International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 3, Issue 2, pp: (594-602), Month: April - June 2015, Available at: www.researchpublish.com

Design of Γ-Source Inverter with Finite Step Model Predictive Control Strategy

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***Abstract*: The Techniques of maximum power point tracking (MPPT) implemented with finite step model predictive control (FSMPC) for the application of Γ -source inverter presented in this paper. Incremental conductance MPPT algorithm and FSMPC model is developed to control the output current of the Γ source inverter in order to extract maximum solar power from the panel. Impedance-source inverters are inverters with voltage-buck-boost capability that cannot be achieved by the traditional inverters. Their boost capability is introduced by shorting their phase-legs without causing damages. Present impedance-source inverters are however burdened by their low modulation ratio at high input-to-output gain. Such low modulation usually leads to high voltage stresses across the components and poor spectral performance at the inverter output. To avoid these problems, inverters with coupled transformers have been introduced, but they usually lead to high turns ratio, and hence many winding turns, at high gain. An alternative would then be the Γ -source inverters proposed in the paper, whose gain is raised by lowering their turns ratio towards unity. The output current, passive component voltage and current are well regulated with proposed MPPT based FSMPC control strategy.**

***Keywords*: MPPT–maximum power point tracking, FSMPC-finite step model protective control, PCC- Predictive current control, PWM-,Pulse with modulation TSI- t-source inverter, SPV-solar photo voltaic, DM-differential mode, MPP–maximum power point.**

I. INTRODUCTION

The renewable energy available on earth is accounted by solar irradiation or its secondary solar power sources. Capturing solar energy becomes a hot research area due to its plenty of resources. Solar energy is radiant light and heat from the sun harnessed using a range of ever-evolving technologies such as solar heating, solar photo voltaics, solar thermal energy, solar architecture and artificial photosynthesis. It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power.

Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. However, there are a lot of challenges ahead during photovoltaic power harvesting. One of them is the efficiency of conversion from solar to electricity.

Maximum power produced by photovoltaic system can be extracted by the implementation of DC-DC buck boost conversion stage to adjust the solar panel output voltage level. Main target of the Maximum Power Point Tracking (MPPT) algorithm is to produce the appropriate input reference for the controller. This controller controls the converter output voltage and makes it follow the Maximum Power Point (MPP) which is located at the knee of the photovoltaic I-V characteristics.

There are number of existing algorithms used for MPPT. They vary in cost, range of operation, complexity, speed of convergence, and applications. Among all the currently existing MPPT techniques, perturbation and observation (P&O) algorithm is very popular and widely used because of their simplicity and ease of implementation. Hill climbing method is perturbed in the duty ratio of the power convertor while P&O is perturbed in the operating voltage of the PV array.

There are also some disadvantages while using P&O methods, such as oscillation at steady state and the operation fail under rapidly changing atmosphere condition. Fuzzy logical control and neural network control types of MPPT provide good performance under rapidly changing sunlight irradiance levels, but the disadvantage of these two methods is that the control algorithm is rather complex and hard to implement under difference circumstances.

On the other hand, incremental conductance method adjusts the PV array output terminal voltage according to the MPP based on the incremental and instantaneous conductance of the photovoltaic module with presents techniques of maximum powerpoint tracking (MPPT) implemented with finite step model predictive control (FSMPC) for the application of Γsource inverter. It has advantage of simplicity, fast responds to changing atmosphere condition; as well as avoids the disadvantages of oscillation. Hence it is chosen to be implemented for Γsource inverter in the application of PV power generation

The asymmetrical Γ-source inverters proposed inverter in this paper for overcoming the limitation of z source inverter. similar to the presented trans-Z-source inverters are therefore capable of operating at high gain and modulation ratio, where is the average dc current drawn from the source. Besides high current stress, the trans-Z-source inverters are burdened by two other constraints. The first is their chopping input current caused by their input diode or six-switch inverter bridge. The second is their accompanied high turns ratio, and hence many winding turns, at high gain. These limitations are addressed while describing the proposed asymmetrical Γ-source inverters

Semiconductor-based power inverters have widely been used in the industry because of their compact size, high power density and efficiency. However, traditional power inverters can only either step down or up their outputs, but not both. To have both capabilities, either front-end dc-dc converters should be added or alternative single-stage buck-boost inverters should be used. The former, being quite straightforward, is not discussed further. The latter, being more integrated, has a few possible topologies for consideration like the Ćuk and SEPIC.Other possibilities are those Z-source inverters proposed. The added impedance network allows two switches from the same phase-leg to be turned on without causing damages. Instead, the shorted shoot-through state is intentionally added for voltage boosting, while retaining the usual voltage-buck capability of the six-switch inverter bridge.

Each Z-source inverter therefore has nine switching states, including those traditional eight non-shoot-through active and null states.Even with their proven advantages, existing Z-source inverters still have some shortcomings to resolve. One of them is their chopped input current, which is resolved earlier by the embedded Z-source, quasi-Z-source and LCCT inverters.Their common objective is to smooth the input current by using an existing Z-source inductor.Alternatively, the source can be shifted fully to the upper or lower inductor only. The asymmetrical *Γ* network thus formed then has different stress distribution among its components. The latter is probably obvious, as understood from classical transformer theory.

In common, they use one coupled transformer, two capacitors and an inductor, which are nearly the same as the traditional Z-source, except for the coupled transformer.Adding the external filter would however not raise the trans-Z-source gain, and hence would not solve the second concern of high turns ratio at high gain.The asymmetrical Γ-source inverters would, on the other hand, have their gain raised and turns ratio lowered at high gain..

II. Γ SOURCE VS Z SOURCE INVERTER

To better compare the Γ -source and trans-Z-source inverters, their input-to-output voltage gains are set equal. That gives rise to the following relationship for their respective turns ratios if their shoot-through times and modulation ratios are further set equal where subscripts *Z* and Γ have again been added to distinguish between the trans-Z-source and asymmetrical Γ -source inverters. Expression tells that their turns ratios are equalized at two, and for greater than two, the corresponding Γ will always be smaller than two, tending toward one, as demonstrated. Their respective variation ranges can therefore be summarized as and Γ with increased and Γ decreased to make their gains higher. The range for Γ is noticeably narrower, reflecting its higher sensitivity (small increment in Γ leading to a large increase in gain), especially near to its lower limit of one. It should therefore be wound more carefully to avoid triggering of unanticipated events.

Other concerns to address are those related to the semiconductor devices, whose voltage and current ratings are summarized. The expressions obtained have assumed that in order to utilize the dc-link voltage fully. They are applicable to all four inverters shown in Fig. The inverters are therefore "similar" in terms of semiconductor requirements, as also commented.

It can particularly be seen that the diode voltage during shoot-through can be comparably high because of the term found in its numerator, but not that of the switch voltage. The figure shows that shoot-through currents of both classes of inverters are the same. Winding currents through *W2* of the trans-Z-source inverter and asymmetrical Γ-source inverter in Fig. also the same and equal to the shoot-through current. Winding current through *W2* of the asymmetrical Γ-source inverter in Fig is however lowered by one when compared with the shoot-through current. In a way, it can be interpreted as the shifting of dc voltage stresses from the bridge switches to the diode. Where necessary, multiple series devices must hence be used, which comparably is easier to realize for the uncontrolled front diode than the controlled six-switch inverter bridge. Solving the Expression we can get the following capacitor voltage equalities, where additional subscripts have been added to distinguish the two circuits shown in Fig 1 .

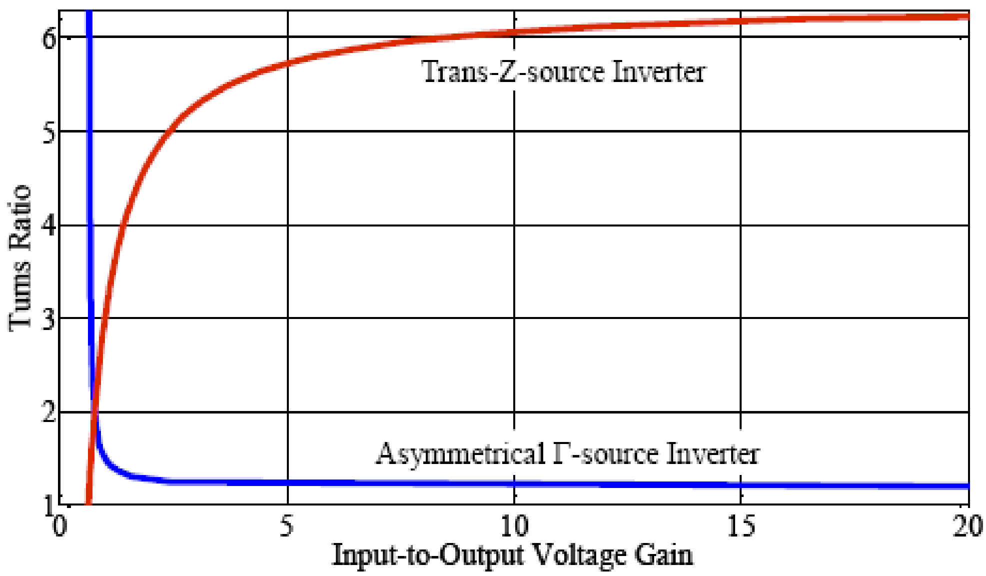

Fig .1 Turns ratio versus input-to-output voltage gain

If a low-pass filter (*Lf* and *Cf*) is added to the inverters shown .its capacitor voltage can also be written as { }, which is usually smaller than under voltage-boost mode. These expressions are summarized in Table I for easier comparison. In addition, by plotting above equation with respect to ̃for different combinations and characteristic curves shown in Fig can be obtained. Those curves are interesting since they prove that a certain desired gain can be obtained by increasing or decreasing Γ n without increasing the capacitor voltages even though it helps to lower the dc-link voltage stress with a smaller.

III. FINITE STEP MODEL PREDICTIVE CONTROL STRATEGY

The first step of this control program is extracting the input voltage and current of the PV panel. Then the MPPT algorithm calculates the voltage *Vm*, current *Im* as well as the corresponding maximum power at MPP and feeds the results into FSMPC. After getting the MPP operating voltage *Vm* and current *Im*, together output voltage and current, the FSMPC decides the switching signals of the inverter. Finally the inverter switches based on the signals produced by FSMPC.

FSMPC control is chosen for its fast dynamic response and suitable for fast changing environmental condition. The main purpose of FSMPC is to precalculate the behavior of a specific model and therewith to choose an optimal value of a control variable. Based on the implementation steps of FSMPC, first the reference (load voltage or current of power converters for example) is set by designer; second the predicted variables are to be generated by a modulation stage; next the predicted variables are used to be compared with reference variable, and the one closest to the reference will be chosen.

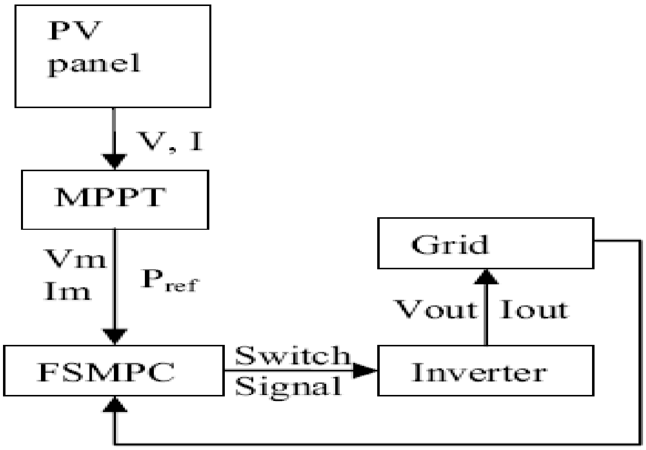

Fig .2 finite step model predictive control

The prediction program chooses the switching state which gives the minimum difference between reference value and predictive value calculated from quation. One possible way to do this is to formulate a cost function to obtain this difference. The control strategy is shown in following fig. The main purpose of FSMPC is to precalculate the behavior of a specific model and therewith to choose an optimal value of a control variable. Based on the implementation steps of FSMPC, first the reference (load voltage or current of power converters for example) is set by designer; second the predicted variables are to be generated by a modulation stage.

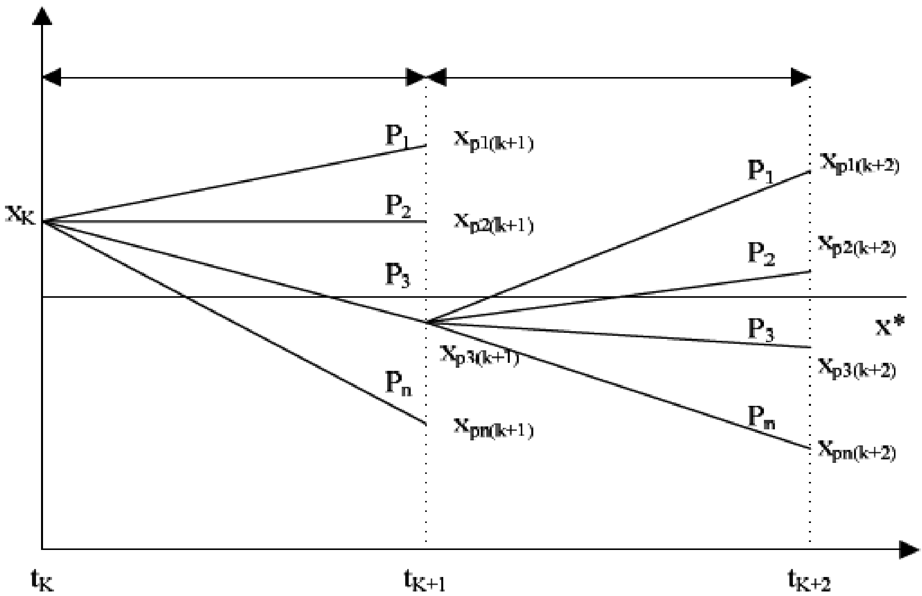

Fig .3 control strategy of model predictive control

IV. INVERTER MODEL

In $\alpha\beta$ plane, the load EMF can be expressed as [1]

$$e = \frac{2}{3}(ea + aeb + a^2 ec) \quad (1)$$

The load dynamics can be described by the vector equation:

$$v = L\frac{di}{dt} + (R + RL)\, i + e \quad (2)$$

Where v is the voltage generated by the inverter, L is the load inductance, R is the load resistance, RL is the resistance of filter inductor and e is the load voltage.

The future load current can be determined by

$$i(k+1) = \frac{(v\,(k+1) - e(k+1))Ts + Li(k)}{(R+RL)Ts+L} \qquad (3)$$

The prediction program chooses the switching state which gives the minimum difference between reference value and predictive value calculated from (3).One possible way to do this is to formula a cost function to obtain this is difference .By minimizing the cost function, proper current or voltage vector can be gained and corresponding switching state can be chosen .for instance,the cost function of load current is formulated.

V. DESIGN OF Γ SOURCE INVERTER

This project Γ source inverter designed with finite step model predictive control strategy. The basic block diagram of Γ source inverter is shown in below fig 4 diagram.

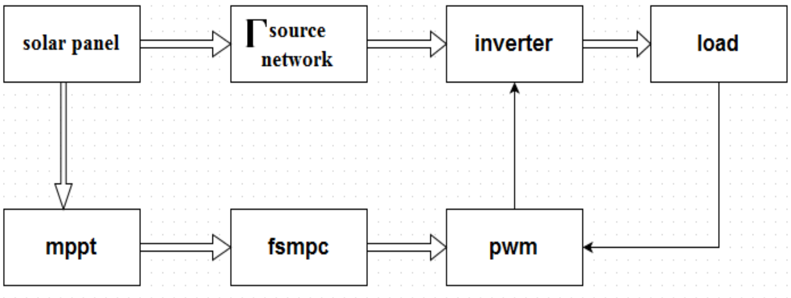

Fig .4 block diagram of Γ source inverter

In this block diagram energy flows from the solar panel to inverter through the Γ source network. The inverter gets triggered respect with the control signal from the finite step model predictive control strategy. The Γsource network is the main circuit for to reduse the turns ratio and increase the gain of the system. finite step model control get the input from the mppt and measured signal then generate the output control signal for triggering the inverter switches for get the maximum power from the renewable energy source like a solar energy in this project.in normal the general inverter have six switches are triggered by the control pulses generated by the pulse generator. The pulse generate with respect to the FSMPCS. Traditional source inverters are Voltage Source Inverter and Current Source Inverter. The input of Voltage Source Inverter is a stiff dc voltage supply, which can be a battery or a controlled rectifier both single phase and three phase voltage source inverter are used in industry. The switching device can be a conventional MOSFET, Thyristor, or a power transistor. When the power requirement is high, three phase inverters are used. When three single phase inverters are connected in parallel, we can get the three phase inverter. The gating signals for the three phase inverters have a phase difference of 120degree. These inverters take their dc supply from a battery or from a rectifier and can be called as six-step bridge inverter

Voltage source inverter is one which the dc source has small or negligible impedance. In other words a voltage source inverter has stiff dc source voltage at its input terminals. A current-fed inverter or current source inverter is fed with adjustable dc current source. In current source inverter output current waves are not affected by the load. Γsource network is the circuit connected between the solar panel and the inverter circuit.

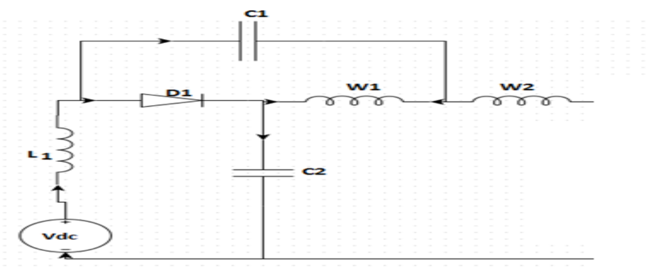

Fig .5 Γsource network

This Γsource network design in the form of Γshape.so only this type of inverter connected with inverter called as the Γsource inverter. that the Γsource network has the coupled transformer, capacitor and inductor as per diagram is shown in above fig 5.

VI. SIMULATION RESULTS

This project Γ source inverter designed with finite step model predictive control strategy. The circuit diagram of Γsource inverter is shown in below diagram fig 6.

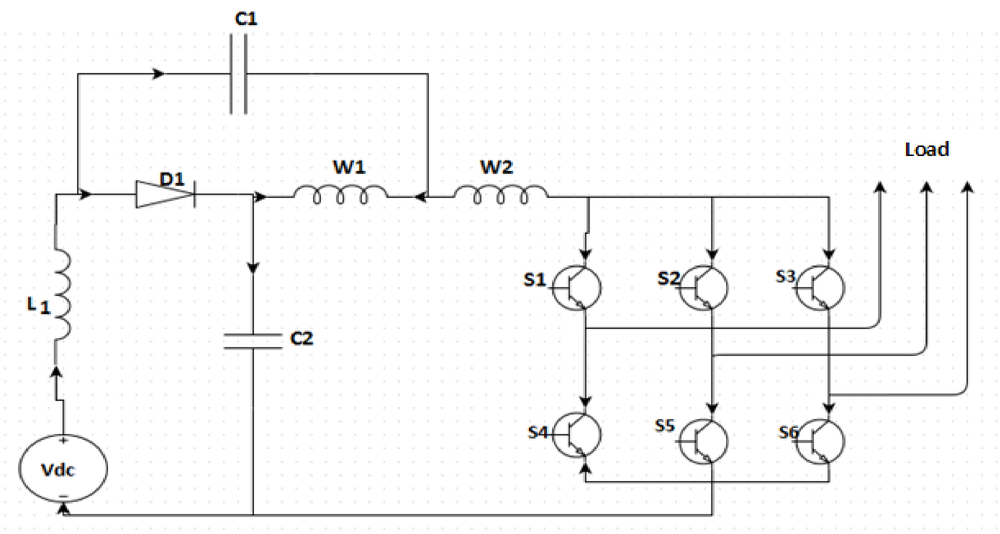

Fig .6 Γsource inverter

In common, they use one coupled transformer, two capacitors and an inductor, which are nearly the same as the traditional Z-source inverter except for the coupled transformer.

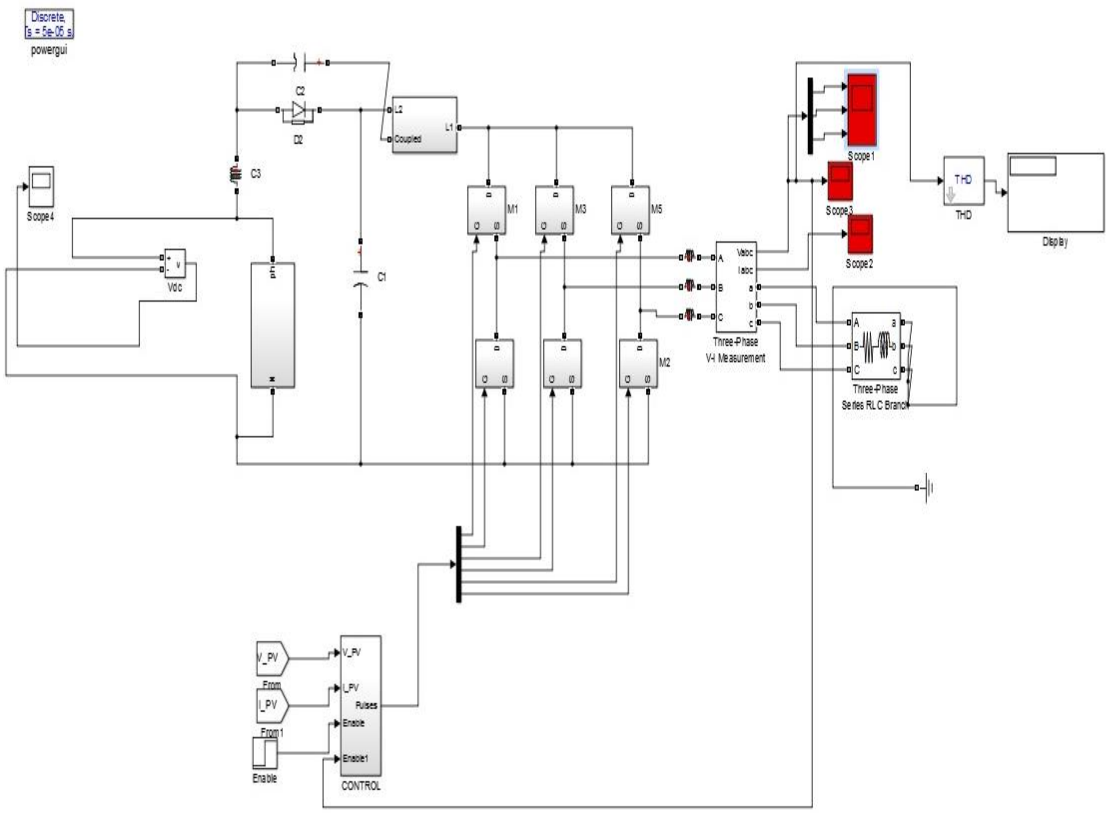

Fig .7 Simulation circuit of Proposed Model

Comparing with the trans-Z-source inverters, the number of components used is the same if an external second-order LC filter is added in shunt with the source for filtering purposes. Adding the external filter would however not raise the trans-Z-source gain, and hence would not solve the second concern of high turns ratio at high gain. The asymmetrical Γ-source inverters would, on the other hand, have their gain raised and turns ratio lowered at high gain .

The model developed in this work has been built in the Mat Lab/Simulink Environment. It integrates different parts of the building from energy production systems to energy consumption specifications. The simulation doing in the mat lab shown in the fig 7. Dc voltage obtained from the Solar Panel is given as input to the Γsource network.The voltage from the energy source (dc) is also focused to the MPPT .The MPPT deduct the maximum voltage and maximum current during the maximum power for to get the maximum power generation from the solar source of energy. After that the finite step predictive control strategy used to generating the control signal for to control the inverter output with the help of pulse generation.

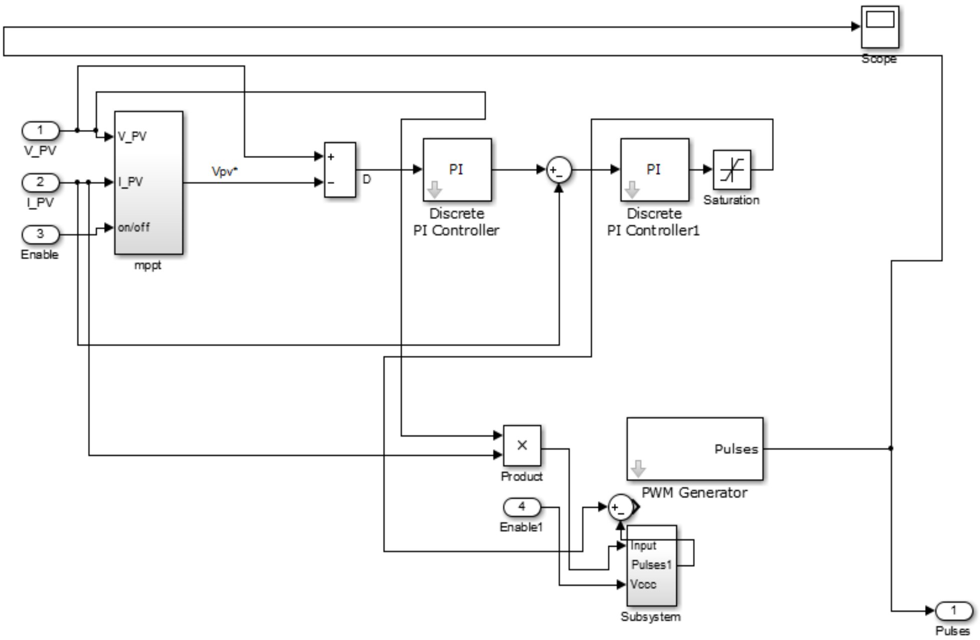

Fig .8 control block

Depending upon the reference value set initially and the measured value measured from the MPPT and solar output, the control signal was generated. Similarly two modes of operation performed in the Γsource network used to step up the voltage of the output of inverter as per control signal. This output is control in dynamic state of solar generation. so we get the constant output at the inverter side by controlling the inverter switches with the help of Γsource network. This system of solar based Γsource inverter is proposed for to eliminate the battery usage in case of battery used for to get the constant power at the inverter output.

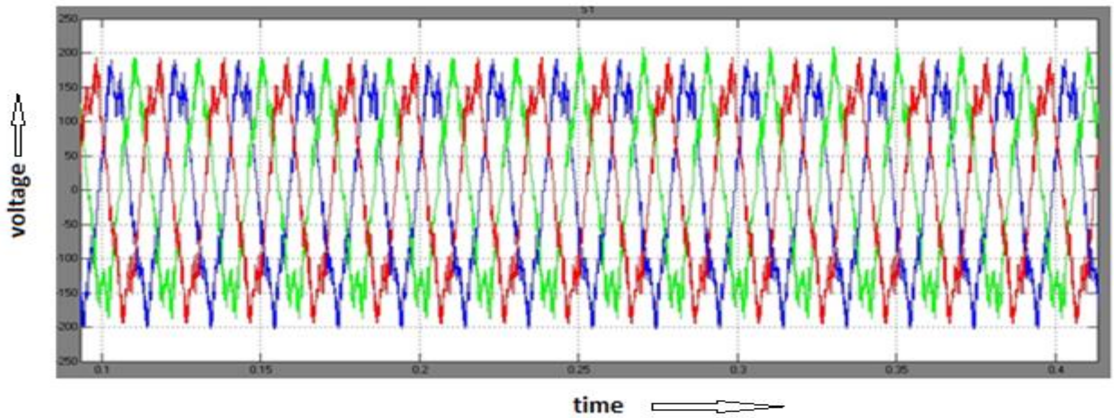

Fig .9 inverter output voltage

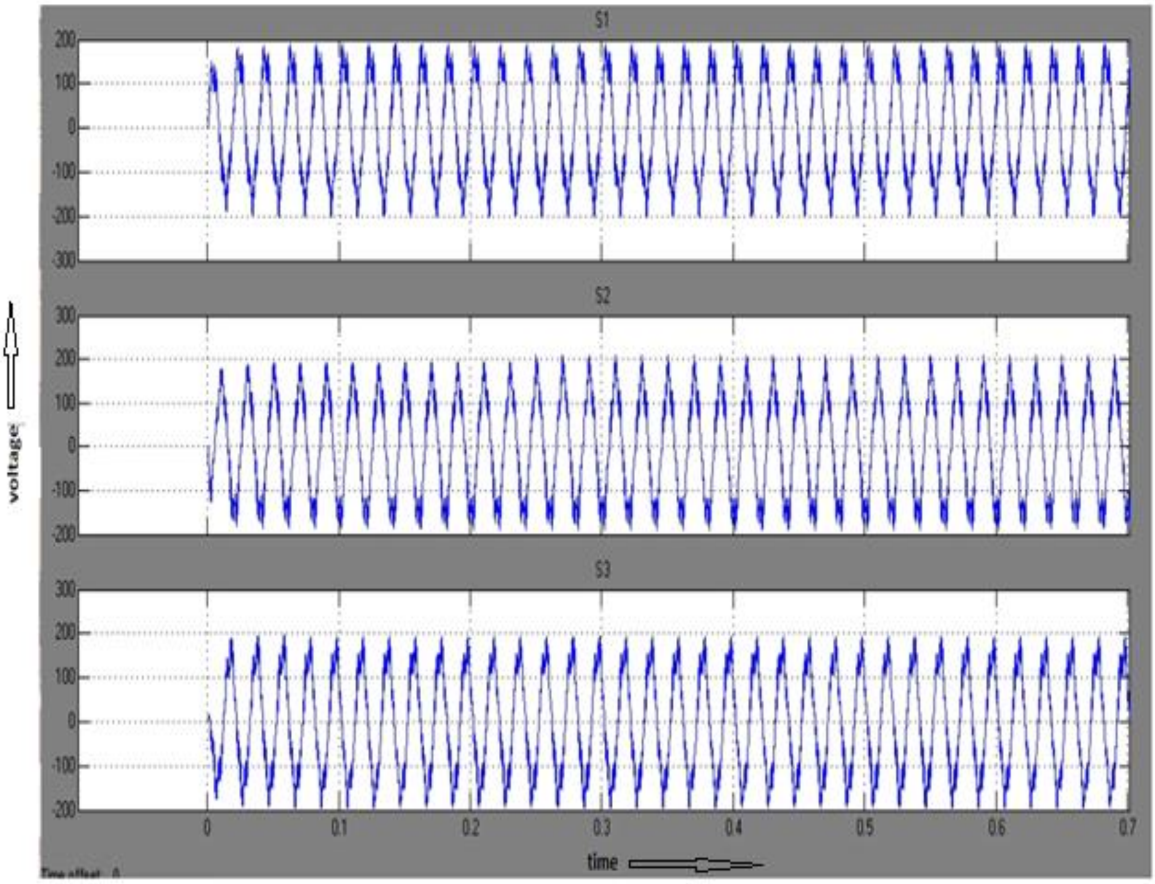

Fig. 10 inverter phase voltages

Based on the implementation steps of FSMPC. With FSMPC's ability of multisystem variables regulation, load current regulations, impedance network inductor current as well as capacitor voltage an all be regulated as subjecting to constraints of this control method minimizing the cost function, proper current or voltage vector can be gained and corresponding switching state can be gained. We get the constant output at the inverter side by controlling the inverter switches with the help of Γsource network. This system of solar based Γsource inverter is proposed for to eliminate the battery usage.

VII. CONCULSION

In this paper, it explore maximum power point tracking technique for Γsource inverter through finite step model predictive control strategy.MPPT algorithm tracks the maximum power point and feeds the corresponding operation voltage Vm and current Im in to the FSMPC controller. FSMPC controller collects the information of MPP and inverter output and produce the control signal`to control the switching devices of inverter.so as to achieve the optimal output power. The FSMPC shows fast dynamic response regards to quickly changing operation and indicates its usefulness in fast changing atmosphere.

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