \ldots (7)$$

This equation shows decoupling between d and q current. Feed forward of this coupling terms ($j\omega_s L_s i_{sq} \& j\omega_s L_s i_{sd}$) decouple active current (I_d) and reactive current (I_q) and provide capability to control active and reactive power separately.
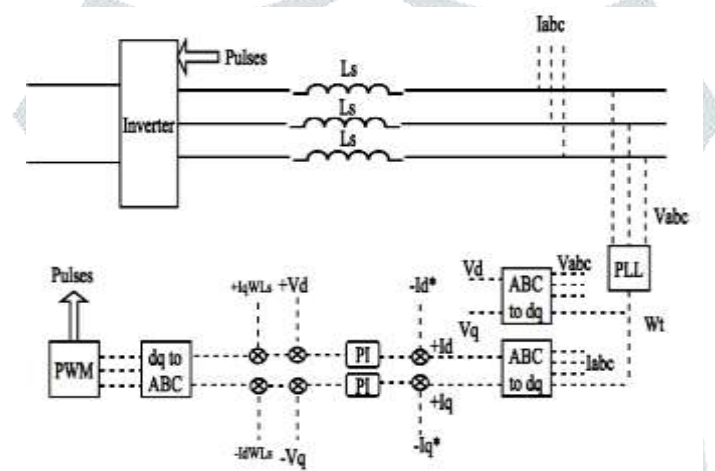

Fig.5 Decouple Current Control with Feed Forward

Fig. 5 shows decoupled current control with feed forward strategy for grid connected inverter. DClink voltage controller is cascaded with active power loop to regulate capacitor power and hence voltage as shown in Fig. 6.
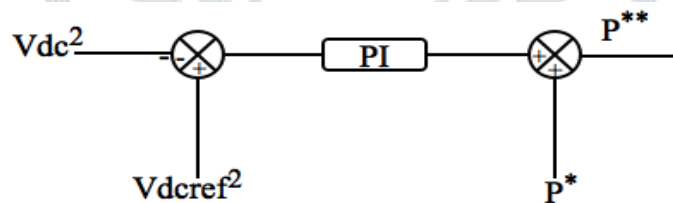

Fig.6 DC-Link voltage controller

Reference active power and reactive power can be calculated from following equation,

$$P = \frac{3}{2} V_{sd} I_{sd} \qquad \ldots \ldots (8)$$

$$Q = \frac{3}{2} V_{sd} I_{sq} \qquad \ldots \ldots (9)$$

III. SIMULATION AND RESULTS
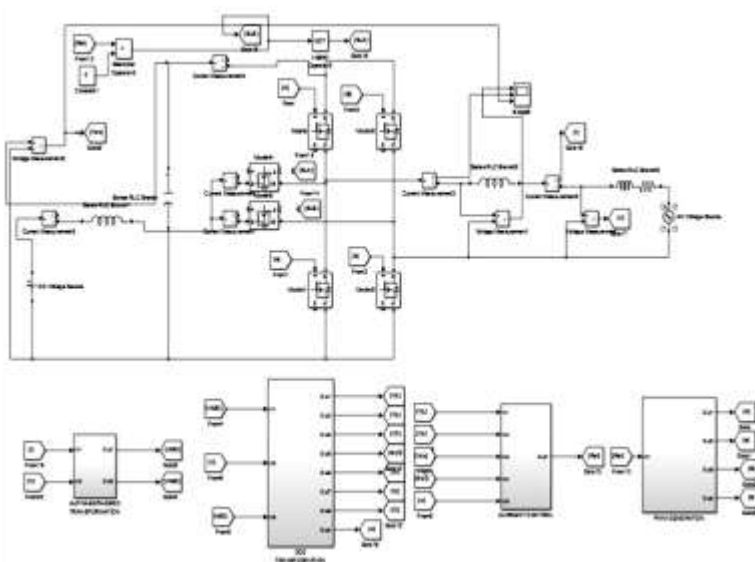
A. Grid Connected Hybrid Inverter

Figure 7 Grid Connected Hybrid Inverter

Hybrid inverter connected with single phase grid by decoupled current control is shown in above figure.

To convert line variables into α-β reference frame line voltage has been considered as Vα , Vβ has been calculated from Vα by considering 90 degree phase shift between them which is shown in below figure.
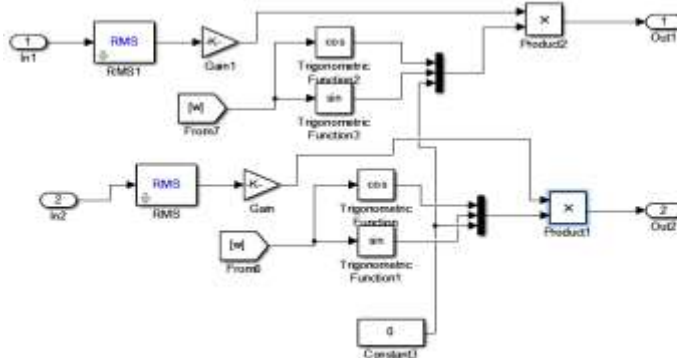

Figure 8 Alpha-Beta Transformation

These αβ-Components than converted into dq reference frame and utilized in decoupled current control for hybrid inverter. Control loop for independent active and reactive power control is shown below.
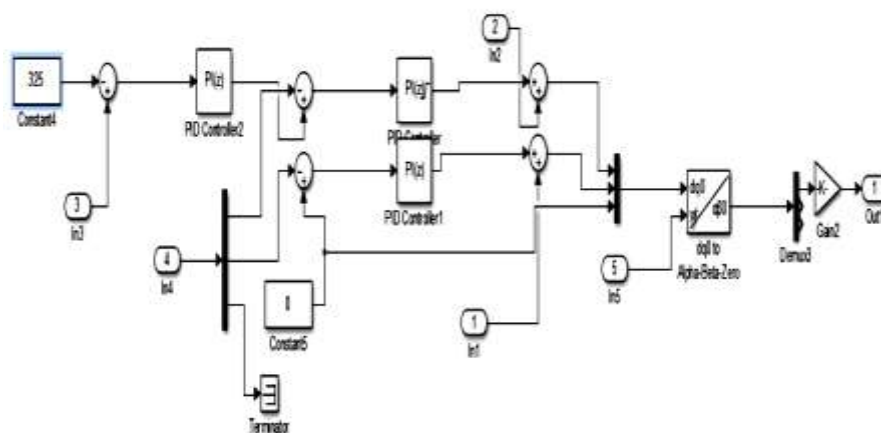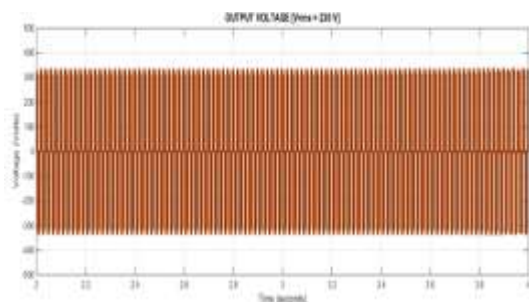

Figure 9 Decoupled Current Control
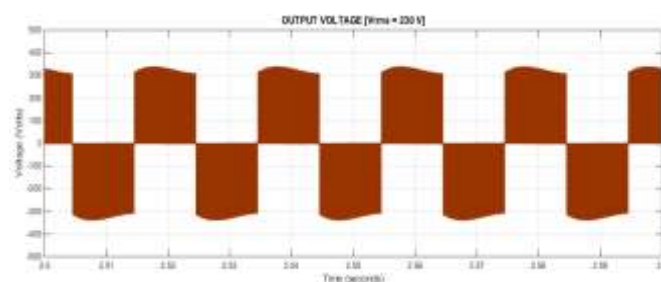
Figure 10 Inverter Output Voltage

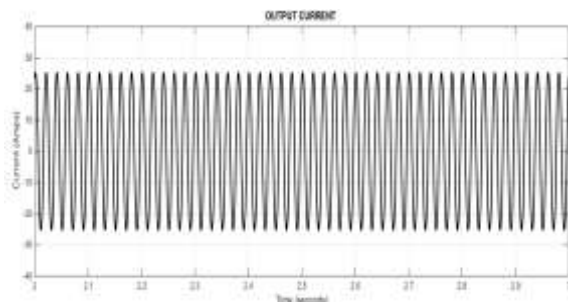Figure 11 Inverter Output Voltage

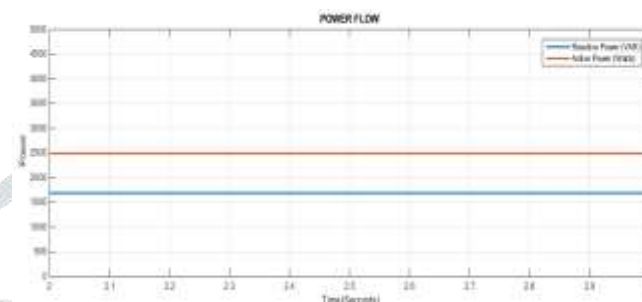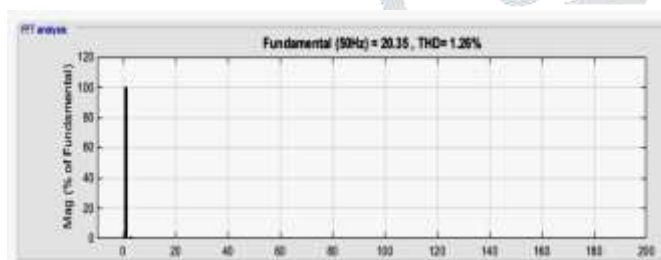*Figure 12 Inverter Injected Current*

Figure 13 Power Flow

Figure.14 FFT Analysis

%THD of injected current is shown in above figure. It shows %THD of 1.26%, which is below 5% as mentioned in IEEEE1547 Standards.

IV. CONCLUSION

Hybrid inverter is capable to provide voltage boosting in grid connected application. Mitigation of transformer in single stage topology provides efficient DC to AC Conversion. Decoupled current control with voltage feed forward technique limit current harmonic up to 1.26 % which is below 5%,ensuring fulfilment of IEEE1547 standard.

V. ACKNOWLEDGMENT

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