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An Integrated Four Port DC/DC Soft Switching Boost Converter with SARC for Renewable Energy Applications

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ABSTRACT-This paper proposes a new converter topology that interfaces four ports: two sources, one bi-directional storage port and one isolated load port. In order to improve the efficiency of energy conversion, a sot switching boost converter using a simple auxiliary resonant circuit(SARC) which is composed of an auxiliary switch, a diode, a resonant inductor and a resonant capacitor is adopted. The conventional boost converter decreases the efficiency because of hard switching which generate losses when the switches are turned ON and turned OFF. But all the switches in proposed system perform zero current switching by resonant inductor at turn-ON and zero voltage switching by resonant capacitor at turn-OFF. This switching pattern reduces the switching loss, voltage and current stress of the switching device. The proposed topology reduces the losses and cost for renewable energy power harvesting systems.

Keywords: Auxiliary Resonant Circuit, Photovoltaic(PV),Soft Switching Boost Converter, Zero-Voltage Switching(ZVS),Zero-Current Switching(ZCS).

I. INTRODUCTION

As interest in renewable energy systems with various sources becomes greater than before, there is a supreme need for integrated power converters that are capable of interfacing, and concurrently, controlling several power terminals with low cost and compact structure. Meanwhile, due to the intermittent nature of renewable sources, a battery backup is normally required when the ac mains is not available.

II.LITERATURE REVIEW

1.Zhijun Qian, Osama Abdel-Rahman and Issa Batarseh,“An Integrated Four-Port DC/DC Converter for Renewable Energy Applications,” *IEEE Trans. Power Electron.*,vol.25,no.7,pp.1877-1887,July.2010.

Zhijun Qian[et al] deals with a novel converter topology that interfaces four power ports.The four-port dc/dc converter is derived by simply adding two switches and two diodes to the traditional half-bridge topology. Zero-voltage switching is realized for all four main switches. Three of the four ports can be tightly regulated by adjusting their independent duty-cycle values, while the fourth port is left unregulated to maintain the power balance for the system. This topology promises significant savings in component count and losses for renewable energy power-harvesting systems.

2. Sang-Hoon Park,Gil-Ro Cha ,Yong-Chae Jung and Chung-Yuen Won,“Design and Application for PV Generation System Using a Soft-Switching Boost Converter With SARC,”*IEEE Trans.Power Electron.*,vol.57,no.2,pp.515-522,Feb.2010.

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Sang-Hoon Park[et al] deals to improve the efficiency of energy conversion for a photovoltaic (PV) system, a soft-switching boost converter using a simple auxiliary resonant circuit. 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.

3.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.

R. Gules [et al] deals with the analysis, design, and implementation of a parallel connected maximum power point tracking (MPPT) system for stand-alone photovoltaic power generation. The parallel connection of the MPPT system reduces the negative influence of power converter losses in the overall efficiency because only a part of the generated power is processed by the MPPT system.

III. PROPOSED METHOD

This paper proposes a new four-port-integrated dc/dc topology, which is suitable for various renewable energy harvesting applications. An application interfacing hybrid photovoltaic (PV) and wind sources, one bidirectional battery port, and an isolated output port is given as a design. It can achieve maximum power-point tracking (MPPT) for both PV and wind power simultaneously while maintaining a regulated output voltage.A soft-switching boost converter uses a simple auxiliary resonant circuit, which is composed of an auxiliary switch, a diode, a resonant inductor and a resonant capacitor. 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.

IV. SOLAR CELL

Solar cells (as the name implies) are designed to convert (at least a portion of) available light into electrical energy. A solar cell is a kind of p-n junction semiconductor device. It converts light energy into electrical energy.. The output characteristics of the solar cell depend on the irradiance and the operating temperature of the cell.Irradiance and operating temperature are important factors influencing the solar cell characteristics.

$$I_s= I_{ph}- I_{sat} [\exp(q (V_s + I_sR_s)/AKT)- 1] -(V_s+ I_sR_s)/R_{sh} \quad (1)$$

In (1), it is assumed that Rs equals zero and that R_{sh} equals infinity; thus, the equation can be simplified as

$$I_s = I_{ph}- I_{sat}[\exp(qV_s /AKT)- 1] \quad (2)$$

If irradiance increases, the fluctuation of the open-circuit voltage is very little. However, the short circuit current has sharp fluctuations with respect to irradiance. However, for a rising operating temperature, the variation of the short-circuit current is decreased, and the open-circuit voltage is decreased in a nonlinear fashion.

V. WIND TURBINE

A wind turbine is an engine that takes the kinetic energy of wind and converts it into mechanical energy. If energy is used directly by machinery, we usually call this machine a windmill. If the mechanical energy is not used directly but is converted into electricity, machine is called a wind generator.According to the aerodynamic characteristics of wind turbine, the output mechanical power is given by

$$P_m = c_p (\lambda, \beta) \rho A/2 (V_{wind})^3 \quad (3)$$

where

P_m	- Mechanical output power of the turbine (W)	c_p	- Performance coefficient of the turbine
ρ	- Air density (kg/m^3)	A	- Turbine swept area (m^2)

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v_{wind} - Wind speed (m/s) λ - Tip speed ratio of the rotor blade tip speed to wind speed

VI. MAXIMUM POWER POINT TRACKING

The maximum power point tracker (MPPT) is necessary to draw the maximum amount of power from the PV module. I choose the perturb and observe algorithm. Also known as the hill climbing method, the P&O algorithm is very popular because of its simplicity and ease of implementation. Basically, the module voltage is perturbed by a small increment, the resulting change in power is observed. If the change in power is positive, the voltage is adjusted by the same increment and the power is again observed .This continues until the power is negative at which point the direction of the change in voltage is reversed.The P&O method is the most popular MPPT algorithm due to its simplicity.

VII. SOFT SWITCHING BOOST CONVERTER

To reduce these switching losses, a soft-switching method is proposed, which involves an added auxiliary circuit, instead of a conventional hard-switching converter. The adopted converter has a simple auxiliary resonant circuit (SARC). Through this circuit, all of the switching devices perform soft-switching under zero-voltage and zero-current conditions. Therefore, the periodic losses generated at turn-on and turn-off can be decreased.The auxiliary circuit is composed of an auxiliary switch (*S*2), a resonant capacitor (*Cr*), a resonant inductor (*Lr*), and twodiodes (*D*1 and *D*2).Shown in Fig. 1, the operational principle of this converter can be divided into six intervals. For a simple analysis of each interval of this converter, the following assumptions are made.

1) All switching devices and passive elements are ideal.
2) The parasitic components of all switching devices and elements are negligible.
3) The input voltage (*Vs*) is in the range of 150–230 V.
4) This converter operates the continuous conduction mode at all intervals

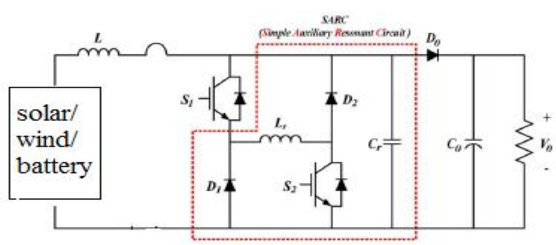

Fig.1 Circuit diagram of boost converter

A. Operation of Mode 1

Switches S_1 and S_2 are both in the OFF state, the current cannot flow through switches S_1 and S_2, and the accumulated energy of the main inductor is transferred to the load. In this interval, the main inductor current decreases linearly. During this time, the current does not flow to the resonant inductor, and the resonant capacitor has charged as output voltage.After two of the switches have been turned on, interval 1 is over.

B. Operation of Mode 2

After turning on switches S_1 and S_2, the current flows to the resonant inductor. At that time, two of the switches are turned on under zero-current condition.This is known as zero-current switching (ZCS). Because the main and auxiliary switches implement ZCS, this converter has lower switch loss than the conventional hard switching converter. As the

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resonant current rises linearly, the load current gradually decreases. At t_2, the main inductor current equals the resonant inductor current, and the output diode current is zero. When the resonant capacitor voltage equals V_o, the output diode is turned off, and interval 2 is over.

C. Operation of Mode 3

The current that flowed to the load through output diode D_o no longer flows, since t_2 and the resonant capacitor C_r, and the resonant inductor $L_r$start a resonance. The current flowing to the resonant inductor is a combination of the main inductor current and the resonant capacitor current. During this resonant period, the resonant capacitor $C_r$is discharged from V_o to zero. When the voltage of the resonant capacitor equals zero, the interval 3 is over.

D. Operation of Mode 4

After the resonant period in interval 3, when the voltage of the resonant capacitor equals zero, interval 4 begins. In this interval, the freewheeling diodes of D_1 and D_2 are turned on, and the current of the resonant inductor is the maximum value. The resonant inductor current flows to the freewheeling diodes $S_1-L_r-D_2$ and $S_2-L_r-D_1$ along the freewheeling path.During this time, the main inductor voltage equals the input voltage, and the current accumulating energy increases linearly.

E. Operation of Mode 5

In interval 5, all of switches are turned off under the zero voltage condition by the resonant capacitor.When all of the switches are turned off, the resonant capacitor $C_r$is charged to the output voltage by two of the inductor currents. Until the resonant capacitor has been charged to V_o, the output diode is in the OFF state.

F. Operation of Mode 6

Interval 6 begins when the resonant capacitor equals the output voltage, and the output diode is turned on under the zero voltage condition. During this interval, the main inductor current $i_L$and the resonant inductor current i_{Lr}flow to the output through the output diode D_o .At that time, two of the inductor currents are linearly decreased, and the energy of the resonant inductor is completely transferred to the load.

VIII. FULL BRIDGE INVERTER

Figure 2 shows the power topology of a full-bridge VSI. This inverter is similar to the half-bridge inverter; however, a second leg provides the neutral point to the load. As expected, both switches S_{1+} and S_{1-} (or S_{2+} and S_{2-}) cannot be on simultaneously because a short circuit across the dc link voltage source v_i would be produced. There are four defined (states 1, 2, 3, and 4) and one undefined (state 5).The undefined condition should be avoided so as to be always capable of defining the ac output voltage. In order to avoid the short circuit across the dc bus and the undefined ac output voltage condition, the modulating technique should ensure that either the top or the bottom switch of each leg is on at any instant. It can be observed that the ac output voltage can take values up to the dc link value v_i, which is twice that obtained with half-bridge VSI topologies. Several modulating techniques have been developed that are applicable to full-bridge VSIs. Among them are the PWM (bipolar and unipolar) techniques.

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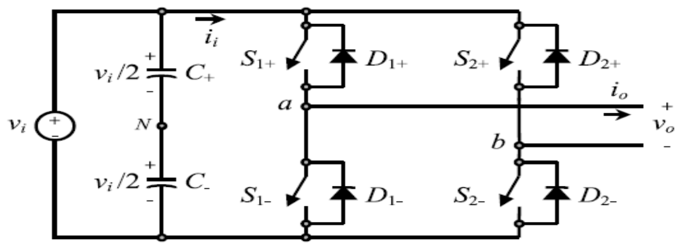

Fig.2 Single Phase Full Bridge VSI

Table 1 Switch states for a full-bridge single-phase VSI

State	State	V_a	V_b	V	Components Conducting	
S_{1+} and S_{2-} are on and S_{1-} and S_{2+} are off	1	v/2	-v/2	v	S_{1+} and S_{2-}	If $V_i > 0$
					S_{1+} and S_{2-}	If $V_i < 0$
S_{1-} and S_{2+} are on and S_{1+} and S_{2-} are off	2	-v/2	v/2	-v	S_{1-} and S_{2+}	If $V_i > 0$
					S_{1-} and S_{2+}	If $V_i < 0$
S_{1+} and S_{2+} are on and $S_{1-}$and S_{2-} are off	3	v/2	v/2	0	S_{1+} and S_{2+}	If $V_i > 0$
					S_{1+} and S_{2+}	If $V_i < 0$
S_{1-} and S_{2-} are on and S_{1+} and S_{2+} are off	4	-v/2	-v/2	0	S_{1-} and S_{2-}	If $V_i > 0$
					S_{1-} and S_{2-}	If $V_i < 0$
S_{1-}, S_{2-}, S_{1+} and S_{2+} are all off	5	-v/2	v/2	-v	S_{1-} and S_{2+}	If $V_i > 0$
		v/2	-v/2	v	S_{1+} and S_{2-}	If $V_i < 0$

IX.SIMULATION RESULTS

In the proposed system there are three inputs, they are solar, wind and battery. These inputs are given to the MPPT. The MPPT tracks the maximum power of the input and it is given to the soft switching boost converter. Then the output from converter is fed to the full bridge inverter and to the load. The simulation of the proposed and the outputs from the solar cell, wind turbine are shown in figures.

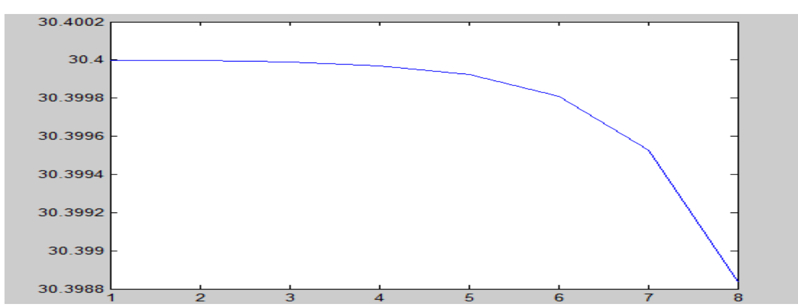

Fig.3 I-V Characteristics of Solar Cell

In the fig. 3, it shows the current Vs voltage characteristics of the solar cell.It is the one of the input to the soft switching boost converter.

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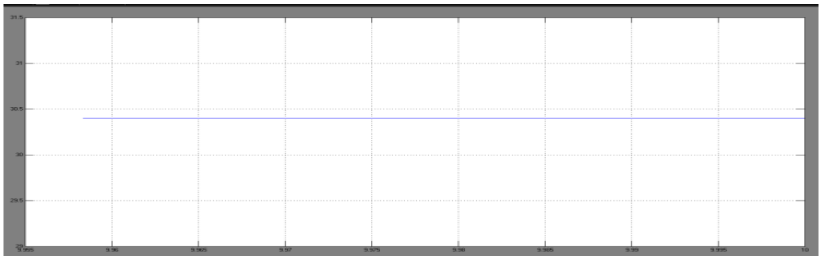

Fig.4Constant DC Voltage curve

In the fig. 4, it shows the constant DC voltage Vs time characteristics of the battery. It is the one of the input to the soft switching boost converter.

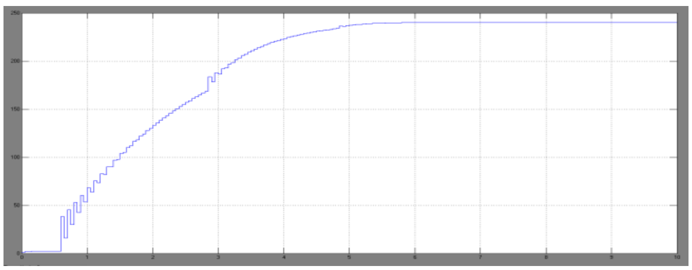

Fig.5 Power-Speed Characteristics

In the fig. 5, it shows the power Vs speed characteristics of the wind turbine.It is the one of the input to the soft switching boost converter.

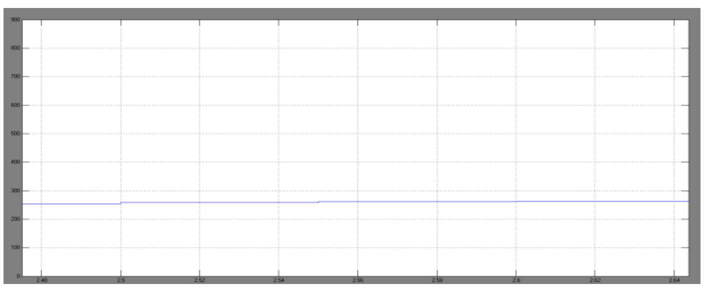

Fig.6 Output Wave from Boost Converter

In the fig. 6, it shows the voltage Vs current characteristics of the soft switching boost converter. After giving inputs from solar, wind and battery we are getting a constant DC voltage wave from a soft switching boost converter.

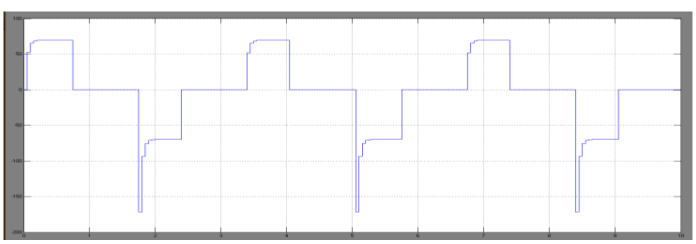

Fig.7 Output Wave for Solar Input

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In the fig. 7, it shows the voltage Vs current characteristics of the full bridge inverter. For solar input we are getting a voltage wave from a full bridge inverter .

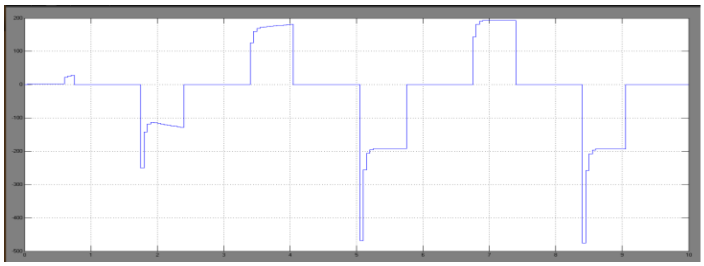

Fig.8 Output Wave Wind Input

In the fig. 8, it shows the voltage Vs current characteristics of the full bridge inverter. For wind input we are getting a voltage wave from a full bridge inverter .

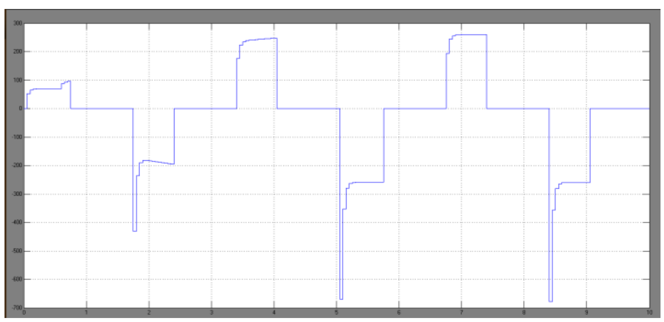

Fig.9 Output Wave for Battery Input

In the fig. 9, it shows the voltage Vs current characteristics of the full bridge inverter. For battery input we are getting a voltage wave from a full bridge inverter .

X. CONCLUSION

In this paper has presented a novel dc/dc converter topology capable of interfacing four dc power ports: two input source ports, a bidirectional storage port, and an isolated loading port. This four-port converter is suitable for renewable energy systems, where the energy storage is required while allowing tight load regulation. It is suitable for low-power applications since based on the half-bridge topology, while the multiport converter based on the full-bridge topology maybe suitable for high-power applications. For the hybrid PV wind system, the proposed control structure is able to achieve maximum power harvesting for PV and wind power sources, meanwhile maintaining a regulated output voltage.In this paper, we proposed a soft-switching boost converter, which involved an added SARC in the conventional boost converter. This soft-switching boost converter is easy to control because the two switches are controlled by the same PWM signal.All of the switching devices in this converter achieved ZCS and ZVS by the resonant inductor and capacitor at turn/off. Therefore, the switching losses were reduced dramatically. This paper has analyzed the operational principles of the adopted converter and applied them to the P&O algorithm, which is a kind of MPPT method. Moreover, this converter was verified by the simulation results.

REFERENCES

[1] R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Rnhoff,(2008) "A maximum power point tracking system with parallel connection for PV standalone applications," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2674–2683,July 2008.

[2] H. Krishnaswami and N. Mohan, (2009)"Three-port series-resonant DC–DC converter to interface renewable energy sources with bidirectional load and energy storage ports," *IEEE Trans. Power Electron.*, vol. 24, no. 9–10, pp. 2289–2297,Oct.2009.

[3] D. Liu and H. Li, (2006)"A ZVS bi-directional DC-DC converter for multiple energy storage elements," *IEEE Trans. Power Electron.*, vol. 21, no. 5,pp. 1513–1517,Sep.2006.

[4] Y. Liu and Y. M. Chen,(2009) "A systematic approach to synthesizing multi input DC–DC converters," *IEEE Trans. Power Electron.*, vol. 24, no. 2, pp. 116–127, Jan. 2009.

[5] Sang-Hoon Park,Gil-Ro Cha ,Yong-Chae Jung and Chung-Yuen Won,(2010)"Design and Application for PV Generation System Using a Soft-Switching Boost Converter With SARC,"*IEEE Trans.Power Electron.*,vol.57,no.2,pp.515-522, Feb.2010.

[6] Z. Qian, O. Abdel-Rahman, J. Reese, H. Al-Atrash, and I. Batarseh, (2009)"Dynamic analysis of three-port DC/DC converter for space applications," in *Proc. IEEE Appl. Power Electron. Conf.*, pp. 28–34,March 2009.

[7] Z. Qian, O. Abdel-Rahman, H. Al-trash, and I. Batarseh,(2010) "Modeling and control of three-port DC/DC converter interface for satellite applications, *IEEE Trans. Power Electron.*, vol. 25, no. 3, pp. 637–649, March 2010.

[8] Zhijun Qian, Osama Abdel- Rahman and Issa Batarseh,(2010)"An Integrated Four-Port DC/DC Converter for Renewable Energy Applications," *IEEE Trans. Power Electron.* vol.25, no.7, pp.1877-1887, July 2010.

BIOGRAPHY

N.Dhivya Devi was born in 1982 in Tamil Nadu,India. She received her B.E. Degree from Bharathidhasan University,Trichy in 2004 and M.E. Degree from Anna University, Chennai in 2011.She has 6 years 11 months teaching experience.Now she is working as Assistant Professor in the Department of Electrical and Electronics Engineering, Adhiparasakthi Engineering College,Melmaruvathur,Tamil Nadu,India.Her research interest includes Power Electronics, Non-Conventional Energy resources.

Dr.J.Baskaran was born in 1976 in Tamil Nadu, India. He received his B.E. Degree from Madras University, Chennai in 1997 and M.E. Degree from Annamalai University, Chidambaram in 2006 and Phd from Anna University, Chennai in 2010.He has 14 years teaching and 4 years research experience. Now he is working as a Professor and Head of EEE Department in Adhiparasakthi Engineering College, Melmaruvathur, Tamil Nadu, India. His research interest includes Power Electronics, Optimization Control in Power System,FACTS, Distributed Power System.