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A High Efficient Converter for Photovoltaic Induction Motor Drives

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Abstract: *This paper presents a converter-inverter system for photovoltaic water pumping application without any batteries. The topology is based on Resonant two inductor boost converter and three phase voltage source inverter. TIBC is modified with a resonant tank and snubber circuit to improve efficiency. The maximum power from solar energy is tracked at all the time. The software used is MATLAB/SIMULINK to verify the proposed system.*
Keywords: *TIBC-Two inductor boost converter, MPPT, P&O- Perturb & Observe algorithm, PV cell*

I. Introduction

Lack of electricity is one of the major issue in many rural areas due to under developed grid system of India. Hence standalone system is most welcome and necessary for rural areas in India. Water pumping is a beneficial application of standalone systems particularly in areas having considerable amount solar energy and have no access to national grids. The presence of chemical storage elements (batteries) allows the motor pump system to operate at rated power under any variations of solar insolation. But the drawback of such systems are low life span compared to PV panels and the presence of large banks of batteries makes the system expensive. Therefore, a converter inverter system for photovoltaic water pumping is proposed without the use of batteries [1]. The proposed system is not new, but most of them uses low voltage dc motors and intermediate energy storage elements. The major disadvantages of DC motor is its less efficiency and requires high maintenance due to the presence of commutator and brushes [2]. Due to this, it cannot be preferred in isolated areas, where specialized persons are not available for maintenance. Many systems has been developed with the use of synchronous motor [3]. But it can’t be used in rural areas because of its high cost. Therefore, the proposed system adopts induction motor due to its higher efficiency ,robustness, lower cost compared to other motors.

II. Literature Survey

The major challenges in designing a standalone motor drive system fed from a PV source is to obtain maximum energy available from PV module and to operate under varying power conditions [4]. To overcome these problems , it demands a high efficient, robust, high life span DC-DC converter for battery less photovoltaic water pumping system. The required dc-dc converter is to boost the output voltage of PV panel. Many dc-dc converter has been developed based on voltage fed topology. But these converter are force to place a large filter capacitor at the input because of high input current ripple. This reduces the life span of the converter, since the capacitors are electrolytic in nature. Current fed converters are used to overcome this problem because it has an inductor at the input side ,thus eliminating the requirement of filter capacitor at the input side. It has high step up voltage gain that reduces transformer turns ratio. Other topologies of current fed converters are current fed push pull converter, current fed full bridge converter. The main drawback of these converters are high voltage spikes due to leakage inductance of the transformer. These limitations can be overcome by resonant topologies. T hey are able to utilize the parasitic components such as leakage inductance and winding capacitance of transformer to achieve zero current switching. The rectifier circuit of conventional TIBC is replace by voltage doubler circuit again reduces the needed transformer ratio.

III. Circuit Operation

The proposed converter consists of two stages of power conversion. First stage consist of a DC-DC converter(TIBC) which is used to boost the panel voltage and the second stage is a three phase inverter connected to the output. The block diagram of proposed system is shown in fig.1. SPWM strategy is of TIBC converter used for the switching patterns of inverter.

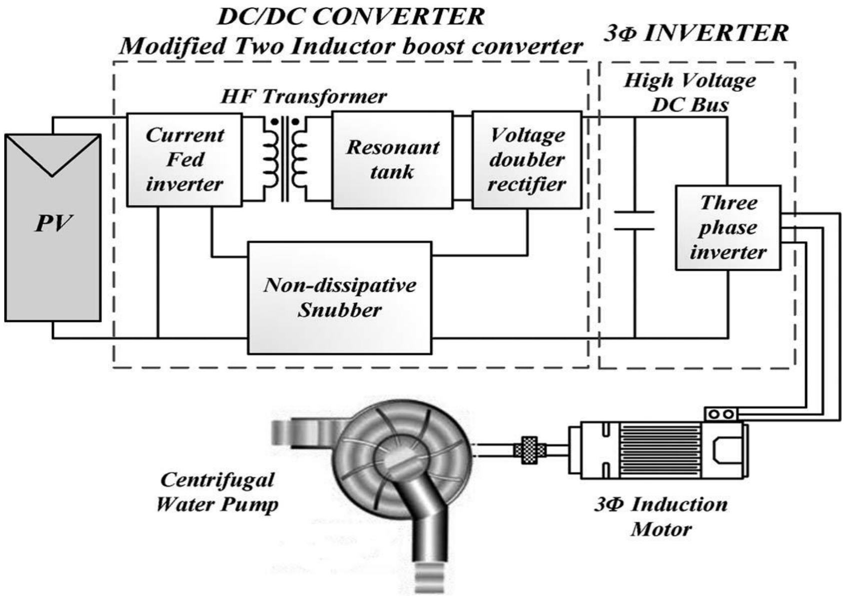


Fig.1 Block Diagram of the proposed system

The current fed converter used in the system is shown in fig.2.The converter used is known as Two Inductor boost converter(TIBC) because it consists of two inductors at the input side thereby reducing the current ripple so that it does not cause oscillations over the maximum power point of the PV panel. To maintain its output voltage, TIBC requires minimum operating load. As a result, it can't be used in motor drive systems. This is because, the inductors at the input side are charged, even there is no load current. So the energy transferred to the capacitor is not completely transferred to load which causes an increase in output voltage. Since the motor is available load in the proposed system, it will demand low power at some operating points (startup and stop).To overcome this drawback, a hysteresis controller with snubber circuit is proposed.

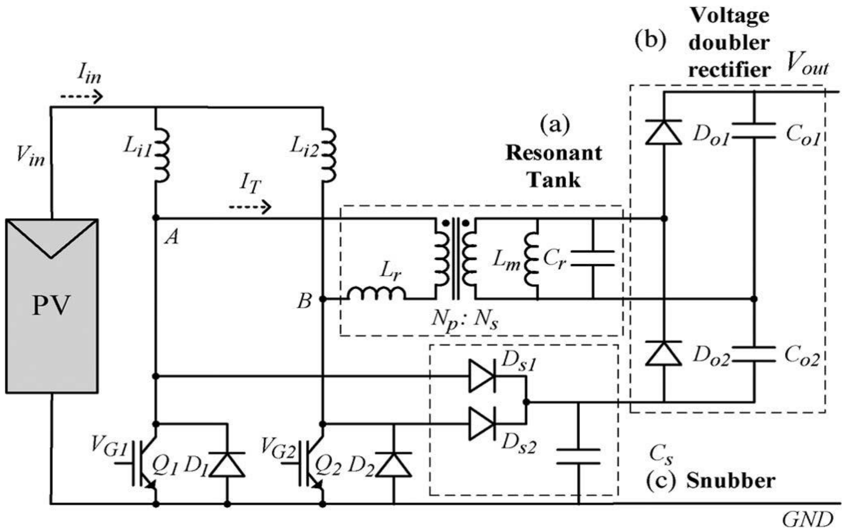


Fig 2. Modified TIBC

During one switching period, two resonant processes are occurring

1) When both the switches are turned on, then the leakage inductance L_r participates with C_r in the resonance.
2) When at least one switch is off, then L_m and C_r participates in the resonance.

When the output voltage of converter is higher than a threshold value, hysteresis controller will be active .With the help of snubber circuit, he switches at the input side are turned off because there is still a path for the inductor current. The energy stored in the inductor is directly transferred to the capacitor in the snubber circuit. Due to turn off of the switch output voltage starts to decrease and switches will operate with normal PWM with fixed duty cycle

IV. Control Of The System

The control part of the system consists of three main aspects.

1) Fixed duty cycle switching scheme is used to control the input switches during the normal operating condition.

2) Hysteresis control is used during no load and start up of the system Since motor is a variable load, it will demand low power at low speed or at transients (start up and stop). In such conditions, hysteresis controller along with fixed duty cycle is used.

3) MPPT algorithm along with PI controller and V/F controller is used to set the speed of the motor and the energy balance of the system at MPP is achieved.

The overview of control system is shown in fig 3.

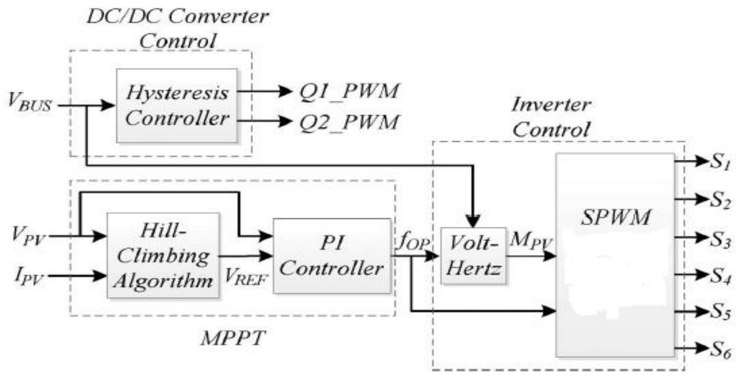


Fig 3. Control of the system

4.1 Fixed duty cycle control

Two inductor boost converter (TIBC) is a current fed multi resonant converter i.e., two resonant process occurs in one switching period. In order to occur resonance, definite time interval in the switching period are necessary. If the duty cycle or switching period are altered, the converter may no longer operate at ZCS condition. Therefore fixed duty cycle control is used.

4.2 Hysteresis Controller

Conventional TIBC doesn't consist of hysteresis controller and snubber circuit. The inability of TIBC to operate under no load or low load conditions are overcome by hysteresis controller and snubber circuit.

4.3 MPPT Controller

The task of MPPT in the system is to continuously tune the system so that it draws maximum power from solar module regardless of atmospheric condition or load condition. MPPT algorithm helps to keep the operating point of the system at MPP voltage. In this system, perturb and observe method is used because of its simple implementation and fast dynamic response. This MPPT method is based on the shape of the shape of the power vs voltage curve of the panel

4.4 V/F Controller

It is important to have a minimum DC voltage on the inverter DC bus necessary to drive the motor at a specified power. To satisfy this condition, the v/f controller is used.Consider that the centrifugal pump has its torque proportional to the square of the motor speed and that the frequency v(f) in the volt/hertz control is proportional to the voltage(V), the motor output power (P) can be expressed as a cubic function of the motor.

V. Simulation Results And Discussion

Figure 4 and 5 shows the simulation model and result of Two inductor boost converter. The system is verified with MATLAB/SIMULINK.. The converter boost the input voltage 26.6V to 350 V. The input signals are controlled using a fixed duty cycle and a Hysteresis controller with its upper limit and lower limits are 355 and 345 respectively.

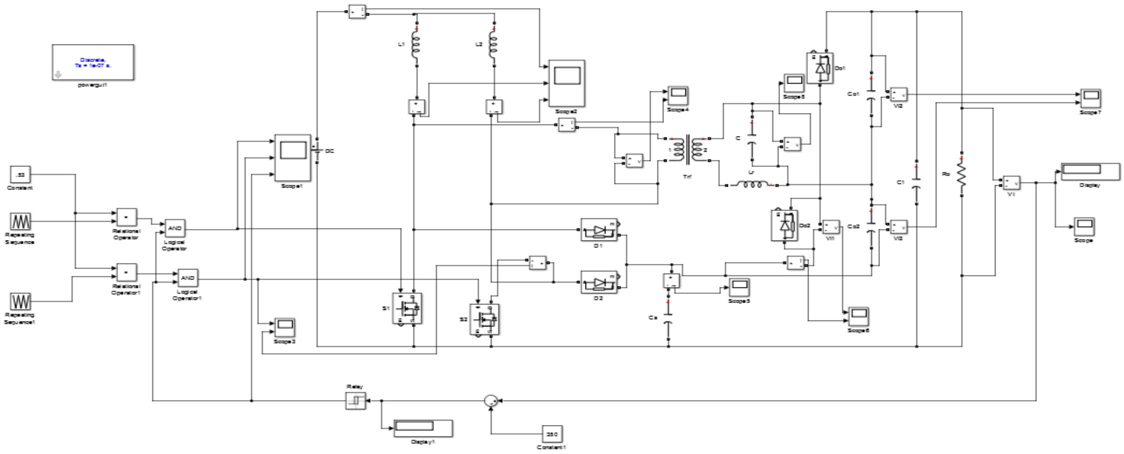


Fig 4. Simulation of TIBC converter

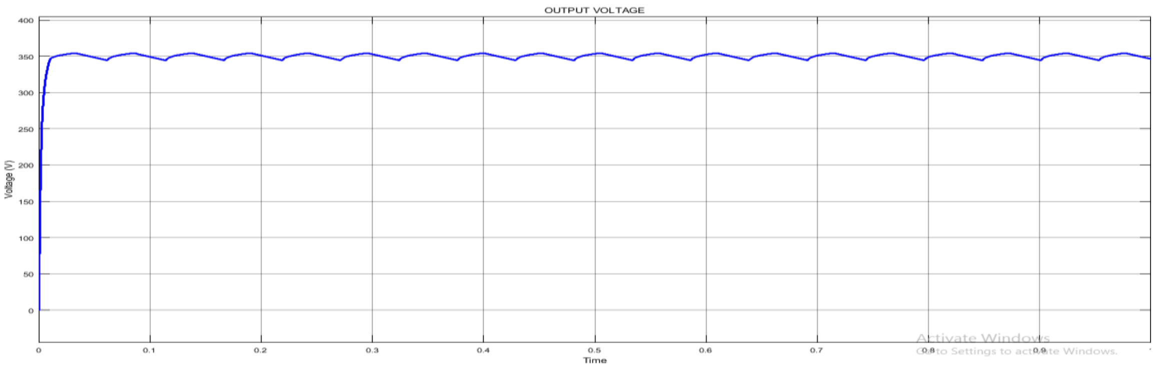


Fig 5. Output voltage of converter

Initially motor speed is very small (it can't run at maximum speed because of inertia) it takes some time to reach steady state. At t=12sec, a small increases in speed due to change in solar radiation. The speed changes from 1050 rpm to 1225 rpm as irradiation varies from 500 W/m^2 to 800 W/m^2. Up to 12 sec, its speed is 1050 rpm because the output of PI controller (after processing the MPP voltage PV voltage) is 40 Hz. After that speed changes to 1225 rpm corresponding to frequency 47 Hz. This is because, solar irradiation is made to change at 12 sec. MPP voltage is determined by using P and O algorithm.

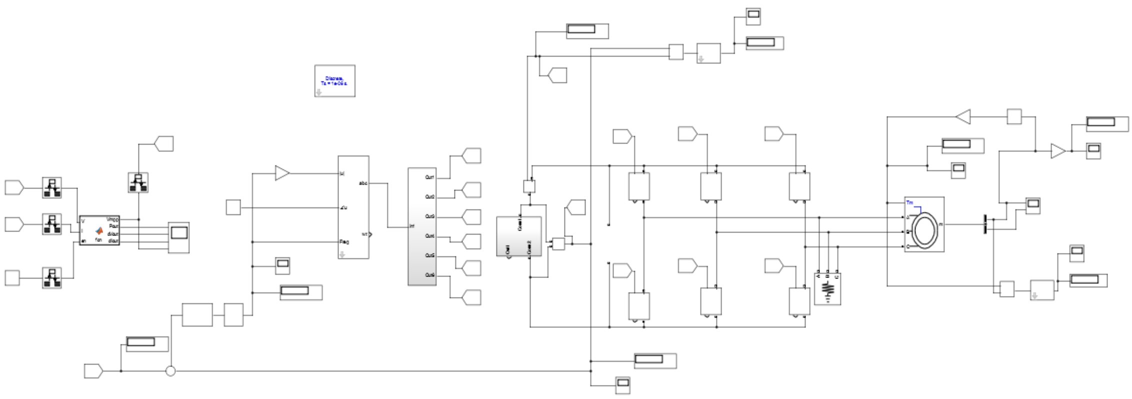
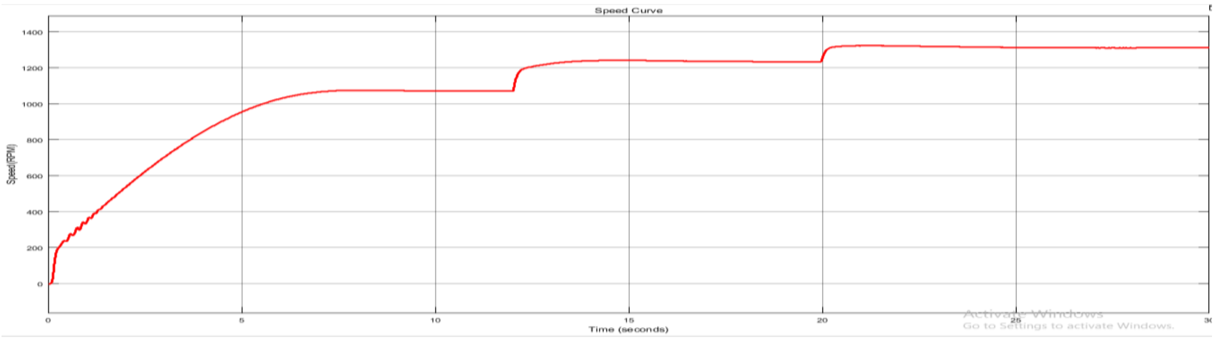
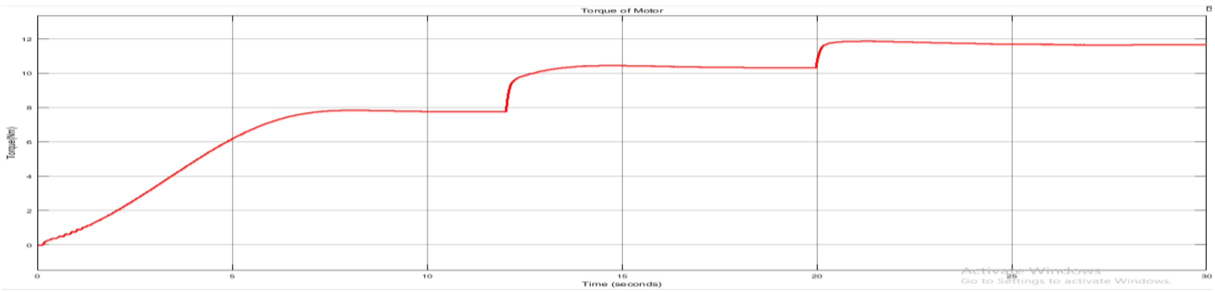


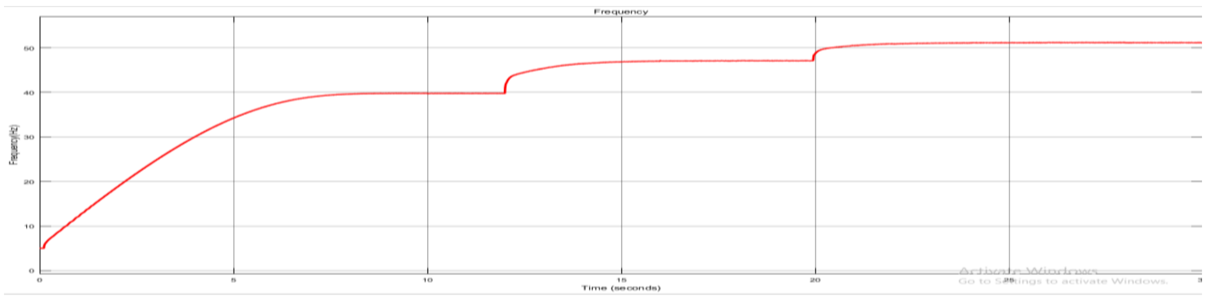
Fig 6. Simulation of overall system



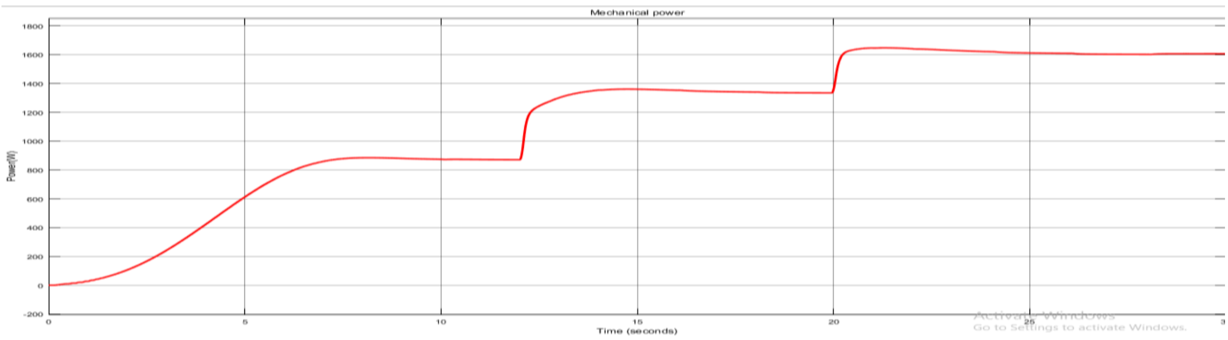
(a)



(b)



(c)



(d)

Fig .7 Simulation result of overall system (a) Speed of induction motor (b) Load Torque (c) Output of PI controller (d) Mechanical power

VI. Conclusion

An efficient converter-inverter drive system for water pumping using photovoltaic module is analyzed. The converter is designed to drive an three phase induction motor directly from PV array. The main characteristics of the proposed converter are low input current ripple and high step-up characteristics. The resonant tank is formed by parasitic parameters of the transformer and the added capacitor. With this converter, the input voltage 26.6 V is boosted to 350 V. The output of TIBC is given to the inverter and motor is controlled under V/F strategy. The modulation index for switching pattern is calculated by V/F controller. MPPT control is provided to operate PV module at maximum power.

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