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Solar Water Pumping System with Ćuk Boost Impedance Source Inverter

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ABSTRACT: Renewable energy sources have energized as the major source of energy in the recent years because the world is facing a serious problem of pollution. In order to prevent these, it is promoted to use sources that are eco-friendly. Various pumping mechanism have been used in the recent years. In this paper it is aimed to produce a solar based water pumping technique for the irrigation purpose. It includes a PV array, Ćuk-booster followed by an impedance source inverter for the electrical applications. It proposes a new three phase inverter with better boosting capabilities, the boosting is expandable with the help of Ćuk and solar array. By boosting we can reduce the number of PV cells which intern reduces the area requirement and the cost of the entire system. The proposed project is developing with the help of MATLAB/simulink.

I. INTRODUCTION

Solar energy and wind energy has proven to be an economic source of energy for many applications in the recent decades. One of the major applications of solar energy is Remote water pumping which is for the residential water supply and small-scale irrigation. In solar water pumping systems, the solar energy obtained is converted to electrical power in DC by photovoltaic cells (PV). The power output of the PV module varies with the intensity of radiation. A power converter is normally used to convert the DC power into AC of suitable voltage and frequency as required by the motor-pump unit. Conventional solar water pumping systems uses a boost chopper and a PWM inverter as power converter [1]. The Z-source inverter can overcome the aforesaid difficulties of the conventional system.

In this paper, the application of the new Ćuk converter with increased buck-boost capability to solar water pumping system is considered for study. A complete simulation model of the solar water pumping system with the proposed inverter is presented. The performance of the pump is analyzed for varying solar intensities.

II. MODELLING OF SOLAR WATER PUMPING SYSTEM WITH ĆUK BOOST IMPEDANCE SOURCE INVERTER

A. PV CELLS

Generally a solar cell is consisting of number of small PV cells for achieving the required amount of power. Here we are using a 12kw panel array under 1000w/m^2 intensity of day light. The solar cell selection is done by the calculations [2].

B. ĆUK CONVERTER

The Ćuk converter is a type of DC/DC converter that has an output voltage magnitude that is either greater than input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

The Ćuk converter is a step-down/step-up converter based on a switching boost-buck topology. Essentially, the converter is composed of two sections, an input stage and an output stage.

The input voltage Vg is fed into the circuit via inductor L1. When transistor Q1 is on, current I1 builds the magnetic field of the inductor in the input stage. The diode CR1 is reverse biased, and energy dissipates from the storage elements in the output stage.

When Q1 turns off, inductor L1 tries to maintain the current flowing through it by reversing polarity and sourcing current as its magnetic field collapses. It thus provides energy to the output stage of the circuit via capacitor C1. R1 and R2 are parasitic or stray resistances of inductor.

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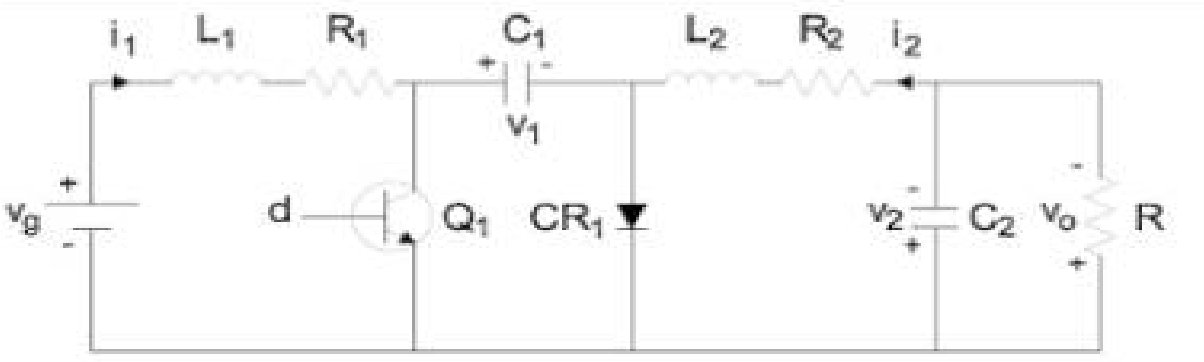

Fig 1. CUK CONVERTER

The inductor currents are the input and output currents, therefore, if the principle of conservation of energy is applied

$$\frac{v_o}{v_g} = \frac{D_s}{1 - D_s}$$

$$D_s \triangleq \frac{t_{on}}{t_{on}+t_{off}}$$

Where "Ds"is the duty cycle.

The voltage ratio of a Ćuk converter is the same as that of a buck-boost converter, but its main advantage over other converters is that the input and output inductors result in a filtered current on both sides of the converter, while buck, boost, and buck-boost converters have a pulsating current that occurs on at least one side of the circuit i.e. either on input side or output side. This pulsation will increase the ripple in the circuit and due to this ripple; the efficiency of battery gets lowered. To ensure good efficiency ripple should be reduced.

By controlling the duty cycle of the switch, the output voltage Vo can be controlled and can be higher or lower than the input voltage Vg.

By using a controller to vary the duty cycle during operation, the circuit can also be made to reject disturbances, as second part of circuit consists of parallel resonance circuit and it work as a tank circuit for specific frequency (Resonant frequency) , and during resonance current will not be allowed to enter in the circuit.

C. IMPEDANCE SOURCE NETWORK

Impedance source inverter provides an efficient power conversion from source to load from DC-AC. Impedance source network is a combination of two linear storage components i.e., inductor (L), capacitor (C).

The working of impedance source network can be improved by means of adding nonlinear elements such as diodes, switches or its combination. Based on the type of input source impedance source inverters can be classified into voltage source inverter (VSI) and current source inverter (CSI).These two have the disadvantages such as they will act either as buck or boost converter only. Thus the output will be limited i.e., either greater than or less than the original one. They have lower reliability. Also the switching devices are related to EMI. The impedance source network has originally invented to overcome these difficulties.

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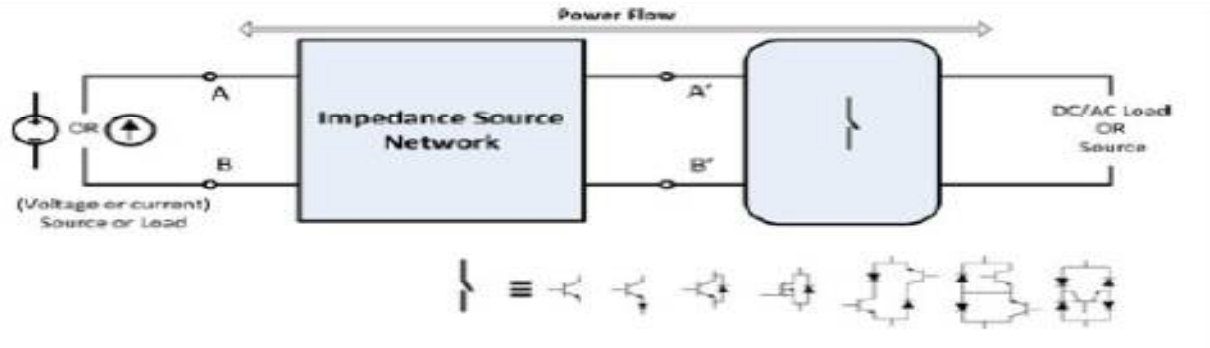

Fig.2. General circuit configuration of impedance-source network for proper conversion with different switching

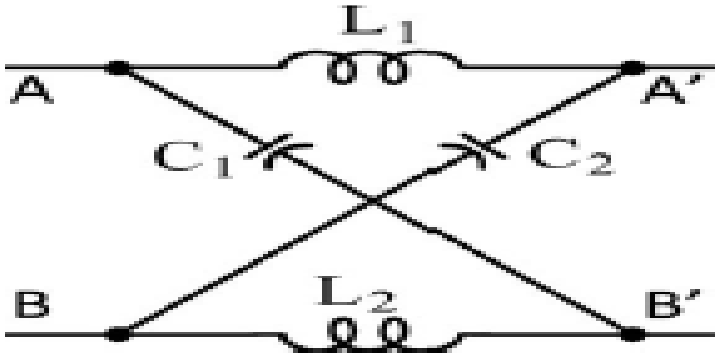

Fig.3.Basic Z-source impedance network

Impedance source network can be classified on the basis of functionality as (1)dc-dc converter(2)dc-ac converter(3)ac-ac converter(4)ac-dc converter. Different control and modulation techniques have been required to get the desired phase, frequency and amplitude of voltage and current to obtain the desired output PWM techniques can be used to control the impedance source network. The dc source and/load can be either a voltage or current source and/a load. Applications such as renewable energy generation using PV and wind power and motor drives are possible by means of impedance source inverter because of its unique buck-boost capability with minimum number of components and low cost.

The original Z source network has been advanced to quasi Z source network, trans Z source network, distributed Z source network and many other Z source network. These modifications are introduced because of one or more reasons (1)increased boosting (2) to reduce number and size of components(3)to reduce voltage stress on device(4)better input voltage utilization(5)to improve EMC of the system(6)to increase the reliability of system.

D. THREE PHASE AC CONVERTER

An insulated-gate bipolar transistor (IGBT) is a three-terminal power semiconductor device primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. It switches electric power in many modern appliances: variable-frequency drives (VFDs) IGBTs are mainly used in power electronics applications, such as inverters, converters and power supplies, were the demands of the solid state switching device are not fully met by power bipolar and power MOSFETs. High-current and high-voltage bipolar are available, but their switching speeds are slow, while power MOSFETs may have higher switching speeds, but high-voltage and high-current devices are expensive and hard to achieve. In our paper we use IGBT as voltage booster and three phase converter.

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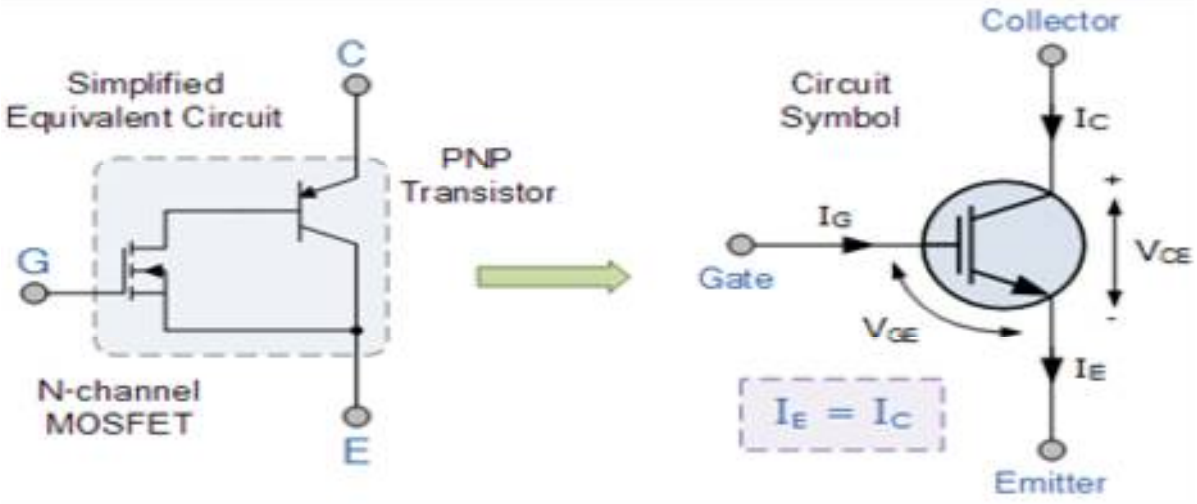
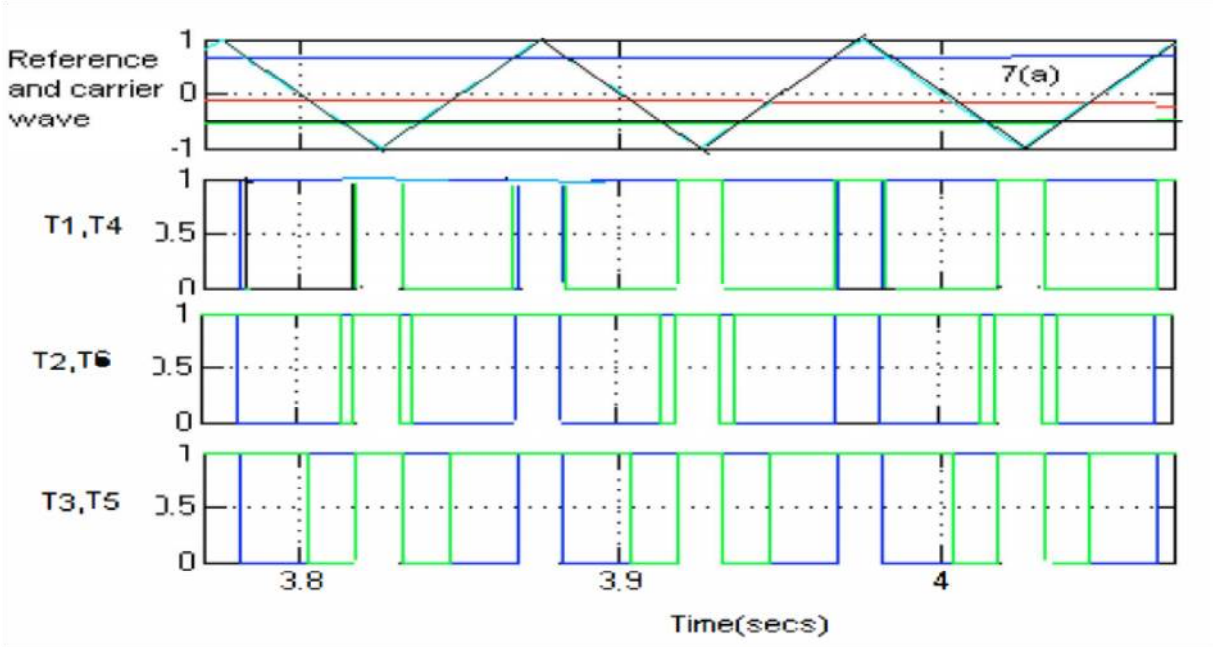


Fig 4. Schematic diagram of IGBT

The IGBT is a four layer N-P-N-P device with an MOS-gated channel connecting the two N-type regions.
The main advantages of using the Insulated Gate Bipolar Transistor over other types of transistor devices are its high voltage capability, low ON-resistance, ease of drive, relatively fast switching speeds and combined with zero gate drive current makes it a good choice for moderate speed, high voltage applications such as in pulse-width modulated (PWM), variable speed control, switch-mode power supplies or solar powered DC-AC inverter and frequency converter applications operating in the hundreds of kilohertz range.



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IV. SIMULINK MODEL

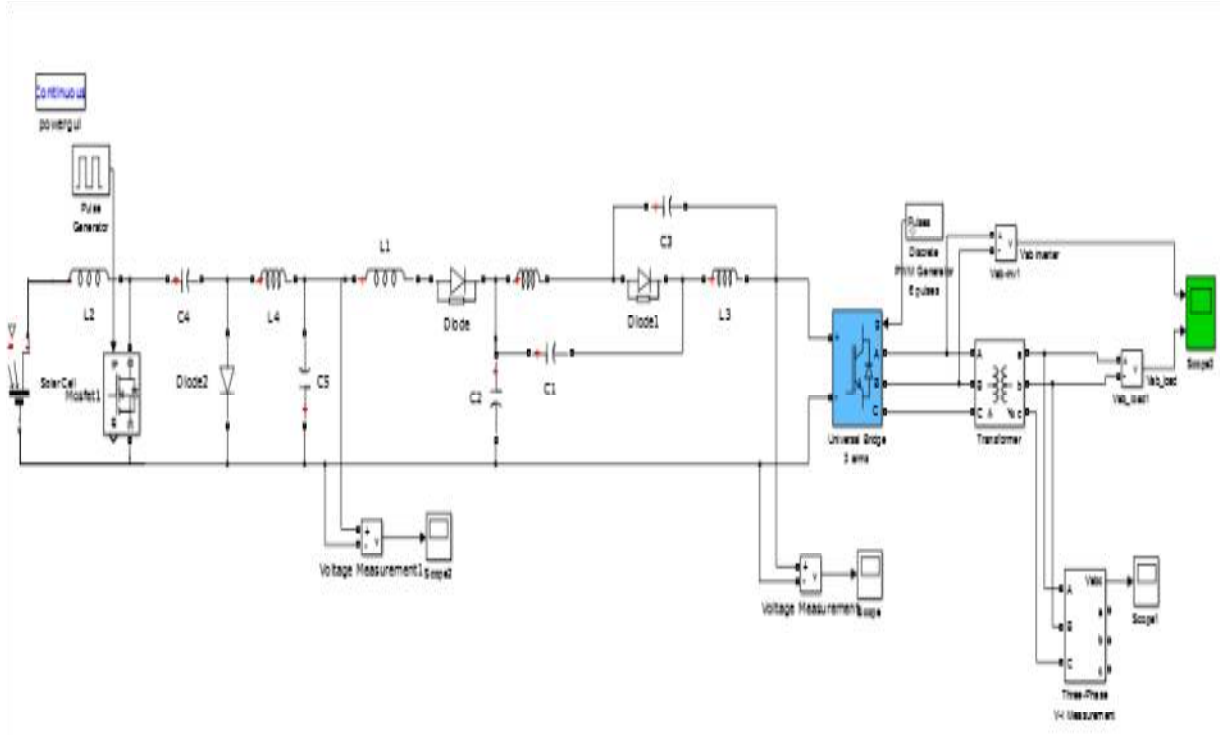

Fig7. Simulink model of the proposed solar water pumping system

V. CONCLUSION

This paper has presented a review of the construction of solar based water pumping system with improved efficiency. By using the Ćuk converter the dc voltage can be raised to get the required dc output voltage. The impedance source inverters provide an efficient power conversion from dc to ac voltage. IGBT's are used for the conversion to three phase ac supply. Thus the overall construction of the system provides an efficient conversion of solar energy into three phase ac irrespective of the amount of solar radiation fall on the PV cells. The amount of area required for the irrigation purpose can be reduced by lowering the number of PV panels required due to the usage of a potential booster. As a result the cost of the components can be reduced. And the presence of MPPT increases the out efficiency of the entire system. The VFD technology reduces starting current and high voltage arrester arrest the high voltage also the no-load cutoff reduces the powerless.

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