DESIGN OF THREE PHASE MICRO SOLAR INVERTER WITH IMPROVED TOTAL HARMONIC DISTORTION

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ABSTRACT— *Single phase micro solar inverter or module integrated converter (MIC) have perceived current market accomplishment due to exclusive topographies. Such as maximum energy production, better system effectiveness, minimum installation expenses, higher flexibility and module linearity. Assuming additional growth of the solar inverter market, this research offers a unique concept of micro inverter integrated in grid tied photovoltaic (PV) systems with improved output voltage/ current efficiency and low ripple. The proposed design increases measurability by designing new inverter architectures, decrease rate per watt and provide advanced consistency. The first stage of this circuit comprises of solar PV panel connected to the high voltage full bridge DC-DC resonant boost converter. The second stage contains a soft switching structure without having extra auxiliary components. An additional merit of the proposed inverter is that total harmonic distortion (THD) of current and voltage is successively achieved much fine than previous inverter topologies.*

Keywords— Micro solar inverter, Space Vector PWM, Three phase module integrated converter (MIC*)*

I. INTRODUCTION

The power generation by solar technique is almost 2% of the total generation due to its cost as associated to fossil fuels. That is why it does not donate its role with significant part [1]. The output of the photo voltaic arrays depends upon the level of the solar irradiance and the temperature of the array surface. In these conditions maximum power can be obtained by using mechanical solar trackers and using maximum power point tracking (MPPT) technique [2]. In this research, a practical approach will be proposed to improve the performance and efficiency of photo voltaic three phase power generation. Several isolated converters used for DC converter applications in order to offer galvanic isolation. The topologies with galvanic isolation have to be characterized in two types: single switched and multi switched topologies. Since last few years, RLC topology has become attractive because of its striking qualities. For example, good proficiency and regular zero voltage and zero current switching commutation. A multilevel bridge RLC converter is deployed to gain higher efficiency HVDC output in first stage. In the conventional solar technologies, MPPT is constructed by using different types of MPPT controllers. In proposed system, there is no need of any MPPT controller to achieve maximum power track. Hence this model offers, cost eliminated system and less extra circuitry. In Last three decades, many active soft-switching topologies have been proposed for the three-phase module integrated converter. The topologies used for DC/AC conversion can be categorized in three different groups: 1) resonant dc-link inverter (RDCLI), has many advantages as compared to ARCP, It needs fewer auxiliary switches and did not require complex circuit. To achieve linearity and minimization of the number of extra components, several soft-switching techniques were proposed in the past. Though switching signals used to drive auxiliary of the gate terminal can easily disturbed by noise, produced by main circuit. 2) Resonant AC-link converter (RACLC), stepup voltage and electrical separation in circuit is achieved at the meanwhile using RACLC which is the most ideal topology for solar power generation [7,8]. 3) Auxiliary resonant commutated pole (ARCP) may be useful generally for the voltage-source type converters [3-5]. There is a drawback of this topology that the control technique for RACLC is complex and required two way switches. Hence, auxiliary circuitry is necessary for all soft switching techniques discussed prior. Soft-switching technique used in the first stage is PWM and in second stage technique is space vector pulse width modulation technique (SVPWM). O/p voltage and I/P current can be controlled effectively as compared to other methods using SVPWM. Using switching vectors, I/P current and O/P voltage can be controlled in a more flexible way in this technique. This also decreases the cost, because it does not need difficult auxiliary circuitry. The resonant circuitry achieved by using combination of main MOSFET and output inductor L1. Inductor L1 current is deliberately flowing in two directions during commutation switching cycle, to produce zero voltage switching conditions. For the meantime the inductor average must be controlled to produce a low ripple current. Soft-switching method is appropriate for micro solar inverter applications because switching damages are typically dominant in these types of circuits.

In recent times inverters used in different power conversion systems. Multilevel inverter is technique in which combination of many switches used to generate stepped or improved AC output waveforms. Due to this topology, the output dv/dt and THD improving the output as compared to other inverter topologies. A multilevel two stage three phase micro solar inverter design is discussed in this paper. Proposed design will surely increase measurability and improve THD as compared to previous techniques used in solar power generation.

II. DESIGNING OF THE PROPOSED INVERTER IN SIMULINK:

Proposed Simulink model of three phase micro solar inverters consist of following separately executions. The input of this inverter is solar power, that produces a specific power fed to the single phase rectifier. Single phase rectifier further supplied AC to the booster circuit. High voltage DC feed three phase inverter. Schematic diagram of three phase micro solar inverter is shown in Figure1. These are the following separately executions of the two stage micro solar inverters.

A. SINGLE PHASE INVERTER CIRCUIT DESIGN

B. SINGLE PHASE INVERTER SWITCHES GATE DRIVE CIRCUIT DESIGN

C. SINGLE PHASE INVERTER WITH LC CONVERTER AND STEP TRANSFORMER

D. GATE DRIVE CIRCUIT OF THREE PHASE SVPWM INVERTER

E. THREE PHASE MICRO SOLAR INVERTER CIRCUIT DESIGN

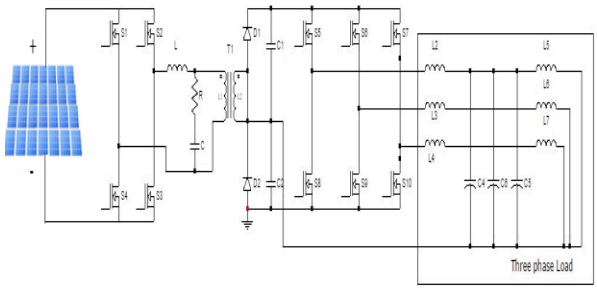

Figure 1Three phase micro solar inverter proposed model

A. SINGLE PHASE INVERTER WITH LC CONVERTER

The MIC architecture deployed from solar panel, that provide DC input to single phase rectifier which converts the DC to AC voltage. This is a very efficient technique because of its maximum frequency capability. The proposed converter with its frequency transformation capability could be categorized into three structures, based on the dc link capacitance configurations: 1) dc link capacitance , 2) dc- pseudo-link capacitance, and 3) high-frequency AC link capacitance [3]–[4]. Typically the micro solar inverter just injected the inverted power to the AC site grid with the single direction flow. Yet, using decoupling linked capacitor, the proposed solar model can sustain AC site grid, a VAR and also harmonics compensation [6]. Remaining two structures DC PSEUDO LINK capacitance and high-frequency AC link

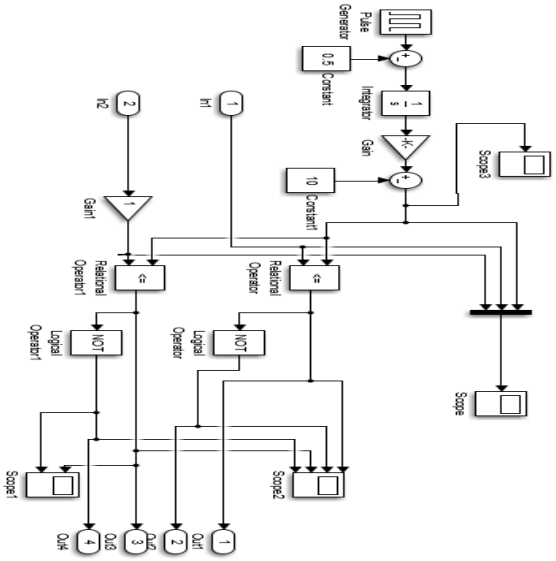

Figure 2 PWM Gate drive circuit for single phase inverter

capacitance is needed two way power flow. the power decoupling capacitor required two way power flow ability in the solar inverter system.

B. SINGLE PHASE INVERTER GATE DRIVE CIRCUIT DESIGN

Gate drive circuit is a very important circuit for the inverters. Efficiency of inverter totally depends on switching of these semiconductor switches. In this first stage of proposed inverter the gate drive circuit is shown in Figure 2. The gate pulses are the important feature for any kind of semiconductor control switches. How the circuit efficiently work is totally depends upon these switches on off time that determined by gate pulses. The technique used in this circuit is the PWM based gate drive pulses. MOSFET are voltage control device and they require very low gating power. The gate signal has to be isolate from main circuit by pulse transformer/ optocouplers.

PWM (Pulse Width Modulation) technique used in this circuit. There is pulse generator that produces Time based pulses with the Period of 1/39e+3 and pulse width of 50%. This gate pulse then multiplied by the constant value of 0.5 and then integrated by the integrator. After then this pulse passed through the gain amplifier with the gain value of 31.2e+5. The output of the gain than again sum up with the constant of 10. After then, this wave pulse passes through the relational operator for the PWM then the gate pulse generated. There are four switches used in the inverter circuit and the Gate signal provided the switching of these switching repeated with iteration of cycle as the two switches turn on at a time while the other two switches kept off.

C. SINGLE PHASE INVERTER WITH LC CONVERTER AND STEP UP TRANSFORMER WITH FULL BRIDGE RECTIFIER CIRCUIT

RLC resonance circuit used in this system is basically important for its current-voltage wave form positioning with regards to its axis. In other words the RLC circuit mainly influences the performance of this circuit. Resonance is a phenomena in which special frequency determined by the values of the resistance, capacitance, and inductance that implies in AC circuits. The condition of resonance is up-front and it is considered by minimum impedance and zero phases. When the inductive and capacitive reactance will be equal in magnitude but cancel each other. They cancel each other due to 180 degrees apart in phase resonance of a series RLC circuit . When a constant voltage is driving Series RLC circuit, at variable frequency, then the magnitude of impedance Z is proportional to the magnitude of current. Consequently, control absorbed by RLC series circuit is must be at its peak value as $P=I^2Z$. Presently we suggesting two recurrence points called half-power points which are - 3dB down from most extreme and taking 0dB as the greatest current reference. Those half points are taken by either reducing or increasing the frequency. Until the change in frequency changes the absorbed power by resistor in series resonance circuit is halved of its maximum value at resonance. The step up transformer boosted the voltage at the turn ratio of 50:150. Then this boosted output AC fed in to the rectifier circuit.

D. GATE DRIVE CIRCUIT OF THREE PHASE SVPWM INVERTER

The gate drive circuit is responsible for the switching operation of the circuit. Gate drive circuit decides the sequence in which the switches are turned on and off. In the proposed gate drive circuit, MOSFET's are used as voltage control devices. They have an important advantage of extremely low gating power comparing to other switches.

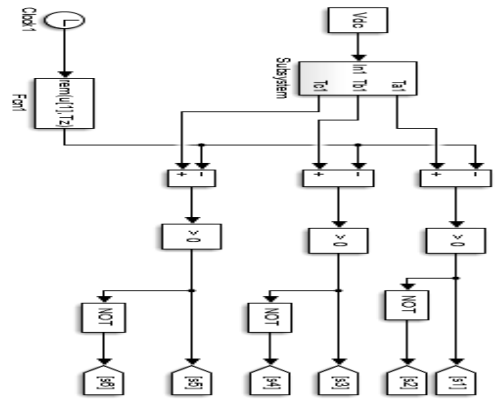

Figure 3Gate drive circuit of three phase SVPWM inverter

This isolation is necessary to prevent any direct influence or damage of gate power circuit in case of any disturbance. In order to bring the device into conduction the capacitance of the gate-source must be charged first. The turn-on delay time td (on) is the required time for the gate to source capacitance to charge to the threshold level to acquire the device in conduction region. The rise time tr is the gate charging time required to drive the electrons through the control range of gate to drain voltage for full conduction of the device. During turn-off, the process is reversed.

they directly effects switches performance, and also disturbs t_d and t_r. Conduction through these switches depends upon its on/off timings which derived by Gate drive circuit. MOSFET connected in this model have some parameters that needs to specify. The internal structure of these switches consists of FET and diodes. Its internal physics depends upon resistance that caused to decrease flow of electrons during active condition. So the internal parameters of switches normally settled as FET resistance to 0.1 ohm and the diode resistance kept at 0.01ohm. Snubber resistance must be used very high to makes opposition for reversed flow of electrons. Normally its value obtained in hundred thousand. Complete simulink circuit diagram of three phase SVPWM micro solar inverter is shown-in-Figure.4.

III . RESULTS AND DISCUSSION

A. SINGLE PHASE INVERTER OUTPUT SIMULATED WAVE FORMS

Various systems and techniques are available to generate sinusoidal voltages for different applications. The most commonly used method for this purpose is the one in which a version of a square waveform voltage is generated at the inverters output and then its first harmonic is detached by a suitable filter.

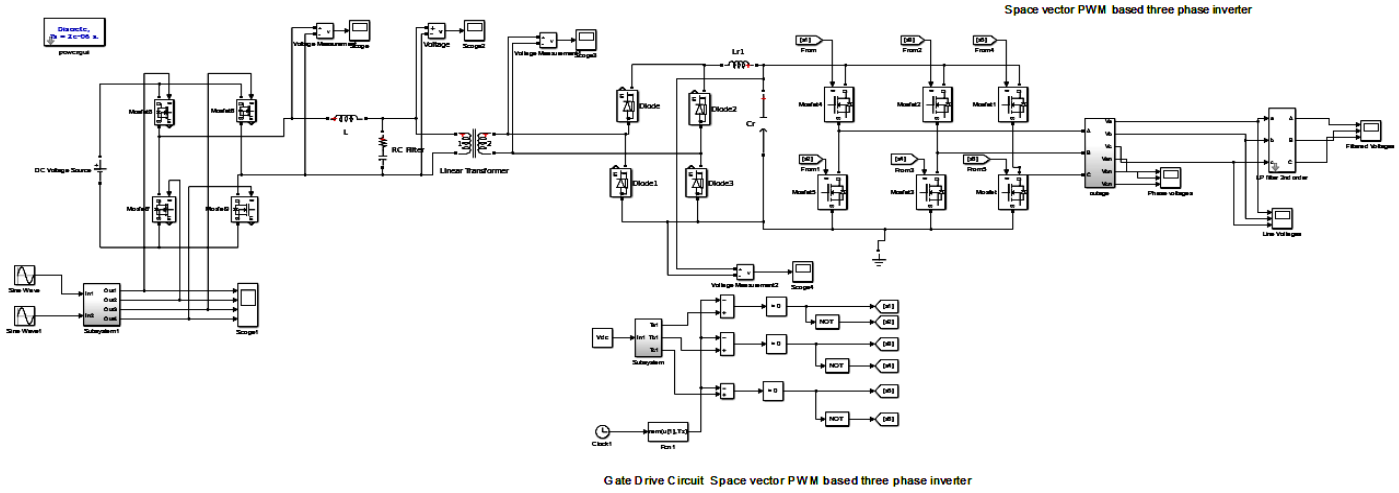

Figure 4 three phase micro solar inverter circuit diagram

Turn-off time delay is the time td (off) required for the gate to release from it's over driven voltage to the threshold voltage to drive switching device into active region and from saturation region. The fall time is the time required for the gate voltage to move electrons through active region before go through to the cutoff region. The switches used in three phase inverter gate control signal diagrams shown in Figure 3.

E. THREE PHASE SVPWM INVERTER CIRCUIT DESIGN

Three phase sinusoidal pulse width modulation inverter is working on the same principal like single phase inverter. The internal properties of MOSFET's switches are very important to choose. Because if the parameters are not correctly chosen

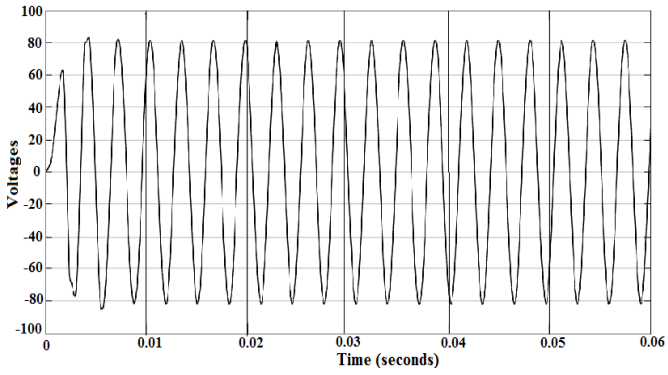

Figure 5 RLC boosted voltage waveform

In order to efficiently progress the voltage harmonic spectrum, unipolar or bi polar PWM (pulse width modulation), multilevel modulation and multilevel inverters can be used. In many important commercial systems which are intended to provide uninterruptible or reserve electrical supply to the customers, it is preferred to use inverters capable of providing sinusoidal output voltages. A PV panel, DC voltage source is used to provide supply to the inverters. At the output of the inverter, LC filters are connected to stabilize the results.In the proposed design, the Inverter is followed by an RLC circuit which is intended to enhance the output of the inverter. Output of single phase solar inverter with LC filter is shown in Figure5.

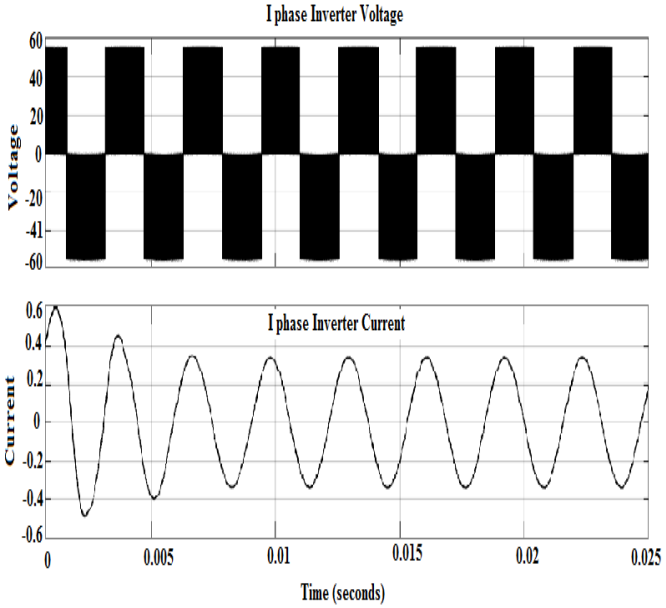

Figure 6 Single phase inverter output voltage/current waveforms

A low cost and low profile transformer is used in this RLC circuit to step up AC voltage of the single phase inverter. The cost of a transformer depends upon the difference between the number of primary and secondary windings. If the difference is small as in our case, then the cost of the transformer decreases. Therefore overall the cost of the resonant circuit is minimized and also makes system cheap as compared to other three phase inverter systems.

Another advantage of this circuit is that it allows the proposed topology to be used in the systems where solar power in not large enough to contribute to DC power for the generation of three phase power supply shown in Figure6 . In such cases this RLC circuit boosts up the systems current and voltages and thus increases the power to the desired level.

B. INVESTIGATION OF HIGH DC VOLTAGES OF PROPOSED IVERTER

In this part a DC converter is implemented generate a high voltage three phase AC supply. This part acts as the most important and final stage of the MIC. In this part a high voltage DC converter used to produce a high level DC which linked to the three phase inverter input to generate three phase AC is shown in Figure7. This three phase AC inverter consists of following components;

(i) First component is a "full wave rectifier" which converts the coming high level AC voltage into DC

(ii) Second component is a LC low pass filter which is intended to make the output of the rectifier smooth and ripple free DC.

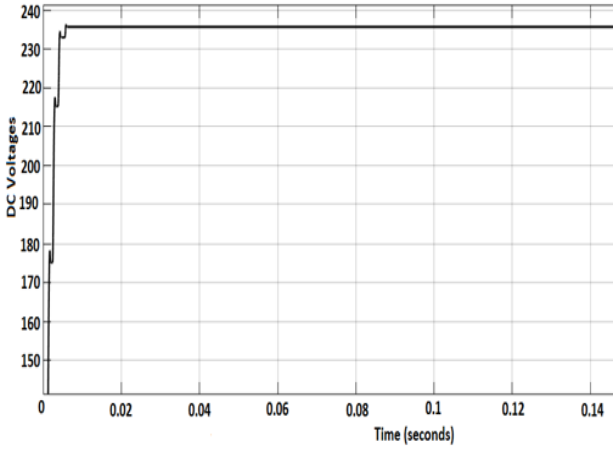

Figure 7 Output of the proposed high voltage DC converter

C. LINE AND PHASE VOLTAGES OF SVPWM INVERTER

Gate drive pulses are responsible for the switching actions and for turning the inverter circuit on and off. The current and voltages are measured as line and phase voltage in inverter circuit. A closer look of the line voltages are shown in Figure 8 illustrates that they exist between two voltage levels.

In the positive half cycle, the line voltages attain their maximum value or the peak value at about 220 volts. These are the voltages that appears between phases to neutral of three phase micro solar inverter output.

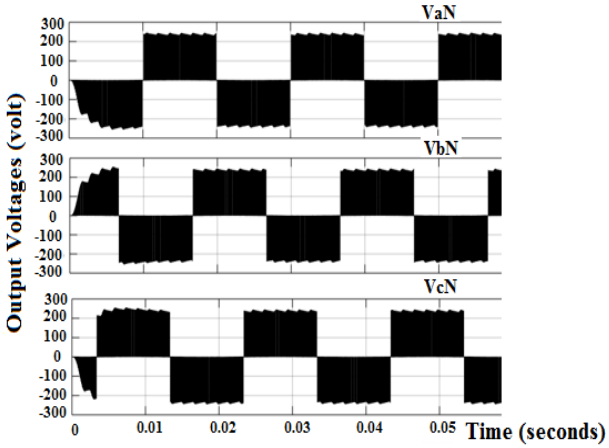

Figure 8 three phase line voltages of SVPWM inverter

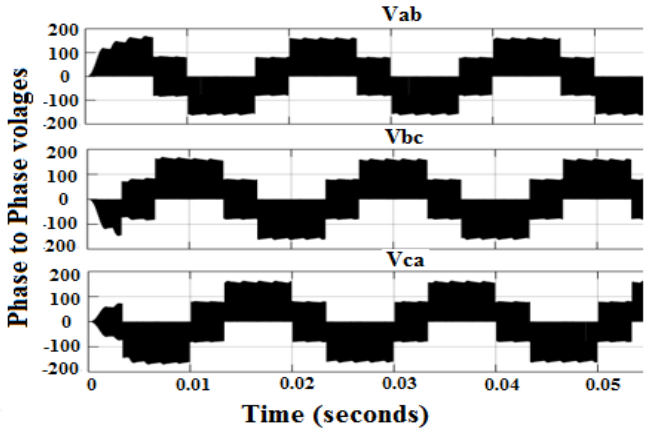

Figure 9 each phase voltages of SVPWM inverter

Three phase micro solar inverter phase to phase voltages shown in the figure 9. It contains six level output voltages because the technique used for switching is six switches. The different levels are shown in the voltage levels due to the switches on/off timings. The level indicates the current conduction through switches at different phases.

Iv. Total harmonic distortion

The parameters which differentiate this proposed research from the previously proposed topologies are the improved results of total harmonic distortion (THD). THD plays important role for a given inverter. The main concern in this inverter topology is to reduce the percentage harmonics in output voltages and load current to improve the stability of this inverter [08]. The advantages of lower harmonics are leads to minimize emission, core loss and reduction in heating in different kind of loads. By using SVPWM technique the aim is to lemmatize the THD percentage to less than 3%. In the proposed three phase high ac voltage inverter THD is minimized to an extremely low level. Reducing THD will result in the minimization of losses in the entire system. Percentage THD in output voltages of the mic are shown in figure 10. It is evident that THD is very low so the losses will be reduced and also the performance of the proposed system for different kind of loads will be very good as compared to previous systems.

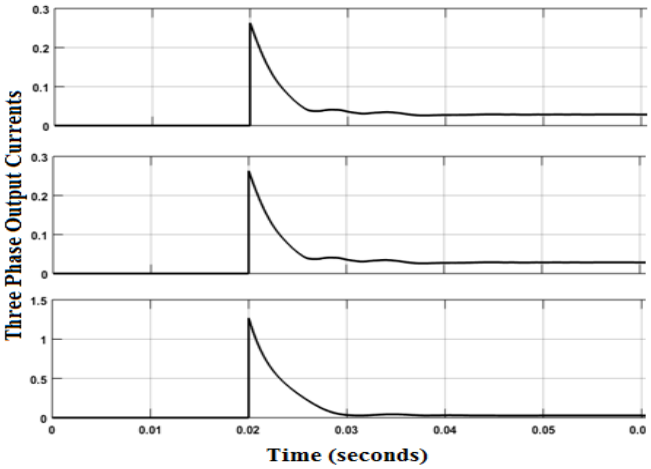

Figure 10 Total Harmonic Distortion wave forms of each phase

V. CONCLUSION

A three-phase micro solar inverter with zero voltage switching and zero current switching is offered in this paper. The paper has successfully confirmed the viability of the design of three phase micro solar inverter for driving multiple heavy loads and grid connected applications. The key benefits are a high efficiency, small footprint and low cost. The suggested method has proven to be accurate and has been used in the design of inverters for the generation of three phase solar power. Finally, the work also implements the rcl resonant converter for single phase boosted output. That fed to transformer for step up voltage level concentrations for high flow rates. The proposed system is expected to be a significant contribution in industrial and domestic applications, particularly where solar power needed to generate at high flow rate.

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