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A High-Efficient Converter for Photovoltaic Water Pumping System Using Modified TIBC with Fuzzy Controller

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ABSTRACT

A new converter fed induction drive system for photovoltaic pumping system is proposed in this paper. The three-phase induction motor presents a better solution to the commercially available dc motor. The proposed system is mainly based on a current fed multi resonant converter which is also known as Two Inductor Boost Converter (TIBC) and a full-bridge three-phase Voltage Source Inverter (VSI). The classic topology of the TIBC has features like high voltage gain and low input current ripple. It is further improved with the use of a non-isolated snubber along with a PI controller. The proposed system is more efficient, low cost and high life span. The analysis of TIBC and FUZZY based system has been simulated using MATLAB Simulink. The developed system was utilized for photovoltaic water pumping system used for agriculture and water supply for isolatedareas.

Keywords—***Photovoltaic (PV) System, TIBC, Inverter, Induction motor***

INTRODUCTION

In India, Agriculture is one of the most important sectors; meanwhile agriculture is purely based on seasonal monsoons and a reliable irrigation system.

Irrigation cost or electrical energy cost or diesel energy cost to drive the water pumps constitutes up to 30% of the total input cost for a farmer. As per the estimation made by government there are about 25 million irrigation water pumps in India. Out of those about 8-10 million pumps are diesel operated, while the rest were electric operated pumps.

The major challenges which are faced by Indian farmers are frequent power outages and the increasing cost of diesel. Mostly the above mentioned factors affect the farm productivity and from this it is clear that there is a need for alternative options? One of the better alternative options for these problems is solar water pumps. The Indian Union government and several state governments have been promoting solar water pumps very actively through financial incentives and also by providing subsidy for optimal solar water pump whereas at present, tamilnadu state government is providing up to 80% subsidy.

The commercial photovoltaic water pumping system in India uses low voltage DC motor and synchronous motor in which efficiency of the dc motor is low and the cost of the synchronous motor are also too high. To overcome these problems in a commercial usage, the induction motor is introduced which has high robustness, lower cost, greater efficiency, availability in local markets, simple maintenance when compared to other types of motors.

During the low solar radiation, the rated operating power of motor and the pump system is allowed by means of battery. Thus the coupling of solar panel and motor which is used for water pumping makes easier. The batteries which are used in this system usually have low life span of about two or three years which is very low when compared to the photovoltaic module which has a life span of about more than 20 years. The installation cost and the maintenance cost of battery is also high. So the batteries are to be replaced often. If not, this will lead to sudden failure of such systems.

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The design of an induction motor drive system which is directly powered from a PV source which gives the solution for operating under variable power restrictions and also maximizes the energy produced and the amount of water pumped.

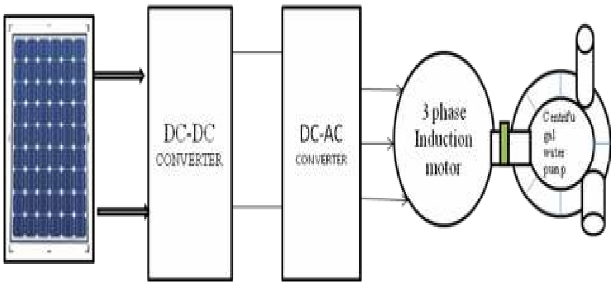

Fig. 1. Overall Block Diagram

This paper is organized as given below. In section 2, the proposed system is described.In section 3, dc-dc converter is presented and its operation is analyzed. In section 4, converter simulation results are presented.

PROPOSEDCONVERTER

To ensure higher efficiency at lower cost and easy accessibility of the proposed system, it was designed to have a single PV module. The proposed converter should be able to drive low-power water pumps. So the energy which is obtained from the Solar panel is fed to the three phase induction motor through two inductor booster convert where the voltage obtained from the panel is boosted and then this is fed to three phase inverter to convert the dc voltage to three phase ac voltage. The inverter design is based on classical topology which has three legs with two switches per leg and a sinusoidal pulse width modulation is used to control switching pulse. The overall block diagram for the proposed system is shown in Fig.1.

As the characteristics of the PV panels have low- voltage and small input current ripple, the proposed system should have a large voltage conversion ratio and the available energy should be utilized fully hence the converter has higher efficiency and life span. The most commonly used voltage fed converters have high input current ripple which require filter capacitors. Instead the current fed converter is used that has few benefits: input inductor remove the ripples present in input side -high step up voltage ratio –transformer turns ratio reduced. Still they contain few problems with high voltage spikes created due to large inductors of the transformer and voltage stress on the converterswitch.

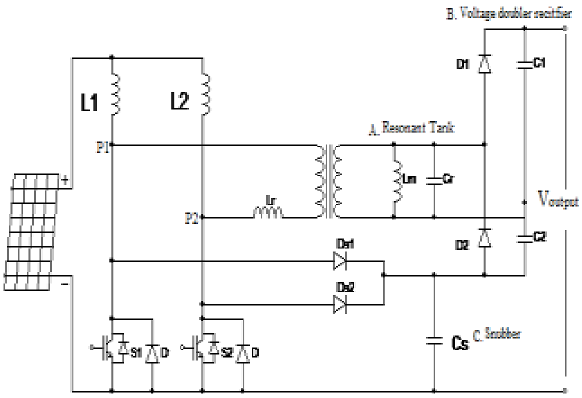

Fig 2. Circuit diagram

Usually the converter has an inductor at its input side, so that it eliminates the usage of input capacitor at the panel voltage. The proposed boost converter is fed through a current source inverter which has high step-up voltage and help to minimize the required transformer turns ratio. The classical topologies of this system are the current fed push pull converter, full bridge and the dual half bridge converter.

Usage of resonant topologies is one of the best solutions for the current fed PWM converters in which it will utilize the leakage inductance and winding capacitance of transformers to achieve zero current switching or zero voltage switching conditions to the active switches and rectifyingdiodes.

A modified TIBC proposed in this paper has some features like less number of components, simplicity, more efficient, easy transformer flux balance and common ground gate driving for both switches.

Two inductor boost converter is also called as multi-resonant converter. The transformer turns ratio with voltage doubler rectifiers at the secondary side of the transformer reduces the cost. The regenerative snubber

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with two diodes and a capacitor that connects the input side directly to the output side of the converter by allowing the energy to transfer directly from input to output without passing the transformer. This reduces its size and improves the efficiency of the converter.

OPERATIONPRINCIPLE

To explain the study of the suggested converter, the subsequent assumptions are required to be correct during a switching period: The input inductors L1 and L2 are adequately large so that their current is around constant; the capacitorsC1, C2 and Cs are huge sufficient tocontinue a uniform voltage; and the output capacitors C1 and C2 are greater than Cr to clamp the resonant voltage.

During hard-switched working of the TIBC, the two primary switches S1 and S2 works at overlapped duty cycle switching pattern to ensure a conduction path for the primary inductor current. When both S1 and S2 are switched on, L1 and L2 are energized by the input energy. When S1 is opened, the charge stored in L1 is passed to C1 through the transformer and the rectifier diode D1. When S2 is opened, the charge stored in L2 is passed to C2 through the transformer and the rectifier diode D2.

When the multi-resonant tank is established, two different resonant processes happen:

1) if both switches are closed, the leakage inductance Lrjoins with capacitance Cr in the resonance at the primary current switching and current polarity inversion, admitting zero current switching operation for the primary switches and

2) when the conduction time period (between t4 and t5), if at least one of the switch is open, Lris join up in series with L1 or L2, not involving the transformer's secondary current resonance, arranged only by Lm and Cr. V_{gS1} and V_{gS2} are the gate signals of the switches S1 and S2. The drain to source voltage of MOSFET S2 is denoted as V_{dsS2}. The current of MOSFET S2 is denoted as I_{Q2}. The voltage at the primary of the transformer is denoted as V_T. ant he current at the primary of the transformer is denoted as I_T. The current of the inductors L1 and L2 are denoted as I_{L1} and I_{L2} respectively. The input current of the converter and the current supplied by the PV panel were denoted byI_{in}.

During the time t1, the rectifying diode D1 is already conducting and the voltage on resonant capacitor C_r is clamped at $+V_{out}/2$. At this moment, the switch S1,is activated by V_{gS1} and it is turned on. Its voltage reduces to zero, and the snubber diode D_{s1} is made to end conducting. From t1 and t2 , the primary switch's resonant process and forcing the current I_{Q2} to minimize.

During t2, the rectifying diode D1 stops conducting, and C_r continues to resonant with the magnetizing inductance L_m. From t2 to t3, the primary switch's resonance (S2) proceed to force its current to decrease until it reverses its polarity. If I_{S2} is negative, the switch can be turned off. This occurs at instant t3 if V_{gS2} is compelled to zero.

During the time t3 the voltage V_{dsS2} begins to increase, S2 is fully blocked and the snubber diode D_{s1} starts to conduct, transferring energy directly to the snubber capacitor C_s. Between t3 and t4, C_r and L_m continue to resonate, minimizing the voltage on thedoubler rectifier's input and on V_{cr}. At instant t4 the voltage across C_r reaches $-V_{out}/2$, and the rectifying diode D2 begins to conduct, clamping V_{Cr} in$-V_{out}/2$.

From t4 to t5, the capacitor C_{o1} is charged, and the current of D2 begins to minimize. At the moment t5, S2 is turned on, initiating the resonant process on S1. As S2 is started, D_{s2} is made to end conduction. At the moment t6, the current in D2 attains zero, and D2 stops conducting, reinitiating the resonance between C_r and L_m. From this instant, the end of the switching period, the process repeats symmetrically as explained for the other input switch.

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A developed explanation of multi-resonant TIBC without the snubber is given and analyzed, resulting in a detailed mathematical modeling for both resonant processes during its working. However, the evaluation is based on several complex mathematical models, and effect, the given design method shows many dependent variables, which translates in a design methodology difficult to be executed.

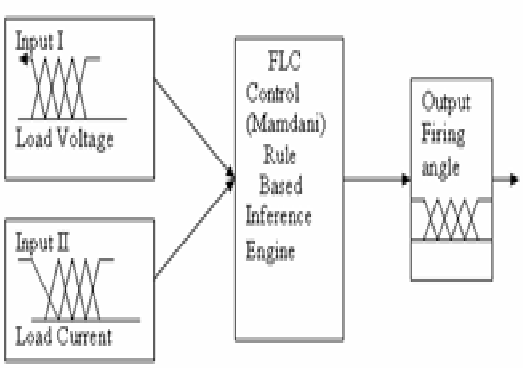
In spike of the resonant function disturb the output voltage, trusting the resonant tank equipment values and the load, this can be ignored because of its low change and multiple impact. Thus, ignoring the resonant consequence over the output voltage, addition to the voltage doubler rectifier and the snubber joining the primary and the secondary side of the converter, the static voltage gain (K_V) of the converter is defined as

$$\frac{Vout}{Vin} = Kv = \frac{1}{1-D}\left\{2\frac{Ns}{Np} + 1\right\}$$

Where Ns/Np represents the transformer turns ratio and D represents the duty cycle of each switch

FUZZY LOGICCONTROLLER

Fuzzy logic is a new control approach with great potential for real time applications [2] [3]. Fig.10 shows the structure of the fuzzy logic controller (FIS-Fuzzy Inference System) in MATLAB Fuzzy logic toolbox. [5][6]. Load voltage and load current are taken as input to fuzzy system. For a closed loop control, error input can be selected as current, voltage or impedance, according to control type [7]. To get the linearity, triangular membership function is taken with 50% overlap.



	Load voltage					
Load current		NL	NM	P	PM	PB
	NL	PB	PB	NM	NM	NL
	NM	PB	PB	NM	P	NL
	P	P	PM	NM	NM	P
	PM	NM	P	NM	NM	PM
	PB	NL	NM	NM	NL	NL

SIMULATIONRESULT

The proposed TIBC converter was simulated on Mat lab package version 7.10 Fig. 3 shows the schematic used for fundamental TIBC simulation circuit. The PI control was used as controller. which can be providing closed loop control in TIBC with induction machine, Fig 3 show the RL load output voltage, inthat simulationmodel 30v give as the input

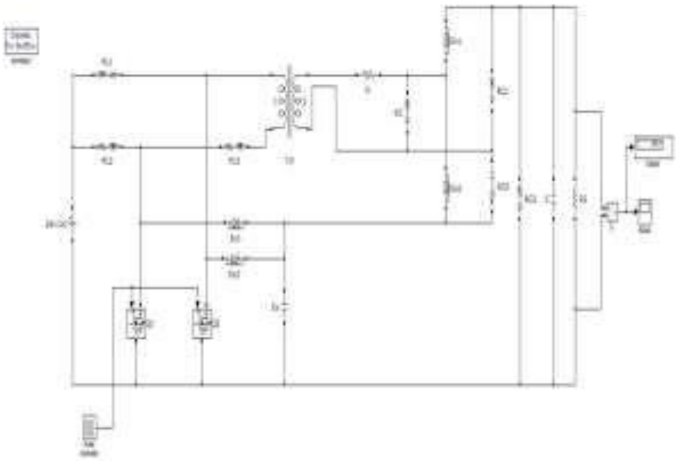


Fig. 3 .MATLAB Model of TIBC

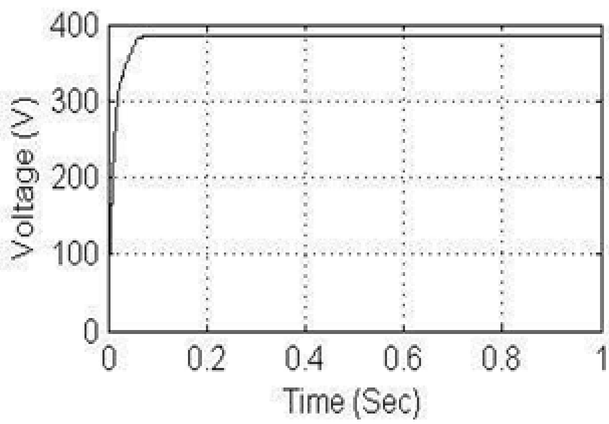


Fig 3.1 TIBC Output Voltage With Fuzzy R load

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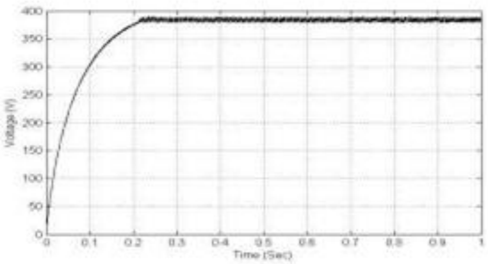

fig 4 ,TIBC Output With Delta Connected Rl Load

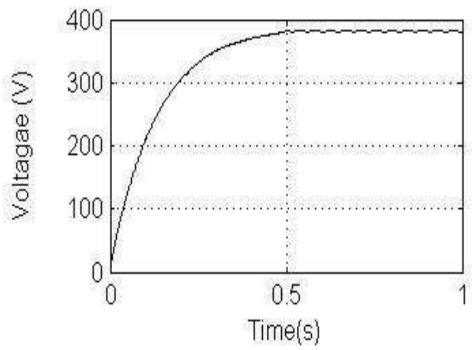

Fig 4 TIBC Output Voltage With out fuzzy

As the result TIBC output voltage 385 5 v. the proposed converter also connected with voltage source inverter , closed loop simulation result show the performs of the induction motor ,Fig 4 show the delta connoted RLload Fig 4 show the TIBC output voltage with motor load. the induction motor stator current in each phase, speed and torque was noted.

The output date show the induction motor performs with proposed converter, Fig. 5 show the induction motor stator current, torque and speed. The stable operation TIBC with PI controller model with Matlab.

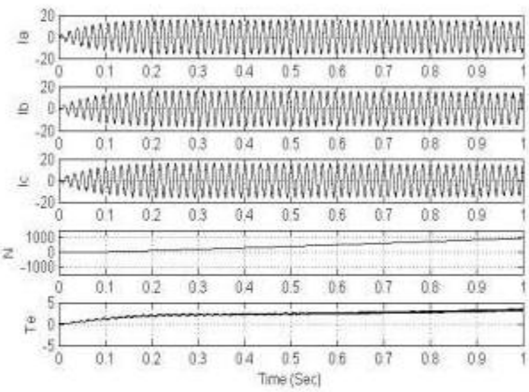

Fig 5 induction motor parameter

In that test result the converter output voltage boost upto 390V, an autonomous photovoltaic water pumping system efficiency and converter efficiency locate near 90% in proposed system modeling.

CONCLUSION

In this paper, a converter for PV water pumping systems without the use of storage elements like battery was designed. The TIBC was designed to drive a three- phase induction motor directly from solar energy, the proposed system advantages low cost, high efficiency and robustness. This paper presented the system block diagram, control system, and converter modeling.

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