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Five Level Inverter with SARC Boost Converter for PV Applications

T.Ranganathan,J.Sunil Kumar

Assistant Professor, Dept. of EEE, Karpagam College of Engineering, Coimbatore, India

ABSTRACT: This paper presents a three phase five level photovoltaic inverter topology for a standalone system with a novel pulse width modulation control scheme. In this paper photo voltaic conversion stages, dc-dc conversion and dc-ac conversion both are made efficient compared to conventional methods. The first stage dc-dc conversion is made effective by soft switching boost converter with simple auxiliary resonant circuit, in which a switch, a resonant inductor, a resonant capacitor are added. This soft switching pattern can reduce the switching losses, voltage and current stress of the switching device. More over its very easy to control. The second stage is inverting operation, which is accomplished by multilevel inverter. In this paper, the five level inverter is adopted, which offers much less total harmonic distortion and can operate at near unity power factor. Simulation results are presented. In this paper the PV arrays are increased for regulated and increased power production. The output from this inverter is fed into the Grid power supply where the grid operated in two way of receiving the power to the grid and also transmitting the power from the grid circuit. The inverter used here is a Three phase five level inverter. The results and performances are analyzed using the waveforms obtained from the simulation circuit as shown in the figures.

KEYWORDS: PV arrays, Soft Boost Converter, Five level inverter, Grid.

I. INTRODUCTION

RENEWABLE energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains: Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and bio fuels and hydrogen derived from renewable resources. Renewable energy replaces conventional fuels in four distinct areas: power generation, hot water/ space heating, transport fuels, and rural (off-grid) energy services.

The ever-increasing demand for conventional energy sources like coal, natural gas and crude oil is driving society towards the research and development of alternate energy sources. Many such energy sources like wind energy and photovoltaic are now well developed, cost effective and are being widely used, while some others like fuel cells are in their advanced developmental stage. These energy sources are preferred for being environmental-friendly. The integration of these energy sources to form a hybrid system is an excellent option for distributed energy production.

Depleting oil and gas reserves, combined with the growing concerns about global warming, have made it inevitable to seek alternative/renewable energy sources. The integration of renewable energies such as solar and wind energy is becoming increasingly attractive and is being used widely, for substitution of oil-produced energy, and eventually to minimize atmospheric degradation. Solar and wind energy are non depletable, site-dependent, non-polluting, and potential sources of alternative energy options. Many countries are pursuing the option of wind energy conversion systems; in an effort to minimize their dependence on fossil-based non-renewable fuels.

Also, presently thousands of photovoltaic (PV) deployments exist worldwide, providing power to small, remote, grid-independent or stand-alone applications. For both systems, variations in meteorological conditions (solar irradiation and average annual wind conditions) are important. The performance of solar and wind energy systems are strongly dependent on the climatic conditions at the location.

The power generated by a PV system is highly dependent on weather conditions. For example, during cloudy periods and at night, a PV system would not generate any power. In addition, it is difficult to store the power generated by a PV system for future use. To overcome this problem, a PV system can be integrated with other alternate power sources and/or storage systems, such as electrolyser, hydrogen storage tank, Fuel Cell systems.

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Combined wind and solar systems are becoming more popular for stand–alone power generation applications, due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. The Economic aspects of these technologies show sufficient promise to include them in developing power generation capacity for developing countries. Research and development efforts in solar, wind, and other renewable energy technologies are required to continue improving their performance, establishing techniques for accurately predicting their output and reliably integrating them with other conventional generating sources.

II. TOPOLOGY AND CONTROL SCHEMES

A. Modelling the SOLAR cell

Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode. The output of the current source is directly proportional to the light falling on the cell (photocurrent Iph). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current ID, called diode (D) current or dark current.

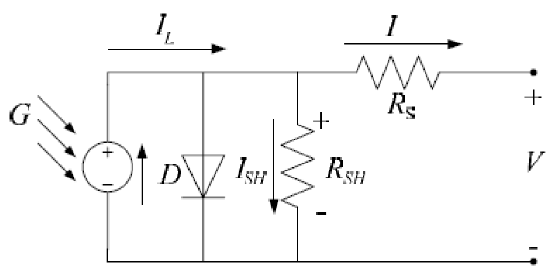

Fig. 1. Equivalent circuit of PV CELL

The equivalent circuit of the solar cell is shown in figure 1. The diode determines the I-V characteristics of the cell. Increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn.
1) Temperature dependence of the diode saturation current I_0.
2) Temperature dependence of the photo current I_L.
Series resistance R_s, which gives more accurate shape between the maximum power point and the increasing sophistication, accuracy and complexity can be introduced to the model by adding in turn.
The net current of the cell is the difference of the photocurrent, IL and the normal diode current I0:

$$I = I_L - I_0\left(e^{\frac{q(V+IR_S)}{nkT}} - 1\right)$$

The model included temperature dependence of the photocurrent I_L and the saturation current of the diode I_0.

$$I_L = I_L(T_1) + K_0(T - T_1)$$
$$I_L(T_1) = I_{SC}(T_{1,nom})\frac{G}{G(_{nom})}$$

A series resistance R_s was included; with represents the resistance inside each cell in the connection between cells. The shunt resistance R_{sh} is neglected. A single shunt diode was used with the diode quality factor set to achieve the best curve match. This model is a simplified version of the two diode model presented.

B. Current-Voltage I-V Curve for a Solar Cell

When A typical I-V characteristic of the solar cell for a certain ambient irradiation G and a certain fixed cell temperature T, is shown in Figure 2. For a resistive load, the load characteristic is a straight line with scope I/V=1/R. It should be pointed out that the power delivered to the load depends on the value of the resistance only. However, if the load R is small, the cell operates in the region M-N of the curve, where the cell behaves as a constant current source, almost equal to the short circuit current. On the other hand, if the load R is large, the cell operates on the regions P-S of the curve, the cell behaves more as a constant voltage source, almost equal to the open-circuit voltage.

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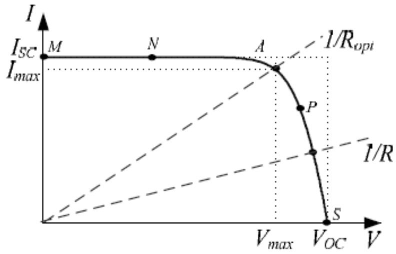

Fig. 2. V-I characteristics of the solar cell

1. **Short circuit current** $I_{sh} = I_{ph}$. It is the greatest value of the current generated by a cell. It is produce by the short circuit conditions: V = 0.
2. **Open circuit voltage** correspond to the voltage drop across the diode (p-n junction), when it is transverse by the photocurrent I_{ph} (namely IL = I_{ph}), namely when the generated currents is I = 0. It reflects the voltage of the cell in the night and it can be mathematically expressed as:

$$V_{OC} = \frac{nkT}{q}\ln\left(\frac{I_L}{I_0}\right) = V_t \ln\left(\frac{I_L}{I_0}\right)$$

Where
V_t = is known as thermal voltage and
T is the absolute cell temperature.
Maximum power point is the operating point A (V_{max}, I_{max}), at which the power dissipated in the resistive load is maximum: $P_{max} = V_{max}I_{max}$.
Maximum efficiency is the ratio between the maximum power and the incident light power.

$$\eta = \frac{P_{max}}{P_{in}} = \frac{I_{max}V_{max}}{AG_a}$$

Fill factor is the ratio of the maximum power that can be delivered to the load and he product of I_{sc} and V_{OC}:

$$FF = \frac{P_{max}}{V_{OC}I_{SC}} = \frac{I_{max}V_{max}}{V_{OC}I_{SC}}$$

The fill factor is a measure of the real I-V characteristic. Its valued is higher than 0.7 for good cells. The fill factor diminishes as the cell temperature is increased.

The open circuit voltage increases logarithmically with the ambient irradiation, while the short circuit current is a linear function of the ambient irradiation. The dominant effect with increasing cell's temperature is the linear decrease of the open circuit voltage, the cell being thus less efficient. The short circuit current slightly increases with the cell temperature; the energy conversion in the PV array is shown in figure 3.

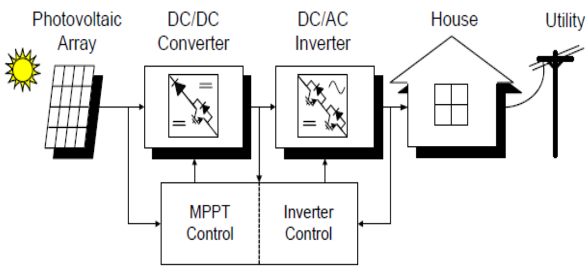

Fig 3.Solar energy power conversion

Thus the solar power conversion system combines two stages to converts the solar power into useful utility supply. First stage rectifying, in this dc solar power is step up by boost converter. Second stage is inverting stage in this boost up dc power is converted into ac power output. By adopting suitable MPPT technique maximum power can be extracted from the solar cell.

C. Maximum power point Tracking

The aim of MPPT is to regulate the actual operation voltage of PV panel to the voltage at MPP. For this purpose MPPT adjusts the output power of inverter or DC converter. If the PV output voltage is higher than MPP voltage, then transferred power to the load or network is increased, otherwise it is decreased. The main criteria taken into

consideration in the selection of MPPT algorithms are summarized below.
1) Ease of Implementation. Some techniques consist of analog circuits and others are digital. Sometimes digital MPPT algorithms may require software and programming.
2) The required number of sensor. Voltage measurement is usually easier and more reliable than current. Current sensors are also often expensive and cumbersome structure. The sensors measure the light level is not easy to find. Therefore, these features should be considered in MPPT design stage.
3) Due to a partial shading on PV panels can be affected the normal operation of the MPPT. If the selected algorithm is too sensitive, virtually MPPT that occurred by shading may be tracked. As a result of this, significant power losses may arise..

D. Perturb and Observe (P&O) Method
The most commonly used MPPT algorithm is P&O method and is also known as hill-climbing algorithm. This technique employs simple feedback arrangement and few measured parameters. In this approach, the array voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. However, the operating point oscillates around the MPP as the system is continuously perturbed. This method can be implemented easily. The operating point towards the maximum power point is adjusted according to the operating voltage the output power is minimizes or maximizes. The power – voltage curve is shown in figure 4, in which MPP determination is depends on the perturb and observe method.

In figure 5 the flow diagram of the perturb and observe algorithm is shown. In this simple algorithm, the operating voltage is perturbed with a small change +ΔV and the power output is observed. The P & O method is easy to implement as few parameters are to be measured and gives moderate efficiencies of about 95%. However, the algorithm becomes complex when rapidly changing site conditions are present and the efficiency depends on how the method is optimized at design stage. The implementation cost of this method is relatively lower. The problems with this method are it gives arbitrary performance with oscillations around MPP particularly with rapidly changing conditions and provides slow response. Sometimes, this method is not reliable as it is difficult to judge whether the algorithm has located the MPP or not.

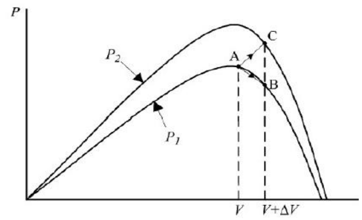

Fig 4. Determination of the MPP in P&O method

E. Existing System
In order to improve the efficiency of energy conversion for a photovoltaic (PV) system, a soft-switching boost converter using a simple auxiliary resonant circuit shown in figure 5, which is composed of an auxiliary switch, a diode, a resonant inductor, and a resonant capacitor, is adopted in this paper.

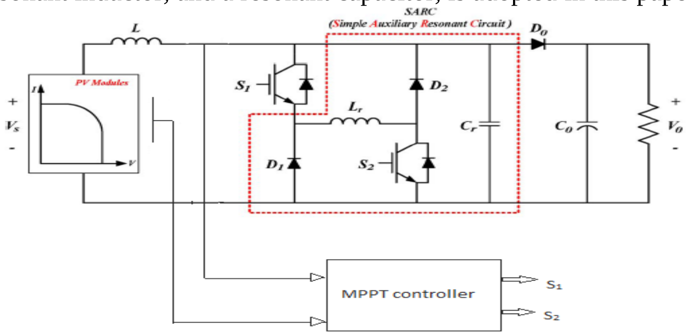

Fig 5. Circuit diagram of the boost converter

The conventional boost converter decreases the efficiency because of hard switching, which generates losses when the switches are turned on/off. During this interval, all switches in the adopted circuit perform zero-current switching by the resonant inductor at turn-on, and zero-voltage switching by the resonant capacitor at turn-off. This switching pattern can reduce the switching losses, voltage and current stress of the switching device. Moreover, it is very easy to control.

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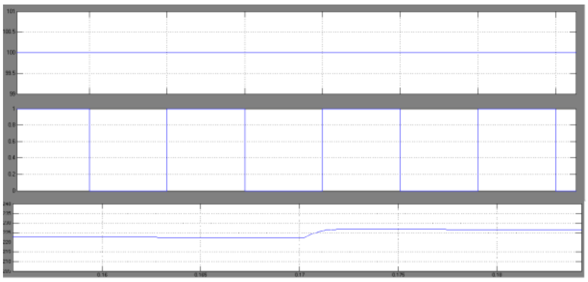

Fig 6. Boost converter Output

In figure 6 output waveforms of the existing circuit are shown. The simulation output of the input supply and output load are taken out by using scope. From the simulation results we can know the input voltage (100 v) is boosted up235 v. And the ripple in the output voltage is less compared hard switching methods. The first scope shows the pwm signal of switches in the circuit. The input voltage is set 100V and is boosted up to 235V by the existing circuit. Thus the SARC boost converter boost up voltage greater than the conventional boost converter

III. PROPOSED MULTILEVEL INVERTER WITH SOFT SWITCHEING BOOST CONVERTER

As the world is concerned with fossil-fuel exhaustion and environmental problems caused by conventional power generation, renewable energy sources, particularly solar and wind energy, have become very popular and demanding. Photovoltaic (PV) sources are used today in many applications because they have the advantages of being maintenance and pollution free. Solar-electric-energy demand has grown consistently by 20%–25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices. This decline has been driven by the following:
1) an increasing efficiency of solar cells
2) manufacturing-technology improvements; and
3) economics

A PV inverter, which is an important element in the PV system, is used to convert dc power from the solar modules into ac power to be fed into the grid. Proposed solar power conversion stages to the utility applications block diagram.
In both the conversion there is lot of switching losses are associated by adding number of switches. So we must concentrate on reducing losses associated with the switches. By making conduction losses lesser the output power efficiency of solar cell can be improved.

A. Multilevel Inverter

A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

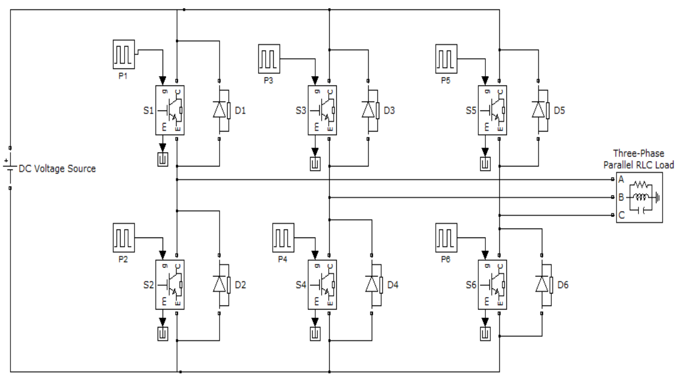

Fig 7. PV multilevel inverter circuit diagram

1. Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.
2. Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings

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of a motor connected to a multilevel motor drive can be reduced.
3. Input current: Multilevel converters can draw input current with low distortion.
4. Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency. In figure proposed multilevel inverter is shown. Proposed multilevel inverter uses six switches. And their switching pattern are aligned to get stepped waveform with five level. Five-level inverter to produce output voltage in five levels: zero, +1/2Vdc, Vdc, −1/2Vdc, and −Vdc. This switching pattern reduce the harmonics in the output waveform.

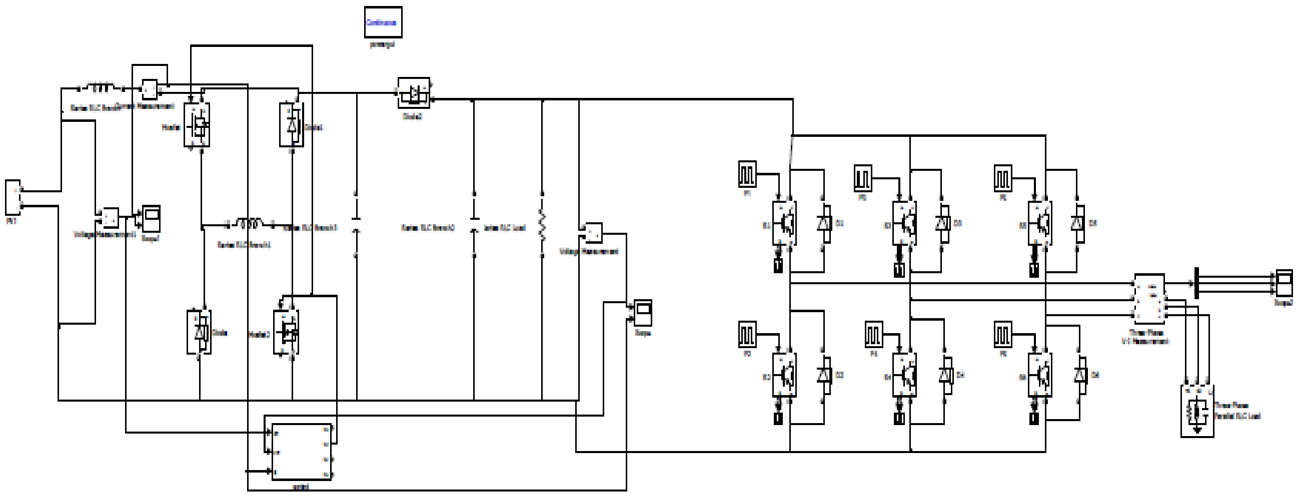

Fig 8. Simulation model of multilevel inverter

In the figure 8 the proposed multilevel inverter circuit diagram is shown. It uses six IGBT switches with parallel diode connection. The three phase multilevel inverter is used for the three phase load. And the proposed circuit is added with the existing boost converter. The gate pulses are produced by pwm signals. The Pulse Generator block generates square wave pulses at regular intervals.

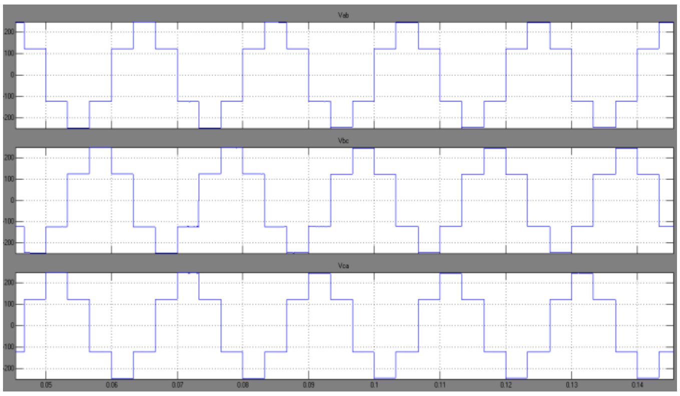

Fig 9. Output waveforms of the inverter circuit

Output Waveform.
The block's waveform parameters, Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform. The pulse amplitude the default is 1.The pulse period specified in seconds if the pulse type is time-based or as number of sample times if the pulse type is sample-based.

This is the output waveform of the proposed circuit using the Five level inverter with existing Soft switching Boost converter. In this the Efficiency of the system is increased. The output waveform has the time limit in its X axis and Phase Voltages across the Y axis.

B. CONCLUSION

A new five level inverter is added with the simple auxiliary resonant circuit to obtain a high efficient power conditioning system for photovoltaic power conversion. This soft switching boost converter is very easy to control because the two switches are controlled by the same PWM signal. All of the switching devices in this converter achieved ZVS and ZCS by the resonant inductor and capacitor at turn on and turn off.

Therefore switching losses were reduced dramatically. By adding this loss less converter with the five level inverter, the power conversion can be done in efficient way. Thus the overall performance of circuit is improved. And five level inverter offers much less total harmonic distortion and can operate unity power factor.

The PV conversion system with grid connection has to be simulated. For this Multi string PV module has to be simulated. Because grid connection applications need to produce more output. So number of PV strings are connected in parallel. And the results has to be compared with the proposed circuit. The whole system will be simulated using MATLAB simulink.

REFERENCES

[1] R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Rnhoff, “A maximum power point tracking system with parallel connection for PV stand alone applications,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2674–2683, Jul. 2008.
[2] F. Liu, S. Duan, F. Liu, and Y. Kang, “A variable step size INC MPPT method for PV system,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2622–2628, Jul. 2008.
[3] H. Bodur and A. Faruk Bakan, “A new ZCT-ZVT-PWM DC–DC converter,” IEEE Trans. Power Electron., vol. 19, no. 3, pp. 676–684, May 2004.
[4] J.-H. Kim, D.-Y. Yung, S.-H. Park, C.-Y.Won, Y.-C. Jung, and S.-W. Lee, “High efficiency soft-switching boost converter using a single switch,” J. Power Electron., vol. 9, no. 6, pp. 929–939, Nov. 2009.
[5] J.-P. Lee, B.-D. Min, T.-J. Kim, D.-W. Yoo, and J.-Y. Yoo, “Design and control of novel topology for photovoltaic dc/dc converter with high efficiency under wide load ranges,” J. Power Electron., vol. 9, no. 2, pp. 300–307, Mar. 2009.
[6] J.-J. Lee, J.-M. Kwon, E.-H. Kim, and B.-H. Kwon, “Dual series resonant active clamp converter,” IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 699-710, Feb. 2008.
[7] X. Wu, J. Zhang, X. Ye, and Z. Qian, “Analysis and derivations for a family ZVS converter based on a new active clamp ZVS cell,” IEEE Trans. Ind. Electron., vol. 55, no. 2, pp. 773–781, Feb. 2008.
[8] S.-S. Lee and G.-W. Moon, “Full ZVS range transient current buildup half bridge converter with different ZVS operations to load variation,” IEEE Trans. Ind. Electron., vol. 55, no. 6, pp. 2557–2559, Jun. 2008.
[9] M. Z. Youssef and P. K. Jain, “Series parallel resonant converter in self sustained oscillation mode with the high frequency transformer leakage inductance effect: Analysis, modeling, and design,” IEEE Trans. Ind. Electron., vol. 54, no. 3, pp. 1329–1341, Jun. 2007.
[10] R. Casanueva, F. J. Azcondo, and C. Branas, “Output current sensitivity analysis of the LCpCs resonant inverter: Current source design criteria,” IEEE Trans. Ind. Electron., vol. 54, no. 3, pp. 1560–1568, Jun. 2007.
[11] S. Zheng and D. Czarkowski, “Modeling and digital control of a phase controlled series parallel resonant converter,” IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 707–715, Apr. 2007.
[12] D. J. Tschirhart and P. K. Jain, “A CLL resonant asymmetrical pulse width modulated converter with improved efficiency,” IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 114–122, Jan. 2008.
[13] N. D. Benavides and P. L. Chapman, “Modeling the effect of voltage ripple on the power output of photovoltaic modules,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2638–2643, Jul. 2008.
[14] G.-R. Cha, S.-H. Park, C.-Y. Won, Y.-C. Jung, and S.-H. Song, “High efficiency soft switching boost converter for photovoltaic system,” in Proc.13th EPE-PEMC, Sep. 1–3, 2008, pp. 383–397.
[15] Y. C. Jung, J. G. Cho, and G. H. Cho, “A new zero voltage switching resonant DC-link inverter with low voltage,” in Proc. IEEE IECON, Oct. 28 Nov. 1 1991, vol. 1, pp. 308–313.

AUTHOR DETAILS

T.Ranganathan, Received B.E.,(Electrical and Electronics Engineering) degree from SNS College of Technology, Coimbatore, affiliated to Anna University in the year 2009, and received M.E., (Power Electronics and Drives) degree from Anna University of Technology, Coimbatore in the year 2012, Currently working as Assistant Professor in EEE of Karpagam College of Engineering, Coimbatore-641 032. His area of interested includes Power Electronics and Drives, Neural networks and Fuzzy systems, Special Electrical Machines and Controls.

2.J.Sunil kumar, Received the B.E., (Electrical and Electronics Engineering) degree from Sasurie college of Engineering, Chennai, Affiliated to Anna university, Tamilnadu, in 2007, and received M.E., (Power Electronics and Drives) degree from Anna University of Technology, Coimbatore in the year 2011, Currently working as Assistant Professor in EEE of Karpagam College of Engineering, Coimbatore-641 032. His area of interested includes Power Electronics and Drives, Neural networks and Fuzzy systems, Special Electrical Machines and Controls.