INCREMENTAL CONDUCTANCE METHOD BASED MPPT APPLIED TO NOVEL DC – DC CONVERTER FOR HIGH POWER APPLICATIONS

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Abstract*— This paper proposes a new novel converter for photovoltaic (PV) water pumping without the use of batteries. The converter is designed to drive a three-phase induction motor directly from PV energy. This is designed to achieve a more efficient, reliable, maintenance free, and cheaper solution than the standard dc motors or low-voltage synchronous motors. The developed system is based on a current-fed multiresonant converter also known as resonant two-inductor boost converter (TIBC) and a full bridge three-phase voltage source inverter (VSI). The converter performance is improved with the use of a nonisolated recovery snubber along with a hysteresis controller and a constant duty cycle control to improve its efficiency. These systems have high lifetime, high efficiency and low cost. Finally, the proposed new topology is simulated by MATLAB/Simulink software to validate the accuracy of the theoretical explanation.

Keywords*—AC motor drives, inverter operation (DC-AC), DC–DC power conversion, Voltage source inverter (VSI), solar power generation.

I. INTRODUCTION

Currently over 900 million people in various countries do not have drinkable water available for consumption. Of this total, a large amount is isolated, located on rural areas where the only water supply comes from the rain or distant rivers. The unavailability of electric power rules out the pumping and water treatment through conventional systems. One of the most efficient ways to solve this problem is by using photovoltaic (PV) solar energy.

Grid tied PV inverters which consists a line frequency transformer are large in size; make the entire system extensive and difficult to install. Generally, the batteries used in this type of system have a low life span, only two years on average. But while coming to solar PV module has a life span of 20 years. Also, the cost of installation and maintenance is high. Therefore the lack of battery replacement is responsible for the failure of such systems in isolated areas. The majority of commercial systems use low-voltage dc motors, thus avoiding a boost stage between the PV module and the motor. Unfortunately, dc motors have lower efficiency and higher maintenance cost compared to induction motors. Another problem is that low-voltage dc motors are not ordinary items in the local. Because of its problems, this work adopted the use of a three phase induction motor. These converters require following features: high efficiency due to the low energy available; low cost to enable its deployment where it is most needed; robustness minimum amount of maintenance possible.

I. PROPOSED CONVERTER

The system should be able to drive low-power water pumps, in the range of 1/3 hp, more than enough to supply water for a family. Fig. 1 presents an overview of the proposed system. The energy produced by the panel is fed to the motor through a converter with two power stages: a dc/dc two-inductor boost converter (TIBC) stage to boost the voltage of the panels and a dc/ac three-phase inverter to convert the dc voltage to three-phase ac voltage. The inverter is based on a classic topology (three legs, with two switches per leg) and uses a sinusoidal pulse width modulation (PWM) (SPWM) strategy with 1/6 optimal third harmonic voltage injection as proposed in [9]. So that it does not cause oscillation over the maximum power point (MPP) of the PV module [10] – [12], thus ensuring the maximum utilization of the available energy.

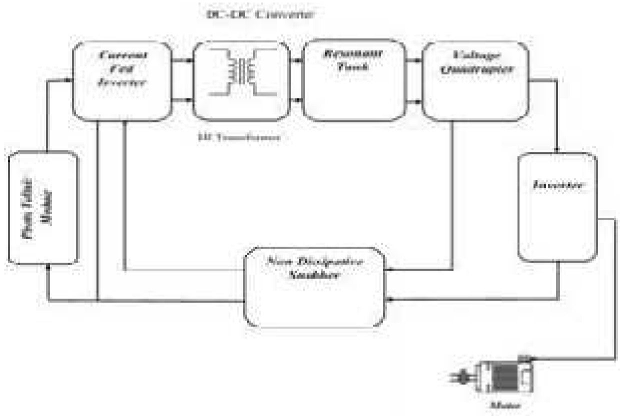

Fig.1. Simplified block diagram of the proposed system.

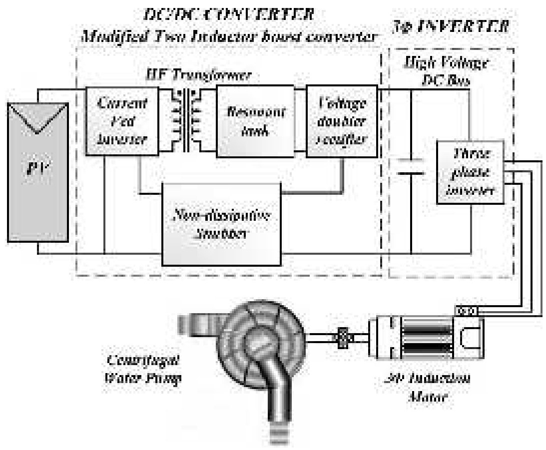

Fig.2 Neat Sketch of the proposed converter system.

The commonly used isolated voltage-fed converters normally have a high input current ripple, which forces the converter to have large input filter capacitors.

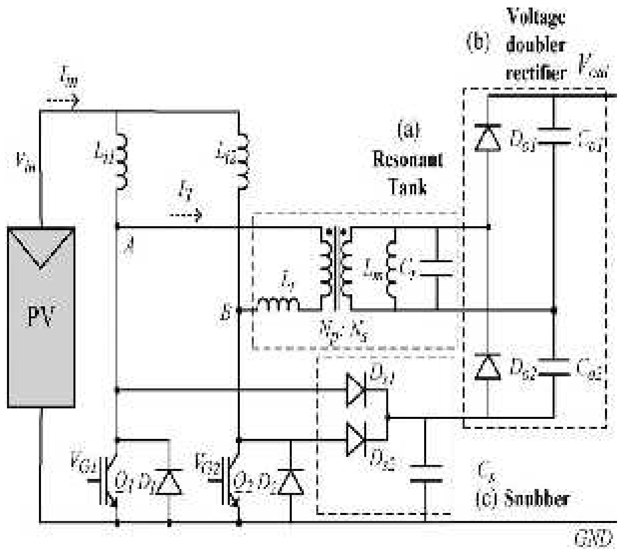

Fig.3. Modified TIBC topology: (a) resonant tank, (b) voltage doubler rectifier, and (c) snubber.

II. Operation Principle

When two primary switches *Q*1 and *Q*2 operate at an overlapped duty cycle switching scheme to guarantee a conduction path for the primary inductor current. When both *Q*1 and *Q*2 are turned on, *Li*1 and*Li*2 are charged. When *Q*1 (*Q*2) is opened, the energy stored in *Li*1(*Li*2) is transferred to *Co*1(*Co*2)through the transformer and the rectifier diode *Do*1(*Do*2).Once the multiresonant tank is introduced, two different resonant processes occur: 1)When both switches are closed, the leakage inductance *Lr* participates along with capacitance *Cr* in the resonance at the primary current switching and current polarity inversion, allowing ZCS operation for the primary switches, and 2) during the conduction time interval (between*t*4 and *t*5 in Fig. 3), when at least one of the switches is open ,*Lr* is associated in series with *Li*1 or *Li*2, not participating on the transformer's secondary current resonance, formed only by *Lm* and *Cr*. *IT* is the current at the primary of the transformer; *ILi*1 and *ILi*2 are the currents of inductors *Li*1 and*Li*2, respectively; and *I*in is the input current of the converter and also the current supplied by the PV panel. At time *t*1, the rectifying diode *Do*1 is already conducting, and the voltage on resonant capacitor *Cr* is clamped at +*V*out/2. At this instant, the switch *Q*1 is activated by *VgQ*1. From *t*1 to *t*2, *Cr* transfers its energy to the leakage inductance *Lr*, beginning the primary switch's resonant process and forcing the current *IQ*2 on the switch *Q*2 to decrease. At the time *t*2, the rectifying diode*Do*1 stops conducting, and *Cr* continues to resonate with the magnetizing inductance *Lm*. From *t*2 to *t*3, the primary switch's resonance (*Q*2) continues to force its current to decrease until it reverses its polarity. When $IQ2$ is negative; the switch can be turned off. Between $t3$ and $t4$, Cr and Lm continue to resonate, decreasing the voltage on the doubler rectifier's input and on VCr. At instant $t4$, the voltage across Cr reaches $-Vout/2$, and the rectifying diode $Do2$ starts to conduct, clamping VCrin $-Vout/2$.

III. CONTROL OF THE SYSTEM

There are three main aspects in the proposed converter control: 1) During normal operation, a fixed duty cycle is used to control the TIBC MOSFETs, thus generating an unregulated high bus voltage for the inverter; 2) an MPP tracking (MPPT)algorithm is used along with a PI controller to set the speed of the motor and achieve the energy balance of the system at the MPP of the PV module; and 3) a hysteresis controller is used during the no-load conditions and start-up of the system.

A. Fixed Duty Cycle Control

Important control aspects of this system are that it is possible to use an unregulated dc output voltage and a fixed duty cycle for the first-stage dc/dc converter. Therefore, the fixed duty cycle is used to overcome these design problems and to ensure converter is operate in ZCS condition despite the input voltage or output load. Therefore, the losses in the input inductors (Li1 and Li2), in the MOSFETs (Q1 and Q2), and in the transformer are smaller.

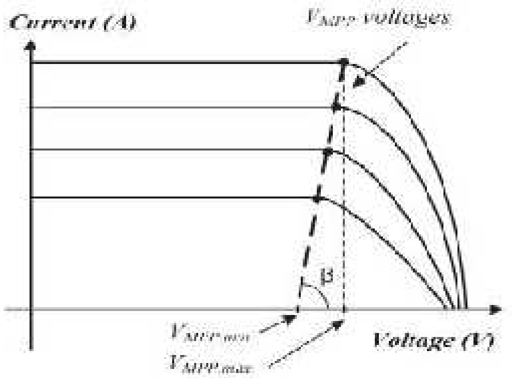

Fig.5 shows the *I–V* characteristic curves for a typical solar panel.

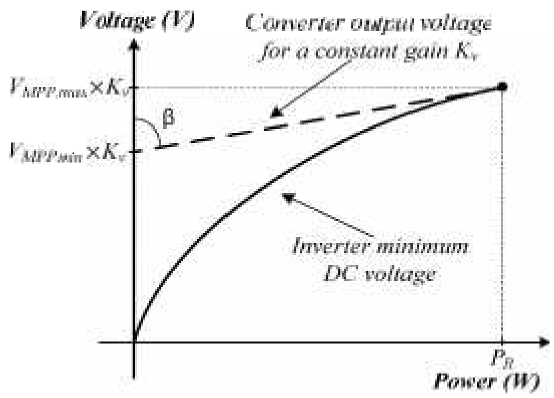

Fig.6. DC bus value and minimum voltage needed for pump operation inconstant volt/hertz.

B. MPPT Control

The MPPT is a strategy used to ensure that the operating point of the system is kept at the MPP of the PV panel. The widely used hill-climbing algorithm was applied due to its simple implementation and fast dynamic response. This MPPT technique is based on the shape of the power curve of the PV panel. By analyzing the power and voltage variation, one can deduce in which side of the curve the PV panel is currently operating and adjust the voltage reference to get closer to the desired point. The voltage reference is used on a PI controller to increase or reduce the motor speed and consequently adjust the bus and panel voltage by changing its operating point.

C. Hysteresis Control

The main drawback of the classical TIBC is its inability to operate with no load or even in low-load conditions. The TIBC input inductors are charged even if there is no output current, and the energy of the inductor is lately transferred to the output capacitor raising its voltage indefinitely until its breakdown.

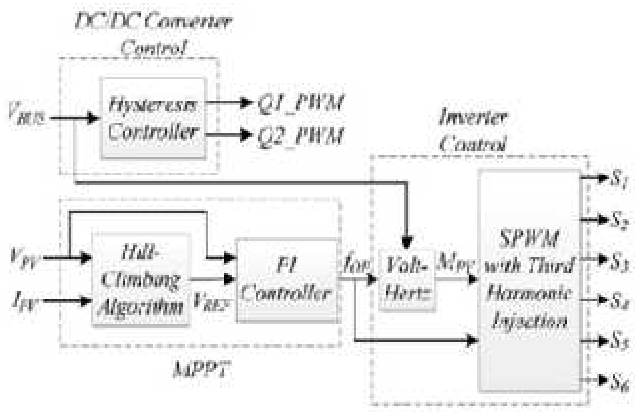

Fig 7 Block diagram of the control system

V. SIMULATION AND EXPERIMENTAL RESULTS

The overlapped pulses used to control Q1 andQ2, the current in both input inductors, and the current in the PV module. It is observed that each one of the inductors has accurate ripple at the converter switching frequency and out of phase with each other; however, both currents are supplied by the PV module, and when they are analyzed together (IPV), a reduction in the ripple amplitude to half of the original ones is seen.

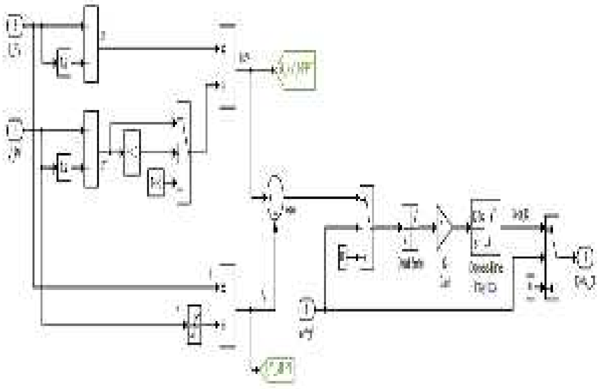

Fig 8: Schematic of Incremental Conducatnce based MPPT for PV Cell.

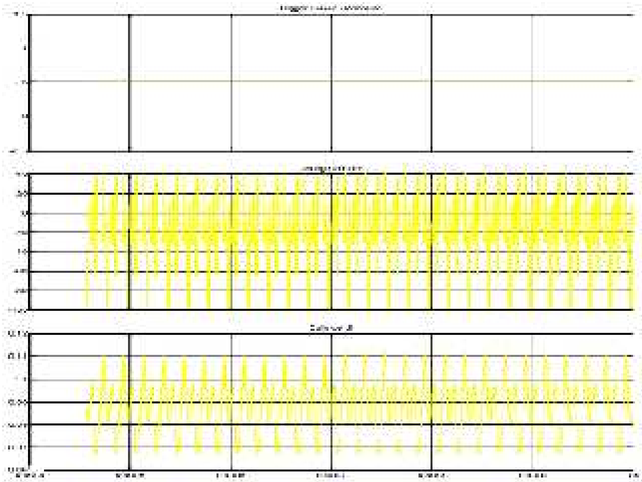

Fig 9: Characteristic values of Incremental Conductance based MPPT Characteristic of a PV Cell.

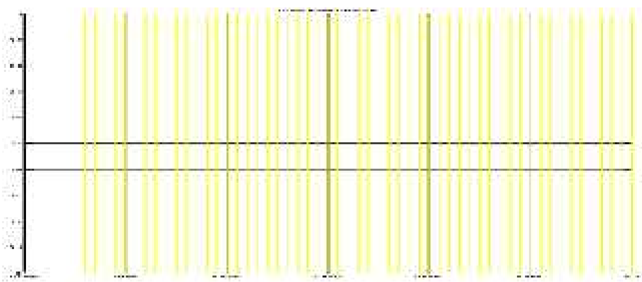

Fig 10: Trigger pulses applied to Q1

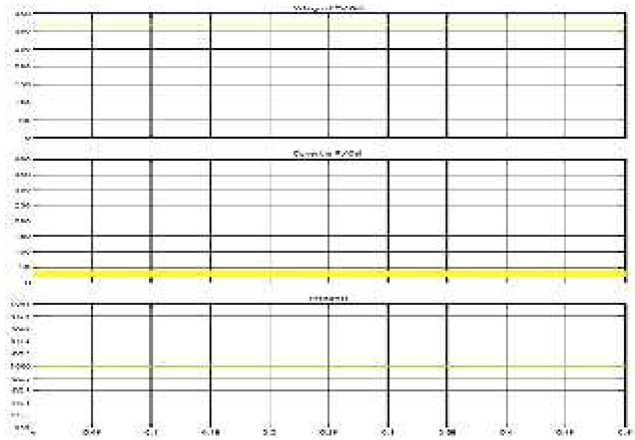

Fig 11: PV Cell Output Current and Voltages for irradience Value = 1000.

VI. CONCLUSION

In this we employ a converter for PV water pumping systems without the use capacitors presented. The converter was designed to drive a three-phase induction motor directly from PV solar energy having low cost, high efficiency. Finally, theoretical analysis and performance evaluation results indicate that the proposed topology can effectively reduce the leakage current to an acceptable level.

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