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Implementation of Pwm Technique For Integrated High Gain Boost Resonant Converter

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Abstract: *The Effective photovoltaic (PV) power conditioning requires well organized power conversion and accurate maximum power point tracking to neutralize the effects of panel mismatch, shading, and variation in power output during a daily cycle. This paper presents a unique method for widening the input range of pulse width modulation of integrated resonant converters and it maintains high conversion efficiency with low component count, galvanic isolation and simple control circuit. The technique primarily unites constant ON, constant OFF, and fixed frequency control depending on the required duty cycle. With hybrid-frequency control, the circuit also retains zero current switching for the output diodes, minimizes the switching loss, and eliminates circulating energy at the transformer across the entire operating range.*

Keywords: C*urrent Source Inverter (CSI), Photovoltaic (PV), Extended Switched Inductor quasi-Z-Source Inverter (ESL-qZSI), Z-Source Inverter (ZSI).*

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I. INTRODUCTION

The Photovoltaic power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After the installation it can generate electricity from the solar irradiation without emitting greenhouse gases. In the 25 years of lifetime, PV panels produce more energy than that for their manufacturing. Also they can be installed in places with no other use, such as roofs and deserts, or they can produce electricity for remote locations, where there is no electricity network [1].The latter type of installations is known as off-grid facilities and sometimes it is the most economical alternative to provide electricity in isolated areas. However, most of the PV power generation comes from grid-connected installations, where the power is fed in the electricity network. In fact, it is a growing business in developed countries such as Germany, which in 2010, is by far the leading in PV power generation followed by Spain, Japan, USA and Italy. On the other hand, due to the equipment required, PV power generation is more expensive than other resources [2].In addition to reducing greenhouse gas emissions, renewable energy's other benefits include employment creation, reduced use of non-renewable resources, reduced atmospheric pollution such as: sulphur oxides, nitrogen oxides, mercury, and a range of other toxins and water based acid mine drainage, and to increased energy security through diversification and improved national balance of payments. For most countries, increased energy security, improved trade balance and reduced dependence on imported fossil fuels are the main drivers for use of renewable energy, although environmental aims, especially greenhouse gas reduction, also play a role. During the last decades, significant changes occurred in the electricity grid [3]. After the oil crisis, many governments supported research into alternatives for oil based energy systems. Concerning the electricity network, this led to a strong increase in electricity generation based on renewable energy sources (e.g. wind, sun, tidal and wave energy [4].In order to limit the use of oil as a primary energy source for generating electricity, power plants based on coal, natural gas or nuclear fission strongly gained popularity [5]. Comparing the present primary energy source usage (2008) with the one, one can see that nuclear energy really emerged as a new important source for electricity production. Also, the use of natural gas strongly increased, whereas coal approximately maintained its relative market share and remains the most important primary energy source for electricity production. The renewable energy sources (RES) still represent a very small percentage of the total electricity production in the world. However, several types of renewable energy sources have significantly increased their degree of grid penetration during the last decade and forecasts project an ongoing positive trend for the years to come. Also, several political treaties and protocols regarding the use of renewable energy resources for electricity generation have been agreed upon, resulting in well defined targets for the deployment of generators using renewable as the primary energy source. It has some additional benefits to large scale centralized renewable in that it can help defer network augmentation, reduce line losses and, being smaller, is more modular and so can be gradually installed as required [6], [7].The government is promoting it with subsidies or feed-in tariffs, expecting the development of the technology so that in the near future it will become competitive. Increasing the efficiency in PV plants so the power generated increases is a key aspect, as it will increase the incomes, reducing consequently the cost of the power generated so it will approach the cost of the power produced from other sources [8].The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel, the efficiency of the inverter (95-98 %) and the efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98%). Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation. The MPPT algorithm has also certain limitations in increasing the efficiency of the solar power generation [9], [10].

II. RELATED WORK

The grid connected PV power system designs focus on converting as much irradiant power as possible into real power and current flowing into the grid in phase with the utility defined voltage. The solar inverter is a critical component in a solar energy system. It performs the conversion of the variable DC output of the solar panel. The different families of power converters have been designed to interface the renewable resources for different applications. The traditional power electronic inverters are VSI and current source inverter (CSI). In VSI two switches of the same leg can never be gated ON at same time because it causes a short circuit, which would destroy the inverter [11]. The maximum output voltage is obtained by interfacing boost converter system with inverter system which leads to additional task to the controller circuits and this voltage can never exceed the bus voltage. These limitations can be overcome by the proposed maximum boost ZSI system. Considering also only multistage solutions allows for increased interoperability between distributed AC and DC systems while permitting the removal of electrolytic capacitors, which have limited lifetime from the system design [12]. The Modern electrical systems like distributed generators, power conditioners, and industrial drives have raised the importance of DC-AC inverter, through which energy is appropriately conditioned. The existing popular inverter topologies still have some constraints to resolve with the first being their inflexible voltage or current conversion ranges. However, the traditional voltage source inverter (VSI) and current source inverter (CSI) have been restricted due to their narrow obtainable output voltage range, shoot-through problems caused by misdating and some other theoretical difficulties due to their bridge type structures. Due to the recent advancements in the fields of energy conversion and energy storage, a need has arisen to design inverters which can operate successfully with variable voltage sources such as fuel cells and ultra capacitors [13], [14]. The worldwide installed photovoltaic (PV) power capacity shows nearly an exponential increase due to decreasing costs and the improvements in solar energy technology. The power converter topologies employed in the PV power generation systems are mainly characterized by two or single stage inverters. The single stage inverter is an attractive solution due to its compactness, low cost, and reliability. However, its conventional structure must be oversized to cope with the wide PV voltage variation derived from changes of irradiation and temperature [15], [16]. The power electronic converters, especially DC/AC sinusoidal pulse width modulation inverters have been extending their range of use in industry because of their numerous advantages. They typically synthesize the stair–case voltage waveform from several DC sources, which has reduced harmonic content. The extend knowledge about the performance of five level Cascaded H-Bridge MLI topology with DC/DC Boost Converter using SPWM for fixed DC Source [17], [18]. The output voltage is the sum of the voltage that is generated by each bridge. The switching angles can be chosen in such a way that the total harmonic distortion is minimized. This topology incorporates boost converter in the input side which magnifies the fundamental output voltage with reduction in total harmonic distortion. It also incorporates LC filter and hence output is drawn near the sine wave because of more levels. Results of experiments proved efficiency of 95%. The performance of the SPWM strategy in terms of output voltage and THD has studied successfully [19]. Multilevel converters have been under research and development for more than three decades and have found successful industrial application [20]. However, this is still a technology under development, and many new contributions and new commercial topologies have been reported in the last few years. The review of these recent contributions, in order to establish the current state of the art and trends of the technology, to provide readers with a comprehensive and insightful review of where multilevel converter technology stands and is heading. This presents a brief overview of well established multilevel converters strongly oriented to their current state in industrial applications to then center the discussion on the new converters that have made their way into the industry. In addition, new promising topologies are discussed. Recent advances made in modulation and control of multilevel converters is also addressed [21]. A great part of this work is devoted to show nontraditional applications powered by multilevel converters and how multilevel converters are becoming an enabling technology in many industrial sectors. The ZSI has attracted wide attention over the others mainly because it continues to employ a conventional VSI as the power converter, yet with a modified DC link stage [22]. As a research in power electronics, the Z-source topology as shown has been greatly explored from various aspects. Due to the obvious advantages of ZSI, it have been adopted for various applications such as ac motor drives, fuel cell vehicles, Uninterruptible power supplies, residential photovoltaic systems, electronic loads, wind power conversion and distributed generation.

III. QUASI-Z-SOURCE INVERTER

The Z-source inverter (ZSI) is widely used in low-voltage input applications such as photovoltaic, fuel cells, motor drivers due to its outstanding compared with the traditional voltage source inverter (VSI). Worst of all, the boost ability is too small. Several control strategies are provided to overcome these disadvantages of the classic ZSI, but they still have limits to avoid the discontinuous input current, as well as reduce the voltage stress [23]. More importantly, the stronger boost ability is achieved, the larger shoot-through duty ratio should be used, which will result in a poor output voltage profile and low voltage-conversion ratio. Thus, the control strategies are not efficient to improve the boost ability [24]. The Z-source inverter (ZSI) with battery operation can balance the stochastic fluctuations of photovoltaic (PV) power injected to the grid/load, but the topology has a power limitation due to the wide range of discontinuous conduction mode during battery discharge. The new topology of the energy stored ZSI to overcome this disadvantage. The two strategies of the related design principles to control the new energy stored ZSI when applied to the PV power system. They can control the inverter output power track the PV panel maximum power. The voltage boost, inversion, and energy storage are integrated in a single stage inverter [25]. An extended switched inductor quasi-Z-source inverter (ESL-qZSI) with high boost voltage inversion ability is presented which combines the SL-qZSI with the traditional boost converter, as well as improves the switched inductor cell. Compared with the classic qZSI topologies, that topology have reduces voltage stresses of capacitors, power devices and diodes for the same input and output voltage. Furthermore, the conversion efficiency is improved. The Operation principle of the topology is analyzed in details, which is followed by the comparison between the three topologies [26]. A control strategy for the quasi-Z-source inverter (qZSI) with a battery based photovoltaic power conversion system was presented. A battery assisted qZSI can buck/boost PV panel voltage by introducing shoot-through states, and make full use of PV power by the energy stored battery paralleled to the quasi-Z-source capacitor. A dynamic small signal model of the battery assisted qZSI is established to design a closed loop controller for regulating shoot-through duty ratio and managing the battery's energy storage. A modified space vector modulation (SVM) technique for the qZSI is applied to achieve low harmonics, high voltage utilization, and high efficiency. A P-Q decoupled grid-tie power injection is fulfilled with the maximum power capture from PV panels and the unity power factor [27]. The results showing the efficient method for energy stored PV power generation. In either system, the DC–DC stage implements local MPPT optimization, while the second stage attempts to regulate the DC-link voltage by sending power to the utility grid. In the distributed PV PCS, the isolated DC–DC stage must operate efficiently at full power, while maintaining high performance at light load, across a range of PV voltages [28]. In order to maintain high efficiency under low power conditions, it is necessary to minimize the amount of circulating energy in the system. An alternate definition of this characteristic would be producing a system with a high power factor at the isolation transformer. Also critical to light load efficiency is mitigating the device. In the system, the DC–DC stage implements local MPPT optimization, while the second stage attempts to regulate the DC-link voltage by sending power to the utility grid [29]. The general Z–source inverter network employs a unique impedance circuit to couple the converter main circuit to that of the power source, in order to obtain the unique features that cannot be achieved using conventional VSI or CSI. The Z-source inverter has the capability of voltage boost and inversion in a single stage. The unique feature about Z- source inverter is that the output voltage can be anywhere from zero to infinity. The inverter can perform both buck and boost operation and provide a wide range of output voltage which is not possible in conventional voltage source and current source inverters [30]. It has nine permissible switching states which has an extra state compared to the conventional inverters. The extra switching two switches of the same leg is switched ON and conduct simultaneously; this is not possible in conventional inverters. The Fig. 1 shows the Z-source inverter circuit diagram.

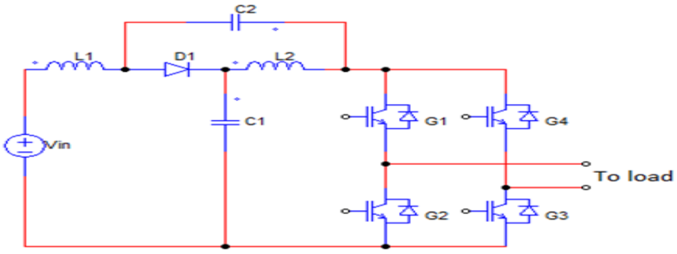


Fig.1. Z Source Inverter

When considering the series-resonant DCX as part of this new hybrid circuit, it is important to notice the half-wave resonant behavior by which it operates. During the on-period of either switch a resonant circuit is formed by a combination of the input-side capacitors, the output-side capacitors, and the transformer leakage inductance. The unidirectional nature of the output diodes prevents this circuit from resonating perpetually, and instead, only a resonant period consisting of one half sine waves is visible. Provided that this resonant period is allowed to complete fully before the primary-side switches change states, the series-resonant circuit is naturally soft-switching on both turn-on and turn-off (ZVS and ZCS) [31], [32]. If both resonant periods are allowed to fully complete, the system has no method by which to regulate the output, and the output is simply a reflection of the input. Hence, the necessary addition of another “regulating element,” in this case a boost converter, is shown in Fig. 2. The boost converter regulates the effective input voltage to the series-resonant converter, allowing it to run as a DCX with high efficiency. The cost is two additional transistors, with their associated gate drive requirements, and some additional switching and conduction loss.

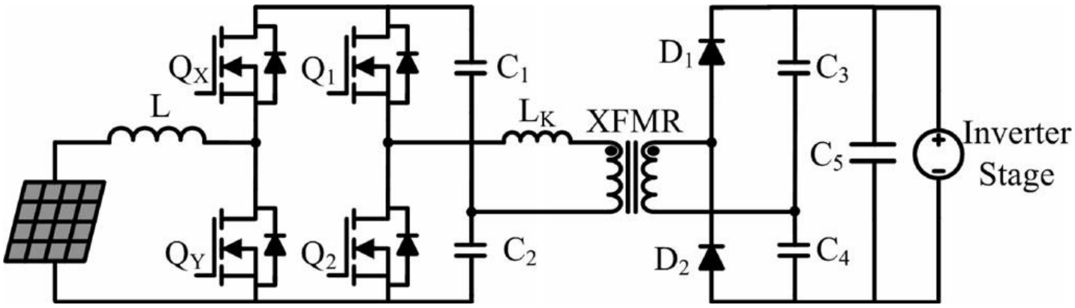


Fig.2. Resonant Half-Bridge with Separate Boost Input Stage

This circuit may be further simplified by integrating the system so that the boost converter function is implemented by the original two MOSFETs. A straight forward method to understand this is to directly tie the input inductor to the midpoints of both active switching legs simultaneously. Note that this change directly ties the inductor to one terminal of the transformer. This additional connection renders the upper MOSFETs (*Qx* and Q_1) as well as the lower MOSFETs (*QY* andQ_2) in parallel, so long as their switching patterns are synchronized. Thus, the circuit may be simplified, with the additional connection and the removal of *QX* and *QY*, into the topology shown in Fig. 3. Because the now single upper and lower FETs (Q_1 and Q_2) are effectively replacing two parallel FETs, they carry the combined current from the original four switches. Also, as long as the resonant behavior is allowed to complete, the output diodes, D_1 and D_2, still achieve ZCS.

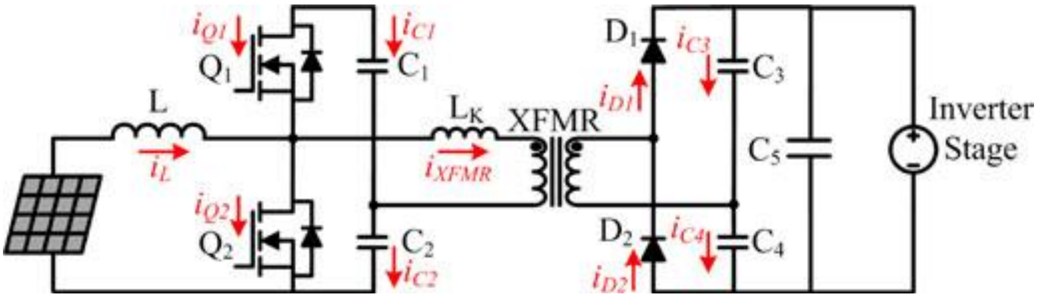
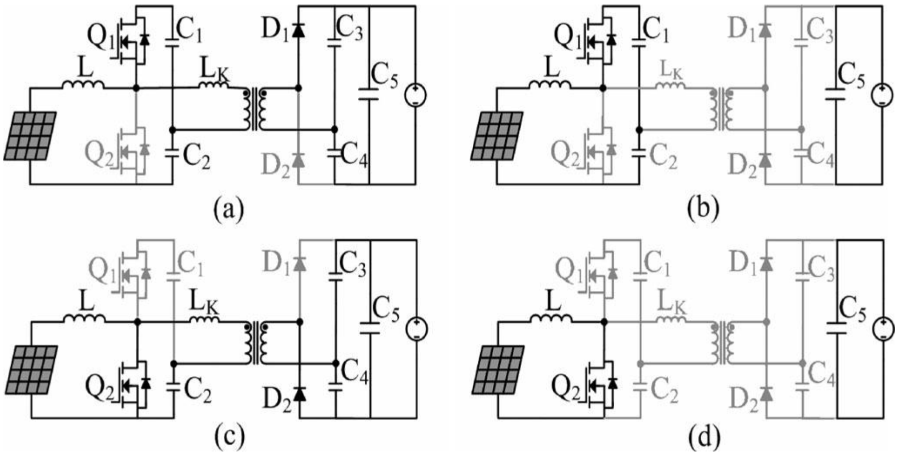


Fig. 3. IBR Converter

This particular circuit topology is similar to that of the “boost half-bridge” (BHB); however, the actual operation of this circuit is quite different [33]. In the BHB, the operating currents are that of the hard-switching half-bridge, giving the converter a poor power factor at the transformer. This makes it difficult for the converter to achieve a wide range of operation, even with ZVS. Also, the voltage transfer ratio is highly nonlinear, leading to much more complex control requirements. On the other hand, this new circuit features a very simple voltage transfer ratio, given in (1), where *n* is the transformer turns ratio, and *D* is the duty cycle of the lower switch, Q_2. Unlike the BHB, this transfer ratio is constant over both input load and frequency

$$\frac{Vout}{Vin} = \frac{n}{1-D} \qquad (1)$$

This voltage transfer ratio (1) is identical between the circuit shown in Figures 2 and 3, indicating that only one pair of switches is necessary to provide controllability. Also, the transfer characteristic is similar to that of a CCM boost converter, simply multiplied by n. MPPT control of the CCM boost converter is widely discussed in the literature, with many different methods available such as perturb and observe (P&O) [34], ripple correlation control [35], and incremental conductance. Also, several different control implementations are possible with the integrated boost resonant (IBR) converter, such as input voltage [36], input current, and direct duty cycle control, giving tremendous control flexibility to the designer. The new topology can be effectively broken down into four distinct operating modes are shown in schematic form in Fig. 4(a) - 4(d).



(a) (b) (c) (d)

Fig.4. IBR Converter Operating Modes

IV. PULSEWIDTH MODULATION

PWM Mainly the power electronic converters are operated in the “switched mode”. Which means the switches within the converter are always in either one of the two states; turned off (no current flows), or turned on (saturated with only a small voltage drop across the switch). Any operation in the linear region, other than for the unavoidable transition from conducting to non-conducting, incurs an undesirable loss of efficiency and an unbearable rise in switch power dissipation. To control the flow of power in the converter, the switches alternate between these two states (i.e. on and off). This happens rapidly enough that the inductors and capacitors at the input and output nodes of the converter average or filter the switched signal. The switched component is attenuated and the desired DC or low frequency AC component is retained. This process is called Pulse Width Modulation (PWM), since the desired average value is controlled by modulating the width of the pulses [37].

For maximum attenuation of the switching component, the switch frequency f_c should be high, many times the frequency of the desired fundamental AC component f_1 seen at the input or output terminals. In large converters, this is in conflict with an upper limit placed on switch frequency by switching losses. For GTO converters, the ratio of switch frequency to fundamental frequency $f_c/f_1=N$, the pulse number may be as low as unity, which is known as square wave switching. Another application where the pulse number may be low is in converters which are better described as amplifiers whose upper output fundamental frequency may be relatively high. These high power switch-mode amplifiers find application in active power filtering test signal generation servo and audio amplifiers. These low pulse numbers place the greatest demands on effective modulation to reduce the distortion as much as possible [38]. The low pulse numbers place the greatest demands on effective modulation to reduce the distortion as much as possible. In these circumstances, multilevel converters can reduce the distortion substantially, by staggering the switching instants of the multiple switches and increasing the apparent pulse number of the overall converter.

V. SIMULATION RESULTS

Table-1shows the power stage element values for 250-W IBR converter. In Fig. 5 shows the simulation model of IBR resonant converter. In that model the MOSFET is used as a switch for the best performance of voltage control, fast switching and low losses. When the MOSFET switch is closed supply voltage is connected to inductor and the inductor current starts to increase and store the energy, when the MOSFET switch is opened the inductor current starts to decreases.

Table-1: Power Stage Element Values for 250-W IBR Converter

Element	Value	Resistance	I_{rms} @ 250W
L	100µH	11mΩ	8.6A
C_1, C_2	10µF	4mΩ	11.46A, 6.64A
C_3, C_4	100nF	50mΩ	0.89A
C_5	2µF	N/A	N/A
$XFMR_{PRI}$	7 turns	3.5mΩ	12.84A
$XFMR_{SEC}$	46 turns	46mΩ	1.74A
Q_1	N/A	4.9mΩ	6.64A
Q_2	N/A	4.9mΩ	13.95A
D_1, D_2	1.3V	N/A	0.625A (Avg.)

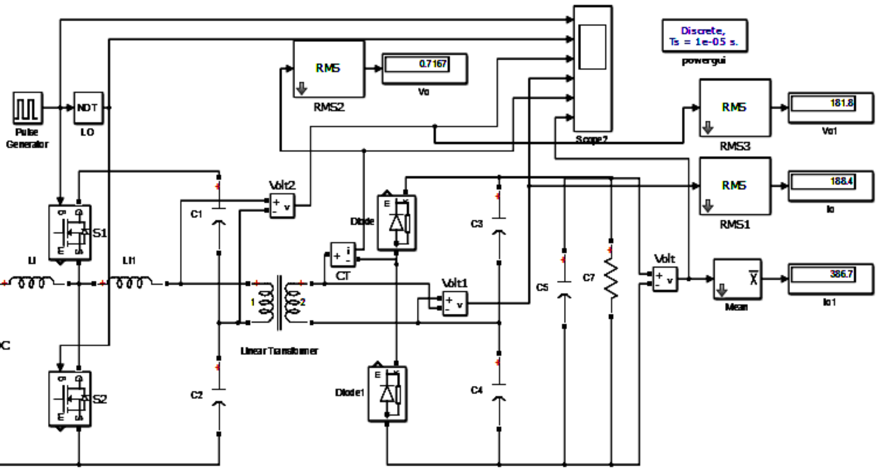


Fig.5. Simulation Model of IBR Converter

The Figure 6 shows the simulation results of IBR resonant converter, the S1 and S2 are the switching pulses of MOSFET switches of converter, the transformer primary and secondary voltages and load voltage are also shown in the Fig. 6 of the resonant converter.

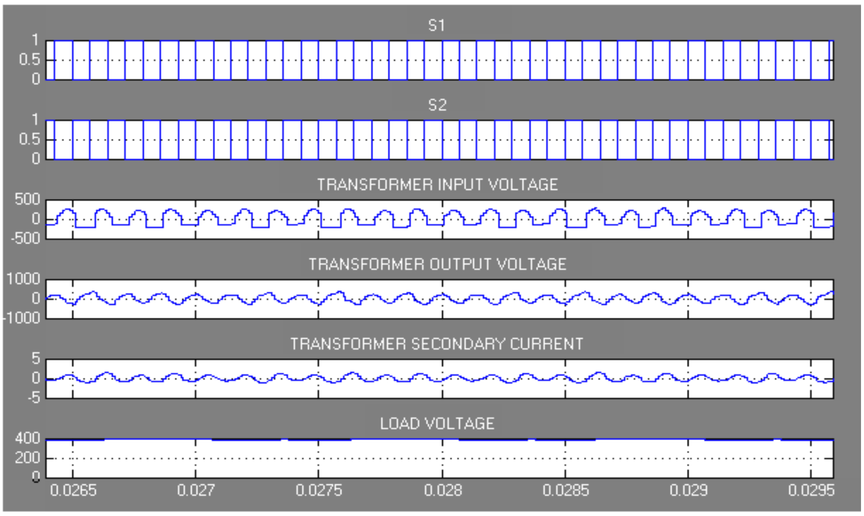


Fig.6. Simulation Results of IBR Converter

VI. CONCLUSION

As a solution for providing efficient, distributed PV conversion, an isolated boost resonant converter has been proposed. The system is a hybrid between a traditional CCM boost converter and a series-resonant half-bridge, employing only two active switches. The synthesis of the converter was described along with the circuit operating modes and key waveforms. The design process was then defined, with a focus on the unique combined resonant and PWM behavior. The result was a simple process, requiring only consideration of the resonant period length in selecting a valid converter duty cycle range. According to above, it can be concluded that the proposed system is more applicable for the distributed generation applications with low voltage sources, such as fuel cells, photovoltaic and so on. Also the analysis were verified by MATLAB/SIMULINK

REFERENCE

[1] Yi-Ping Hsieh, Jiann-Fuh Chen, Tsorng-Juu Liang and Lung-Sheng Yang, Novel High step up DC-DC Converter with Coupled-Inductor and Switched-Capacitor Techniques for a Sustainable Energy System, IEEE Trans. Power Electron. Vol. 26, No. 12, December 2011.

[2] R.Nagarajan and M,Saravanan, “Performance Analysis of Multicarrier PWM Strategies for Cascaded Multilevel Inverter,” European Journal of Scientific Research (EJSR), Vol.92 No.4, pp. 608-625, Dec. 2012.

[3] A. S. Masoum, F. Padovan, and M. A. S. Masoum, “Impact of partial shading on voltage- and current-based maximum power point tracking of solar modules,”Proc. IEEE PES General Meet., 2010, pp. 1–5.

[4] R.Nagarajan and M,Saravanan, “A Carrier - Based Pulse Width Modulation Control Strategies for Cascaded Multilevel Inverter,” International Review on Modeling and Simulations (IRMOS), Vol 6.No1, pp-8-19, Feb. 2013.

[5] M.Elangovan, R.Yuvara, S.Sathishkumar and R.Nagarajan, “Modelling and Simulation of High Gain Hybrid Boost Converter,” International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 6, pp. 9- 14, June-2017

[6] O. Lopez, R. Teodorescu, F. Freijedo, and J. DovalGandoy, “Leakage current evaluation of a single-phase transformerless PV inverter connected to the grid,” in Proc. IEEE Appl. Power Electron. Conf., 2007, pp. 907–912.

[7] Dr.R.Nagarajan, S.Sathishkumar, K.Balasubramani, C.Boobalan, S.Naveen and N.Sridhar. “Chopper Fed Speed Control of DC Motor Using PI Controller,” IOSR- Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 11, Issue 3, Ver. I, pp. 65-69, May – Jun. 2016.

[8] M. Sridhar, S.Sathishkumar, R.Nagarajan and R.Yuvaraj, “An Integrated High Gain Boost Resonant Converter for PV System,” International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 6, pp. 54- 59, June-2017.

[9] R.Prabhu, R.Nagarajan, N.Karthick and S.Suresh, “Implementation of Direct Sequence Spread Spectrum Communication System Using FPGA,” International Journal of Advanced Engineering, Management and Science (IJAEMS), Vol-3.Issue-5, pp. 488-496, May. 2017

[10] R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Imhoff, “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.

[11] R.Nagarajan, R.Yuvaraj, V.Hemalatha, S.Logapriya, A.Mekala and S.Priyanga, "Implementation of PV - Based Boost Converter Using PI Controller with PSO Algorithm," International Journal of Engineering And Computer Science (IJECS), Volume 6, Issue 3, pp. 20479-20484, March, 2017.

[12] M.Meenakshi, R.Nagarajan, R. Banupriya and M.Dharani Devi, “Stepped Multicarrier SPWM Techniques for Seven - Level Cascaded Inverter,” International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 12, pp. 43- 49, December-2017.

[13] R.Nagarajan, S.Sathishkumar, S.Deepika, G.Keerthana, J.K.Kiruthika and R.Nandhini, "Implementation of Chopper Fed Speed Control of Separately Excited DC Motor Using PI Controller", International Journal of Engineering And Computer Science (IJECS), Volume 6, Issue 3, pp. 20629-20633, March, 2017.

[14] B. Liu, S. Duan, and T. Cai, “Photovoltaic dc-building-module-based BIPV system: Concept and design considerations,” IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1418–1429, May 2011.

[15] G. Vidhya Krishnan, R.Nagarajan, T. Durka, M.Kalaiselvi, M.Pushpa and S. Shanmuga priya, "Vehicle Communication System Using Li-Fi Technology," International Journal of Engineering And Computer Science (IJECS), Volume 6, Issue 3, pp. 20651-20657, March 2017.

[16] R.Nagarajan, J.Chandramohan, S.Sathishkumar, S.Anantharaj, G.Jayakumar, M.Visnukumar and R.Viswanathan, “Implementation of PI Controller for Boost Converter in PV System,” International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE). Vol.11, Issue.XII, pp. 6-10, December. 2016.

[17] M.Dharani Devi and R.Nagarajan, “Implementation of Different PWM Control Strategies for Cascaded MLI,” Journal of Network Communications and Emerging Technologies (JNCET), Volume 7, Issue 7, pp. 49- 55, July-2017.

[18] R.Nagarajan and M, Saravanan, “Comparison of PWM Control Techniques for Cascaded Multilevel Inverter” International Review of Automatic control (IRACO), Vol.5, No.6, pp. 815-828. Nov. 2012.

[19] M.Dharani Devi, M.Malarvizhi and R.Nagarajan, “Development of Multicarrier SPWM Techniques for Cascaded MLI.” International Journal of Computational Engineering Research (IJCER), Vol. 7, Issue 10, October 2017, pp. 44-52.

[20] R Rameshkumar and R Nagarajan, “Sine Multicarrier SPWM Technique for Seven Level Cascaded Inverter,” CiiT-Programmable Device Circuits and Systems. Vol. 5, Issue- 6, 2013.

[21] R.Nagarajan and M,Saravanan “Staircase Multicarrier SPWM Technique for Nine Level Cascaded Inverter,” 2013 International Conference on Power, Energy and Control (ICPEC), IEEE Press, pp-668-675. 2013.

[22] G.Carrara, S.Gardella, M.Marchesoni, R.Salutari, G.Sciutto, “A New Multilevel PWM Method: A Theoretical Analysis,” IEEE Trans. Power Electronics, vol. 7, n.3, July 1992, pp 497-505.

[23] R.Nagarajan and M, Saravanan. “Performance Analysis of a Novel Reduced Switch Cascaded Multilevel Inverter,” Journal of Power Electronics, Vol.14, No.1, pp. 48-60, Jan.2014.

[24] S.Suresh, R.Nagarajan, R.Prabhu and N.Karthick, "Energy Efficient E0 Algorithm for Wireless Transceivers," International Journal of Engineering and Computer Science (IJECS), Volume 6, Issue 7, July 2017, pp. 21982-21985, DOI: 10.18535/ijecs/v6i7.15.

[25] R. Banupriya, R.Nagarajan, M.Malarvizhi and M.Dharani Devi, “Multicarrier - Based PWM Control Strategies for Five - Level CMLI.” Journal of Network Communications and Emerging Technologies (JNCET), Vol. 7, Issue 11, November - 2017, pp. 33-39.

[26] R.Nagarajan, J.Chandramohan, R.Yuvaraj, S.Sathishkumar and S.Chandran, “Performance Analysis of Synchronous SEPIC Converter for a Stand-Alone PV System,” International Journal of Emerging Technologies in Engineering Research (IJETER), Vol. 5, Issue - 5, pp. 12-16, May-2017

[27] M.Padmavathi and R.Nagarajan, “Smart Intelligent ATM Using LABVIEW,” International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 5, pp. 41- 45, May-2017.

[28] L. Zhang, K. Sun,Y. Xing, L. Feng, andH.Ge, “A modular grid-connected photovoltaic generation system based on dc bus,” IEEE Trans. Power Electron., vol. 26, no. 2, pp. 523–531, Feb. 2011.

[29] J.Chandramohan, R.Nagarajan, K.Satheeshkumar, N.Ajithkumar, P.A.Gopinath and S.Ranjithkumar, "Intelligent Smart Home Automation and Security System Using Arduino and Wi-fi," International Journal of Engineering And Computer Science (IJECS), Volume 6, Issue 3, pp. 20694-20698, March, 2017.

[30] K. Anandhi and Dr. R. Nagarajan, “Mutex-Heart: Fail Safe Dual Chamber Cardiac Pacemaker Device with Rate Responsive Control and Cryptographic Security,” IJSRD- International Journal for Scientific Research & Development. Vol. 3, Issue- 2, pp. 489-493, 2015.

[31] Q. Li and P. Wolfs, “A review of the single phase photovoltaic module integrated converter topologies with three different dc link configurations,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1320–1333, May 2008.

[32] M.Malarvizhi, R.Nagarajan, M.Meenakshi and R. Banupriya, “Unipolar Sine Multicarrier SPWM Control Strategies for Seven - Level Cascaded Inverter,” International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 6, Issue 1, pp. 111- 117, January-2018.

[33] J.Chandramohan, R.Nagarajan, M.Ashok kumar, T.Dineshkumar, G.Kannan and R.Prakash, “Attendance Monitoring System of Students Based on Biometric and GPS Tracking System,” International Journal of Advanced Engineering, Management and Science (IJAEMS), Vol-3.Issue-3, pp. 241-246, Mar. 2017.

[34] C. Yoon and S. Choi, “Multi-phase dc-dc converters using a boost half bridge cell for high voltage and high power applications,” in Proc. IEEE Int. Power Electron. Motion Control Conf., 2009, pp. 780–786.

[35] N.Karthick, R.Nagarajan, S.Suresh and R.Prabhu, "Implementation of Railway Track Crack Detection and Protection," International Journal Of Engineering And Computer Science (IJECS), Volume 6, Issue 5, May 2017, pp. 21476-21481, DOI: 10.18535/ijecs/v6i5.47

[36] Ms. C. Hemalatha, Mr. R. Nagarajan, P. Suresh, G. Ganesh Shankar and A. Vijay, “Brushless DC Motor Controlled by using Internet of Things,” IJSTE - International Journal of Science Technology & Engineering, Volume -3.Issue-09, pp. 373-377, March-2017.

[37] S.Suresh, R.Nagarajan, L.Sakthivel, V.Logesh, C.Mohandass and G.Tamilselvan, “Transmission Line Fault Monitoring and Identification System by Using Internet of Things,” International Journal of Advanced Engineering Research and Science (IJAERS), Vol - 4.Issue - 4, pp. 9-14, Apr- 2017.

[38] A. F. Boehringer, “Self-adapting dc converter for solar spacecraft power supply,” IEEE Trans. Aerosp. Electron. Syst., vol. AES-4, no. 1, pp. 102–111, Jan. 1968.

S.Sathishkumar "Implementation of Pwm Technique For Integrated High Gain Boost Resonant Converter.” IOSR Journal of Engineering (IOSRJEN), vol. 08, no. 03, 2018, pp. 59–66.