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SINGLE INDUCTOR DUAL BUCK FULL-BRIDGE INVERTER FOR PV GRID CONNECTED SYSTEM

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ABSTRACT:
This project develops a novel single-switch resonant power converter for renewable energy generation applications. This circuit topology integrates a novel single-switch resonant inverter with zero-voltage switching (ZVS) with an energy-blocking diode with zero-current switching (ZCS). The energy-blocking diode with a direct-current output filter filters the output stage of the novel single-switch resonant inverter. Only one active power switch is used for power energy conversion to reduce the cost of active power switches and control circuits. The active power switch is controlled by pulse width modulation at a fixed switching frequency and a constant duty cycle. When the resonant converter is operated at discontinuous conduction mode, the inductor current through the resonant tank could achieve ZCS of the energy-blocking diode. Accordingly, a high energy conversion efficiency is ensured. Operating principles are derived, and analyses are carried out based on the equivalent circuits for the proposed power converter under different operating modes. Further this project is enhanced by using SINGLE INDUCTOR DUAL BUCK FULL-BRIDGE INVERTER. The inverter has just one filter inductor, which can make the volume and weight of the system decreased observably and improve the integration.

I. INTRODUCTION
NOWADAYS, most power that is used to meet our daily needs is obtained from fossil fuels. Owing to increases in consumption, fossil fuel sources may be exhausted in the near future [1]–[3]. The Kyoto agreement on the global reduction of greenhouse gas emissions that are produced by the burning of fossil fuels seeks a reduction in the use energy from such sources. However, Taiwan is a highly energy-dependent nation, which meets approximately 97% of its energy needs by importing fuels. Environmental pollution and greenhouse gas emissions are becoming significant environmental issues in the country. Therefore, renewable energy has become attractive in recent years, following the implementation of a policy for sustainable development and mitigation of environmental pollution in Taiwan. Accordingly, means of generating renewable energy are being developed. They include wind turbines, photovoltaic (PV) modules, and fuel cell systems [4]–[7]. PV power generation systems have been regarded as the most promising future sources of energy because of their advantages, such as the absence of a need for fuel and the associated cost saving, low maintenance, and lack of noise. Fortunately, Taiwan is located in a subtropical zone that is close to the equator, and southern Taiwan, in particular, experiences strong sunshine in the summer. Consequently, the energy collected on PV arrays is utilized as the source of a renewable energy for reduction of fossil fuel energy. If the direct-current (dc) output of renewable energy generation systems is directly connected to a battery energy storage system (BESS), then the output voltage of the dc output source of the renewable energy generation system will be fixed to the voltage of the BESS, so the renewable energy generation system cannot always operate optimally. Hence, a dc/dc interface must be installed between the renewable energy generation system and the BESS to ensure that the renewable energy generation system always operates at its optimum operating points. Power electronics use switching circuits to transform energy and control power flow. Power semiconductor switches critical components of power electronic circuits. The simplest method for controlling power semiconductor switches is pulsewidth modulation (PWM) [8]–[13]. The PWM approach is to control power flow by interrupting current or voltage by switching with control of the duty cycles. Conventionally, the voltage across or current through the semiconductor switch is abruptly altered;

this approach is called hard-switching PWM. Because of its simplicity, relatively low current stress, and ease of control, hard-switching PWM approaches have been preferred in modern power electronics converters. Owing to the rapid developments of new power device technologies, the switching speed of power devices has increased greatly. Therefore, PWM power converters can now operate at a much higher switching frequency, reducing the size of passive components, reducing the overall cost of the system. However, the converter switching loss also increases in proportion to the frequency. The increases in *dv/dt* and *di/dt* caused by the increased speed increase stress on the device and system electromagnetic interference noise. These effects set an upper limit on the frequencies at which conventional hard-switching PWM converters can operate. In the last few decades, various research studies have been performed to improve the switch transition to overcome this inherent problem of hard-switching PWM converters. By solving these high voltage and current stress problems, energy conversions using resonant converters have been important in ensuring both high performance and supporting energy conservation applications in renewable energy generation systems.

Resonant converters are extensively utilized in the application of renewable energy generation systems. The basic requirements of resonant converters are their small size and high efficiency. A high switching frequency is required to achieve small size. However, the switching loss increases with the switching frequency, reducing the efficiency of the resonant converters. To solve this problem, some soft-switching approaches must be used at high switching frequencies. Zerovoltage switching (ZVS) and zero-current switching (ZCS) techniques are two commonly used soft-switching methods [14]–[19]. In these techniques, either voltage or current is zero during the switching transition, substantially reducing the switching loss and increasing the reliability of resonant converters in renewable energy generation systems. Traditional ZCS converters operate with constant on-time control. They must operate with a wide range of switching frequencies when the ranges of the input source and load are wide, making the filter circuit design difficult to optimize. However, the traditional ZVS scheme eliminates capacitive turn-on losses and decreases the turnoff switching losses by reducing the rate of increase in voltage, reducing the overlap between the switch voltage and the switch current. This work develops a novel single-switch highly efficient converter with ZVS topology based on the traditional ZVS concept for renewable energy generation applications.

Its important features include a simple circuit structure, ease of control, soft switching for active power devices, low switching losses, and high energy conversion efficiency. This novel single-switch high-efficiency converter with ZVS topology can be considered to be an extension of the traditional ZVS power converter. It utilizes a capacitor across the active power switch in the novel single-switch power converter to generate a freewheeling stage with a traditional ZVS power converter, enabling the novel converter to operate with a constant frequency and a markedly much reduced circulating energy.

OVERVIEW OF RESONANT CONVERTER

Resonant converters use a resonant circuit for switching the transistors when they are at the zero current or zerovoltage point, this reduces the stress on the switching transistors and the radio interference. To control the outputvoltage, resonant converters are driven with a constant pulse duration at a variable frequency. The pulse duration isrequired to be equal to half of the resonant period time for switching at the zero-crossing points of current or voltage.There are many different types of resonant converters. For example the resonant circuit can be placed at the primary orsecondary side of the transformer. Another alternative is that a serial or parallel resonant circuit can be used, dependingon whether it is required to turn off the transistor, when the current is zero or the voltage is zero. Since the converter iscontrolled through frequency modulation, the impedance of the resonant network will be changed by changing theswitching frequency in response to load changes. Consequently the output voltage can be regulated by changingimpedance of the resonant tank circuit. For example, if the load current increases the output voltage will have atendency to decrease.The feedback circuit will sense this decrease and move the switching frequency of the convertertoward resonance such that more voltage applied to the resonant network will be dropped across the load therebyincreasing the output voltage.Conversely, if the load current decreases, the feedback circuit will move the frequency away from resonance such thatmore voltage is dropped across the tank circuit. The fact that the converter works as a voltage divider means that themaximum gain that can be achieved in the power train of the converter is one. The advantage of the series resonantconverter is that it can zero voltage the main switches, Q1 and Q2, in Figure 1. This improves the efficiency of theconverter particularly as higher switching frequencies are used.

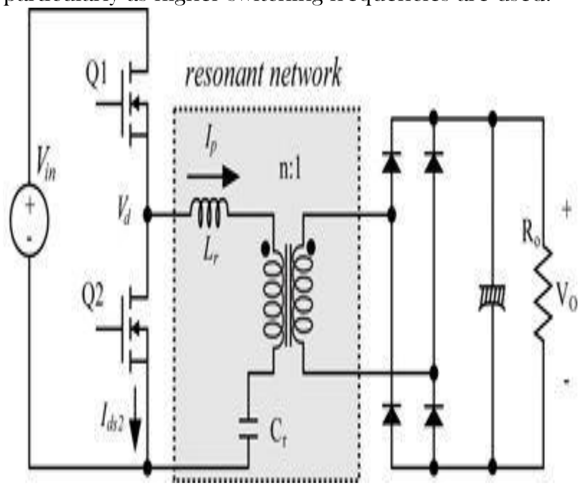


Fig 1: Series Resonant Converter

2.3 CIRCUIT DESCRIPTION OF CLLCSYSTEM

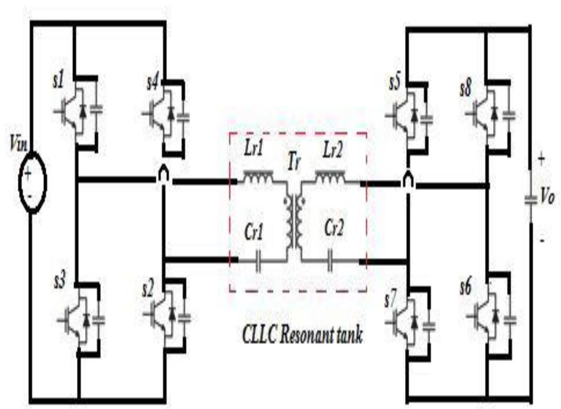


Fig 2: Bidirectional full bridge CLLC resonant converter

In the proposed system DC voltage is given to the primary inverting stage. CLLC Resonant tank has twocapacitances Cr1 and Cr2 for automatic flux balance. It also has two inductance Lr1 and Lr2 for achieving highresonant frequency. IGBTs operate under ZVS condition with minimum switching loss when compared to theconventional system. For soft commutation of the output rectifiers switching frequency must be less than resonantfrequency. Turn-on or turn-off transitions of semiconductor devices can occur at zero crossings of tank voltage orcurrent waveforms, thereby reducing or eliminating some of the switching loss mechanisms. Hence resonant converterscan operate at higher switching frequencies than comparable PWM converters Zero-voltage switching also reducesconverter-generated EMI .Zero-current switching can be used to commutate the switches. In specialized applications,resonant networks may be unavoidable. High voltage converters have significant transformer leakage inductance andwinding capacitance leads to resonant network. The primary and secondary windings of the transformer may be used to

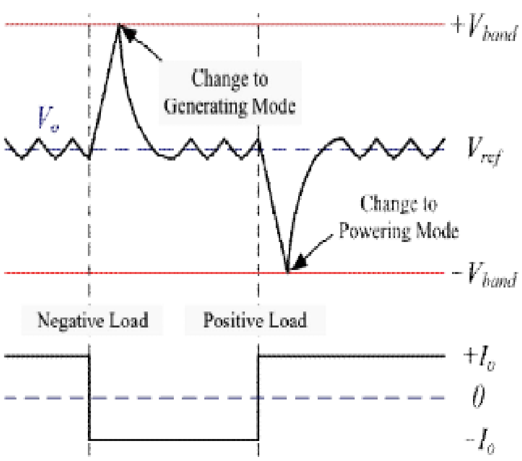
step up or step down the voltage output. So, it can be made in such a way that a 120 V load can match a 208V load.Isolation transformers which have the Faraday shield will have improved power quality because of attenuated higherfrequency noise currents. The Faraday shield also decreases the leakage current of the equipment and the isolator below300 microamphs. They help in giving a better impedance matching of a critical load to an electrical circuit.

SOFT-SWITCHING CONDITIONS

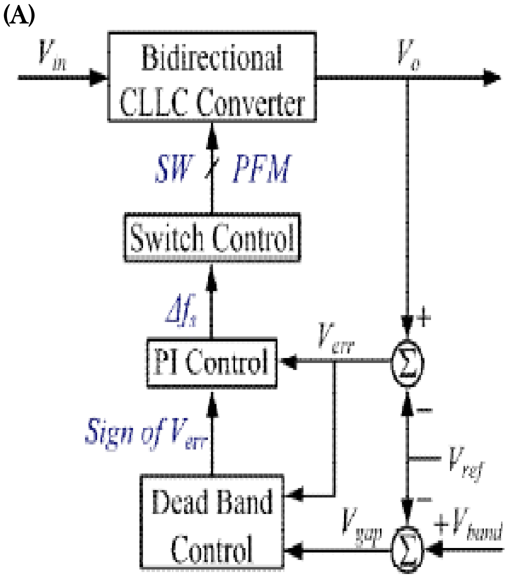
The ZVS operation of the primary power IGBTs and the soft commutation of the output rectifiers are significant factorsfor the efficiency-optimal design of the bidirectional full-bridge *CLLC* resonant converter. The lower operatingfrequency than the resonant frequency can guarantee the soft commutation of the output rectifiers because thedifference between the switching frequency and the resonant frequency makes discontinuous rectifying current. Inaddition, during the dead time of the switches, the primary current should discharge the output capacitance of fourprimary switches for their ZVS turn-on.

2.4DIGITAL CONTROL SCHEME FOR BIDIRECTIONAL OPERATION

Bidirectional power converters require a mode change algorithm to select their power conversion direction. This powerconversion mode should be selected considering the direction of the power flow in the converter. The direction of thepower flow will be easily detected if there is a current sensor connected between the converter's output capacitor andload side. However, it can decrease the flexibility of the bidirectional power conversion system since the currentinformation has to contain the power flow direction of the entire load. It means that if the proposed system is expandedto a multiple module system connected in parallel, additional and huge current sensors will be required to obtain thepower flow information for the entire load. To avoid this problem, a dead-band control algorithm is proposed tosmoothly change the power conversion direction only using output voltage information. When the load becomesnegative, the output voltage of the converter Fig.3(a) shows the theoretical waveforms of the proposed dead-bandcontrol algorithm for the bidirectional CLLC resonant converter. When the load becomes negative, the output voltageof the converter will drastically increase because power is supplied to the output capacitor from two sides: the converterside and the load side. At this time, the converter is uncontrollable without changing the power conversion modebecause of the negative power flow. If the output voltage reaches the positive dead-band voltage + *V*band, the powerconversion mode changes from the powering mode to the generating mode. In this generating mode, the convertertransfers power from load to input side. Then, the output voltage will decrease to the reference voltage *V*ref, which willbe regulated by a pulse frequency modulation (PFM) controller. In the same manner, the power conversion mode canbe changed from the generating mode to the powering mode



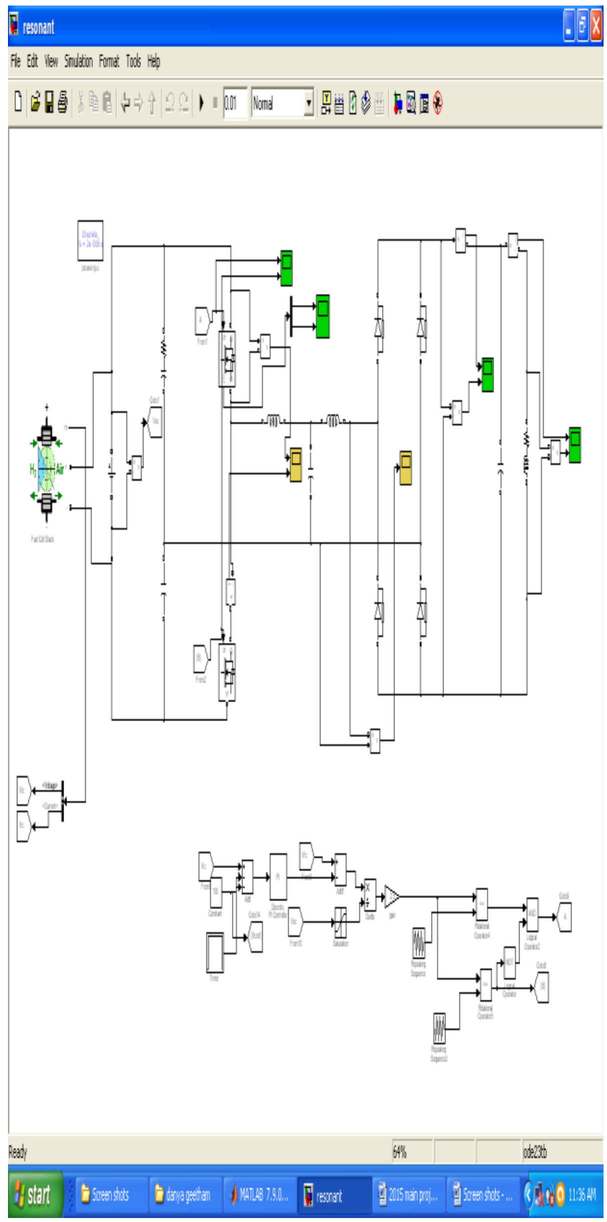
(A)



(B)

When the load becomes positive, the output voltage will decrease to the negative dead-band voltage −Vband. Then, the power conversion mode is changed and the output voltage will increase to Vref.Fig.3(b) shows the block diagram of the proposed digital controller. The dead-band controller can select the power conversion mode using the voltage gap Vgapwhich is the voltage difference between the output voltage and the dead-band voltage. This dead-band controller generates the sign of the voltage error Verrwhich is the voltage difference between the output voltage and the reference voltage. The PI controller regulates the output voltage using Verrand its sign. The switch control block generates PFM switching pulses using the calculated.

CIRUICUIT DIAGRAM:



RESULT:

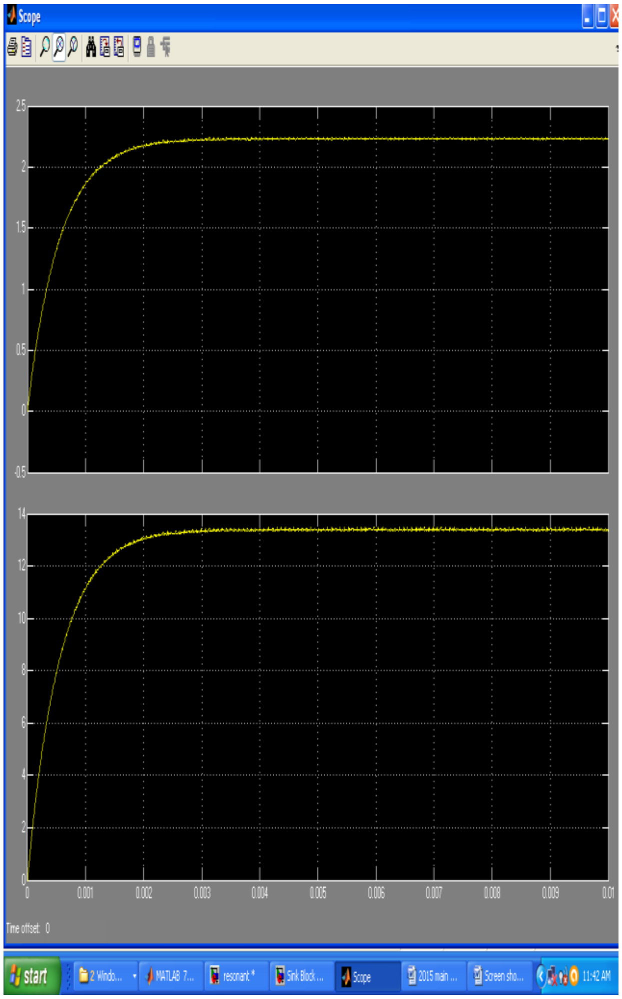


Fig: Current vs Voltage

CONCLUSION:

In this paper, a novel single-switch resonant power converter with an energy-blocking diode has been designed for use in a solar energy generation system. The structure of the proposed converter is simpler and cheaper than other resonant power converters, which require numerous components. The novel resonant converter is analyzed, and performance characteristics are presented. The developed novel single-switch resonant power converter offers the advantages of soft switching, reduced switching losses, and increased energy conversion efficiency. The output power can be determined from the characteristic impedance of the resonant tank by adjusting the switching frequency of the converter. The novel single-switch resonant power converter is supplied by a solar energy generation system to yield the required output conditions. The experimental results reveal the effectiveness of the developed novel single-switch resonant power converter in solar energy generation. When the high-frequency novel single-switch resonant power converter is applied to a resistive load, the satisfactory energy conversion efficiency is 97.3%. The novel single-switch resonant power converter topology yields a higher energy conversion efficiency than conventional class-D resonant converters. Favorable performance is obtained at lower cost with fewer circuit components. In addition, the proposed inverter also has independent freewheeling diodes with lower reverse recovery time, which can be used to reduce the reverse recovery loss. The passive components (namely, inductors and capacitors) play an important role in determining the volume and weight of inverter system

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