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DESIGN AND ANALYSIS OF A DC-DC BOOSTCONVERTER WITH SOLAR PV MODULE INTEGRATED TO THREE- PHASE GRID USING SRF CONTROLLER.

B. SIRISHA
ASSOCIATE PROFESSOR
OSMANIA UNIVERSITY
SAI MAHESH KURRE, J. UPENDER
STUDENT,ASSISTANT PROFESSOR
OSMANIA UNIVERSITY.

ABSTRACT:-

There has been a huge demand of renewable sources due to the conventional sources exhaustibility. Photovoltaic cells being the first priority of renewable sources due to its availability throughout the year. The problem with the PV cell is its requirement to boost the voltage because of its low operating voltage. This paper proposes a boost converter which helps in boosting the voltage with low duty ratio and high efficiency having low switching losses. Voltage stress is limited with the presence of passive clamp circuit. This adds up the advantage of using low switch voltage rating and increase in the system efficiency. The output is then converted to alternating current using two level inverter and supplied to three phase grid, synchronized with SRF controller.

Keywords:-Maximum power point tracking (MPPT), boost converter, inverter, grid, solar cell, coupled inductor, synchronous reference frame,

INTRODUCTION:-

Conventional energy sources have been the only resource for the production of electricity for past many years. As these sources are non-renewable, they should be replaced by renewable sources like solar, wind, tidal, geothermal etc[1]. Photo voltaic cells provide electrical energy when subjected to solar rays and this effect is called photo voltaic effect. PV cells generate direct current and are operated at lower voltages as a safety precaution[2]. Voltage boosting is required for the output of PV cell and converted to alternating current to integrate with electric grid. The boosting of voltage can be done by novel high gain dc-dc converter with soft switching feature and passive clamp circuit. The input to the converter is supplied by the PV module which is then stored in intermediate capacitor and as magnetic field of coupled inductor in a loss less manner. Later it is passed on to the output for its conversion to alternating current using inverter. Some amount of energy is trapped in the form of leakage inductance. In order to recover the trapped energy a passive clamp is placed around the primary inductor[3].

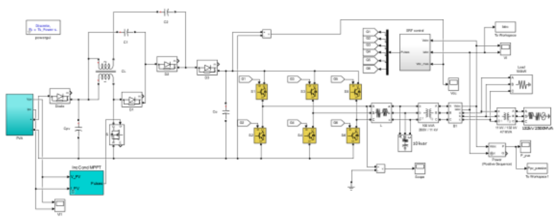

Fig 1:- Schematic representation of the circuit.

The pv panel output is increased by the boost converter and then passed on to the inverter. Two level current controlled voltage source inverter is used to convert to alternating current from the direct current boosted by the boost converter. Voltage controlled inverter is not used due to some drawbacks mentioned in the inverter section.

LC filters are used to reduce the harmonics generated by the inverter and injected into the system. The reduced harmonic waveforms are then passed to transformer for step up in the voltage for transmission and synchronising with the grid. Synchronous reference frame, a control strategy is used for proper synchronisation with the grid[9].

DC-DC BOOST CONVERTER:-

The whole circuit of the proposed converter with the integration of PV module and MPPT is shown in below figure. The gate pulse of the switch is supplied by MPPT[7].

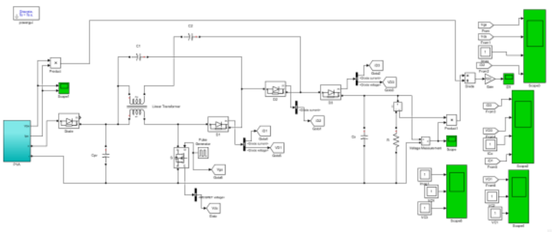

Fig 2:- The above picture is a graphical representation of DC-DC converter

The converter is operated in five different modes and their respective current flows are mentioned below.

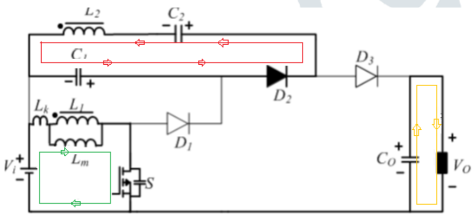

Fig 3:-Mode 1 current flow

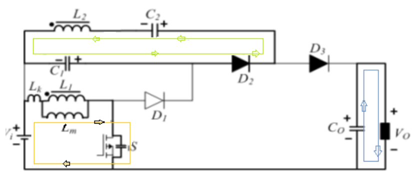

Fig 4:- Mode 2 current flow

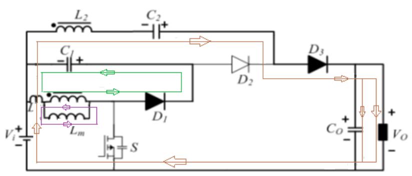

Fig 5:- Mode 3 current flow

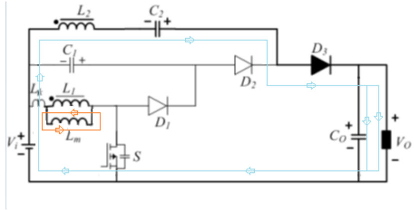

Fig 6:- Mode 4 current flow

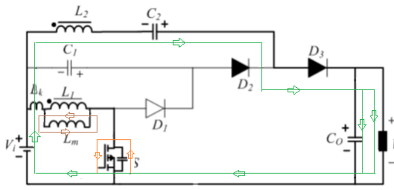

Fig 7:-Mode 5 current flow

The detailed study of the suggested converter is mentioned in this paper which in-turn can be helpful for its design. All the components which are used in designing this converter are considered to be ideal.

By using all the above modes implementing volt-sec balance and current-sec balance, the voltage gain equation can be derived as below:-

$$\frac{Vo}{Vi} = \frac{(ak+1)+D(a-1)}{(1-D)}$$

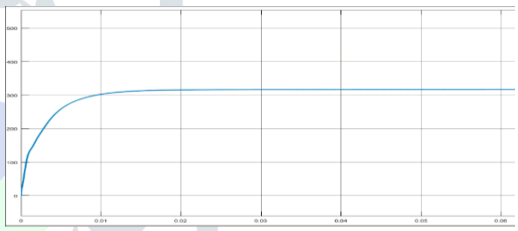

Fig 8:- Output voltage of boost converter with input voltage as 36V.

The output of boost converter remains constant after increasing gradually during transient state.

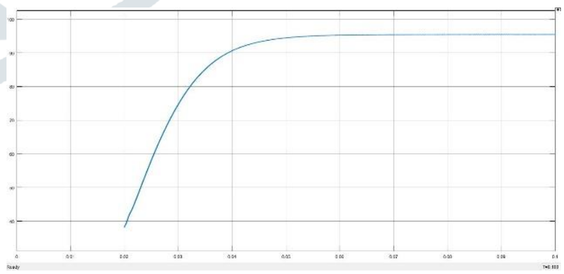

Fig 9:-Power efficiency

The power is found at both output and input sides and its efficiency is calculated which is found to be 89.7

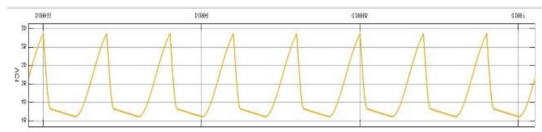

Fig 10:-Passive clamp capacitor 1 voltage

Capacitor discharges in mode 1, mode 2 and charges in mode 3. There won't be any effect on capacitor in mode 4, mode 5.

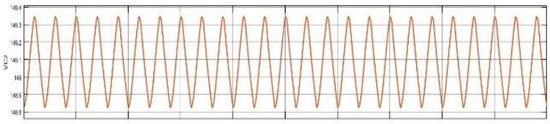

Fig 11:-Capacitor 2 voltage

Capacitor charges in mode 1, mode 2 and starts discharging continuously in the remaining modes.

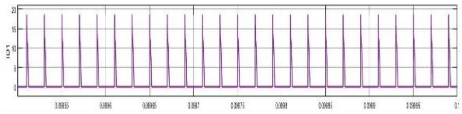

Fig 12:-Diode 1 current

Diode 1 is ON only in mode 3 i.e t_2-t_3. Current flows in diode only when it is in the on state. Current wont flow in remaining states.

MAXIMUM POWER POINT TRACKING (MPPT):-

The photo voltaic cell provides output based on the factors like temperature, insolation, sunlight, dirt, etc. insolation on panels can be changed according to the change in climate and weather resulting in the increase or decrease of output voltage. It is observed from the plot of voltage vs current of solar cell that maximum power output is obtained at a certain point[5]. For operating the system at that particular point a new concept called MPPT is introduced.

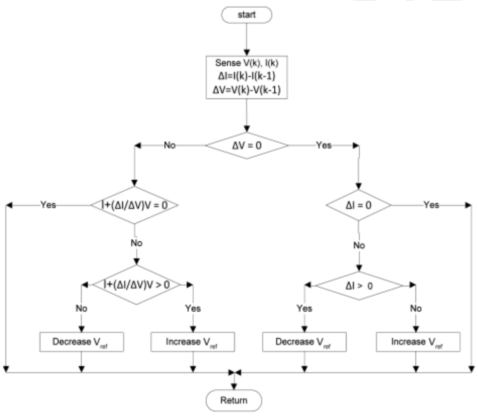

Fig 13:- Flowchart of the IC MPPT method

Perturb and observe (P&O), Incremental conductance(IC) are the two important MPPT methods. Though all the MPPT methods work towards same goal, incremental conductance is used in this project because of its effectiveness towards the elimination of the PI control loop and ensures the effect of control circuit within limits[11]. Therefore the system is made successful in finding MPPs and operating at maximum power points effectively with satisfactory dynamic performance.

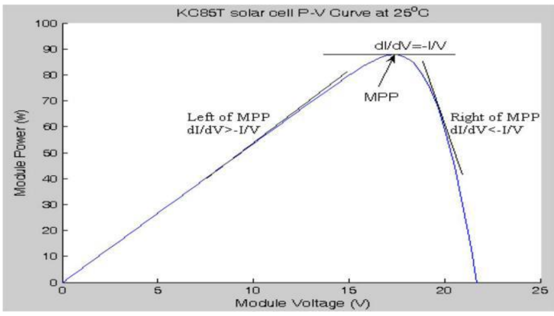

Fig 14:- IncCond method on a *P–V* curve of a solar module.

GRID CONNECTED INVERTER:-

The photo voltaic cell supplies DC voltage to the system. The end part of the system contains grid with AC voltage. DC voltage must be converter to AC voltage which can be done by three phase two level inverter[4]. Primarily the DC voltage is boosted with the help of boost converter and send to the inverter for the conversion. Voltage source inverters are of two types:-

(a) Voltage controlled voltage source inverter.
(b) Current controlled current source inverter.

Though both type of inverters are effective, there are some drawbacks which should be considered. Increase in filter size as well as decoupling inductor because of the necessity for the inverter to supply active power and reactive power which is a major drawback of VCVSI. In addition to the above correction of power factor is also not possible[14-18]. To overcome all the drawbacks we have chosen CCVSI.

In addition to the conversion inverter has to perform the following operations:-

- Control of active and reactive power flow.
- Grid synchronization.
- Reduction of harmonics.
- Control of dc link voltage.

Inner current control loop and outer voltage control loop are the two loops applied in the control strategy. Current loop main function is to control the grid current value while the voltage control loop function is to control the DC link voltage. abc to dq trandformation is used to transform the grid voltage and current to transform into 2 dimensional reference frame converting all the AC parameters to DC making it easier for calculations.

SYNCHRONOUS REFERENCE FRAME:-

To measure phase angle(θ) which can be obtained from the angular frequency(ω) is considered as the basic function of the phase locked loop. Assume(E_r, E_y, E_b) as the three phase voltages separated by a phase angle of 120° which are converted into dq reference frame. This conversion is happened in two stage transform process. First transformation is from abc frame to αβ frame and the secong stage transformation is from αβ frame to dq reference frame.
After solving a series of equations, we get an equation as

$$s\theta(s) = K(s)\, E_{max}(\theta_g(s) - \theta_{pll}(s))$$

Below is the representation of the above equation.

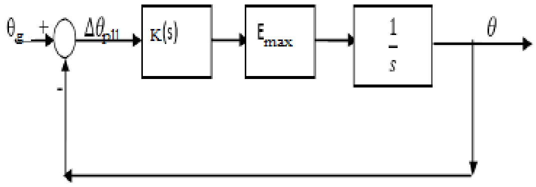

Fig 15:- Linear model of the Phase Locked Loop

From the above equation we can conclude that E_q (grid synchronization) should be set to zero. With this step the overall control structure of the PLL shown in the below structure is obtained.

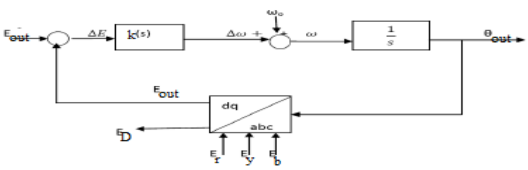

Fig 16:- Overall pll control structure.

The below equation should be satisfied by the inverter output.

$$V_D = W_D + E_D + L\omega I_Q$$

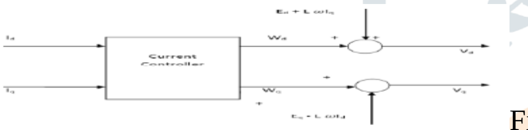

Fig 17:-

Inner current control loop

RESULTS:-

The circuit is modelled using matlab simulink and the results are drawn.

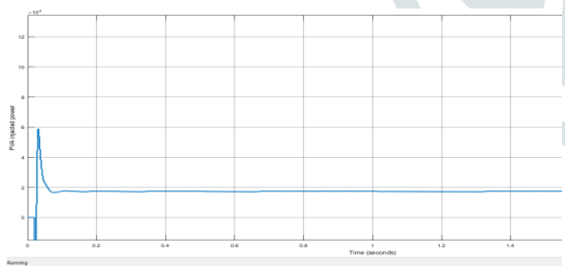

Fig 18:- Output power of the inverter

Figure shows the output power of the inverter with an input of 50V from the PV panel. Change in the irradiance results in the change in the inverter output as shown in the above figure.

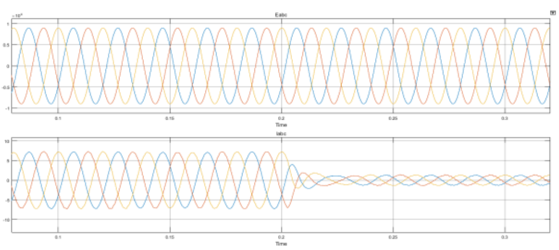

Fig 19:- Change in voltage and current according to the variation in irradiance of 1000 and 500.

The above figure contributes in describing the difference in the change in voltage and current with change in irradiance of 1000 and 500. A considerable amount of change is achieved in the proposed circuit.

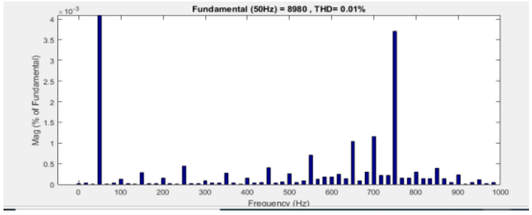

Fig 20:- Total harmonic distortion of output voltage waveform.

Table 1.Change in temperature with constant irradiance

Irradiance	Temperature	Input voltage	Output voltage	Power from PV panel	Output power
1000 W/m²	40° c	48.93 V	413.4 V	588.1 W	569.7 W
1000 W/m²	35° c	49.95 V	422.3 V	613.4 W	594.5 W
1000 W/m²	30° c	50.96 V	431.3 V	639W	620W
1000 W/m²	25° c	51.98 V	440.2 V	665.3 W	646W

Table-1 represents the change in the different values for change in temperature keeping the irradiance constant.

Table 1.Change in irradiance with constant temperature

Irradiance	Temperature	Input voltage	Output voltage	Power from PV panel	Output power
1000 W/m²	35° c	49.95 V	422.3 V	613.4 W	594.5 W
750 W/m²	35° c	38.82 V	324.7 V	366.5 W	351.3 W
500 W/m²	35° c	27.91 V	228.9 V	185.9 W	174.6 W
250 W/m²	35° c	17.23 V	135.1 V	67.82 W	60.84 W

The above table indicates the change in the voltage and power with change in irradiance keeping temperature constant.

CONCLUSION:-

The proposed converter in this project has high efficiency, high gain which is very much suitable for sources having low output voltage (Ex:- solar PV, fuel cell stack, battery). Under full load conditions the efficiency of the circuit is found to be 96%. The drawn plots from the converter are used to suggest that the best suitable turns ratio of the inductor would be to use 4 or 5 turns and the duty ratio may be changed from 0 to 0.7

while operating for better conversion. Implementing the conversion process other than the above mentioned values of turns ratio and duty ratio will lead to the incremental of losses.

This proposed converter helped in boosting the input PV voltage of 50V to ten times its value i.e 500V. Taking MPPT into consideration to track the point having maximum power with initial duty ratio as 0.5 we have achieved effective voltage boosting. Two level inverter helps in converting DC voltage output of boost converter to AC voltage of grid for synchronization and the gate pulse is given to the switches of the inverter by SRF control method (synchronous reference frame) which resulted in the voltage waveform with total harmonic distortion(THD) of 0.01% and current waveform with total harmonic distortion(THD) of 5.33%. LC filters reduced the harmonics of voltage and current waveforms from 86.69% to 0.01% and 97.68% to 5.33%.

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