Implementation of a High Efficiency and Low Cost Converter with Analog MPPT Using Photovoltaic Water Pumping System for Agriculture

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ABSTRACT

A new converter for photovoltaic water pumping and treatment systems with and without the use of storage elements. The converter is designed to drive a three-phase induction motor directly from Photovoltaic (PV) solar energy. The use of this motor has the objective of presenting a better solution to the standard DC motor water pumping system for Agriculture. The control signals for the drivers are generated using Perturb & Observe Algorithm. The development is oriented to achieve a commercially viable solution and a market friendly product. The converter topology is based on a Resonant Two Inductor Boost converter and a Three-phase Voltage Source inverter achieving 99% efficiency at a rated power range of 750W-2500W. The total cost of the proposed converter and the system is expected to have high lifetime, due to the inexistence of electrolytic capacitors.

The real work can be tested according to the Geographical area and Implementation existence based on the Climatic Condition. Using Embedded Technologies we can monitor and control system automatically using WSN.

Keywords: Photovoltaic, WSN, MPPT, TIBC

1. INTRODUCTION

Currently, over 900 million people in various countries don’t have drinkable water available for consumption. Of this total, a large amount is isolated, located on country areas where the only water supply comes from the rain or distant rivers [1]. In such places, the lack of availability of electric power rules out the pumping and treating of water through conventional systems. One of the most efficient and promising way to solve this problem is the use of pumping and water treatment systems supplied by photovoltaic (PV) solar energy. Such systems aren’t new, and are already used for more than three decades [2-3]. But until recently the majority of the available commercial converters are based on an intermediate storage system performed with the use of batteries or DC motors to drive the water pump.

The batteries allow the system to always operate at its rated power even in temporary conditions of low solar radiation. This facilitates the coupling of the electric dynamics of the solar panel and the motor used for pumping [5]. Generally, batteries used in this type of system have a low life span, only two years on average, which is extremely low compared to useful life of 15 years of a photovoltaic module. Also, they make the cost of installation and maintenance of such systems substantially high.
Furthermore, the lack of batteries replacement is responsible for total failure of such systems in isolated areas. This type of system normally uses low-voltage DC motors, thus avoiding a boost stage between the PV module and the motor. Unfortunately, DC motors have low efficiency and high maintenance cost and is not suitable for the premises of the project. For such applications this paper proposes the use of a three phase induction motor, due to its high degree of robustness, low cost, higher efficiency and lower maintenance cost compared to other types of motors.

The design of a motor drive system powered directly from a photovoltaic source demands creative solutions to face the challenge of operating under variable power restrictions and still maximizes the energy produced by the module and the amount of pumped water. These requirements make necessary the use of a converter with the following features: high efficiency – due to the low energy available; low cost – to enable its deployment where it is most needed; autonomous operation – no specific training needed to operate the system robustness – the minimum amount of maintenance as possible; and high life span – comparable to the 15 years of usable life of a PV panel.

This paper proposes a converter for photovoltaic water pumping and treatment that fulfill most of the afore mentioned features. The paper is organized as follows: in section 2 is described the proposed system; in section 3 the converter itself is presented and analyzed; in section 4 the control strategy is explained; in section 5 the experimental results are presented.

2. PROPOSED CONVERTER

To ensure low cost and accessibility of the proposed system, it was designed to use a single PV panel. 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.

![Figure 1. Simplified Block Diagram of the System](image-url)
The energy produced by the panel is fed to the motor through a converter with two power stages: a DC/DC 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 set. The inverter is based on a classical topology (three legs, two switches/leg) and uses a sinusoidal PWM (SPWM) strategy with 1/6 optimal third harmonic voltage injection as proposed in [8]. The use of this PWM strategy is to improve the output voltage level as compared to sinusoidal PWM. In digital implementations, the algorithms are mainly programmed in microcontrollers (MCU), Field Programmable Gate Array (FPGA) or Digital Signal Processors (DSP). Advanced MPPT algorithms can improve the PV system efficiency and dynamic response of the system during transient conditions such as varying weather and/or load. One disadvantage of the digitally implemented MPPT controller is the higher cost and probably higher power consumption compared to its analog counterpart. Compared to digital MPPT controller, the analog counterpart has the advantages of lower cost and smaller size circuit.[5].

The required DC/DC converter for this kind of system needs to have large voltage conversion ratio, high efficiency and small input current ripple so it do not causes oscillation over the maximum power point (MPP) of the PV module. The commonly used isolated voltage-fed converters normally have a high input current ripple, which forces the converter to have large input filter capacitors. These are normally electrolytic, which are known to have a very small life-time and thus affect the overall life span and MTBF of the converter. Furthermore, the inherent step-down characteristic of the voltage-fed converters, the large transformer turn ratio needed, the high output diode voltage stress, and the need of an LC output filter [12] makes voltage-fed converters not the best choice for this application. When compared to the voltage-fed topologies, current-fed converters have some advantages. Usually they have an inductor at the input so the system can be sized to have input current as low as needed, thus eliminating the need of the large input capacitor at the panel voltage. Current-fed converters are normally derived from the boost converter, having an inherent high step-up voltage ratio. The classic topology of this kind of converter is the current-fed push-pull converter due to its simple structure.

In this paper is proposed the use of a modified two inductor boost converter (TIBC) for the first stage of photovoltaic water pumping systems due to its very small number of components, simplicity, high efficiency and easy transformer flux balance. These features make it the ideal choice for achieving the system’s necessary characteristics.

Besides the high DC voltage gain of the TIBC, it also compares favorably with other current-fed converters concerning switch voltage stress, conduction losses and transformer utilization. In addition, the input current is distributed through the two boost inductors having its current ripple amplitude halved and twice the PWM frequency. This last feature minimizes the oscillations at the module operation point and makes it easier to achieve the maximum power point (MPP).[2,3]

Classically the TIBC have a minimum operation load. This is because the inductors are charged even if there’s no output current. As a result this converter has a drawback when used in motor drive systems, since the motor is a variable load and will demand low power at some times. Technical literature addresses some solutions to this problem: auxiliary transformer is added in series to the input inductors, and a proposed an implementation of this auxiliary Transformer is shown in fig 2 and the two input inductor into one unique core. These solutions make the converter able to operate at almost no load. However, even with these previous solutions the TIBC still can’t regulate the output voltage for no load conditions.
In this paper the previously mentioned resonant solution was implemented in the two inductor boost converter along with a voltage doubler rectifier, an innovative recovery snubber for this converter, along with a fixed duty cycle and a hysteresis controller. With the use of a voltage doubler rectifier at secondary of the transformer it is possible to reduce the transformer turn ratio, the necessary ferrite core and the voltage stress on the MOSFETs to half of the original ones. As a result the transformer is cheaper; the MOSFETs are cheaper, and the number of diodes in the secondary side is halved. The regenerative snubber is formed of two diodes and a capacitor connecting the input side directly to the output side of the converter.

This makes it a non-isolated converter, what have no undesirable effect in the photovoltaic motor driver application. The voltage over the MOSFETs is applied to a capacitor connected to the circuit ground and the voltage of this capacitor is coupled in series with the output of the rectifier. This modification allows part of the energy to be transferred from the input directly to the output, through the snubber, without going through the transformer, reducing its size and improving even more the efficiency of the converter.

3. OPERATION OF SEPIC CONVERTER

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the switch. It consists of an active power switch, a diode, two inductors, and two capacitors and is thus a 4th order nonlinear system. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted the isolation between its input and output (provided by a capacitor in series), and true shutdown mode: when the switch is turned off, its output drops to 0 V. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output.

Nowadays, the use of a DC-DC converter is widespread in modern electronic equipment and system. When renewable energy source is used, the voltage can vary over a wide range. Hence to continue supplying a constant load voltage, the converter must be able to work in both buck and boost modes. The DC-DC converters that meet this operational requirement are Buck-boost, Cuk, and SEPIC converters. However, the Buck-boost and Cuk converters, in their basic form, produce the output voltage, whose polarity is reversed from the input voltage. [1,5]
The hardware was designed to achieve a final system with low cost, thus an accessible and market friendly product. The motor used in the centrifugal pump is a 0.2Hp three-phase induction motor. Considering the nominal power and Efficiency, low cost and robustness of the system depends directly on the choice of components. To obtain the expected higher level of efficiency each component was carefully elected. The TIBC and inverter’s MOSFETs were chosen to minimize the conduction losses. Extra low equivalent series resistance (ESR) MOSFETs was used. Normally the ESR is inversely proportional to the gate charge and output capacitance.

These features have large impacts on the switching losses, but this effect is reduced by the fact that the DC/DC converter is resonant and has almost no switching losses. All the diodes used in the voltage doubler rectifier and in the snubber of the TIBC were chosen as superfast diodes. This way, not only the conduction losses but also the ringing caused by the diodes reverse recovery time is reduced.

4. CONCLUSION

In this paper, a converter for photovoltaic water pumping and treatment system without the use of storage element was presented. The converter was designed to drive a three-phase induction motor directly from PV solar energy, and was conceived to be a commercially viable solution having low cost, high efficiency and high robustness. The paper presented the system block diagram, control algorithm, and design. The experimental results suggest that the proposed solution could be a viable solution to this problem after more reliability test are performed to guarantee its robustness.
5. FUTURE WORK

The real time work only for the photovoltaic approach. So we are in research for the work to function in heat emission.

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REFERENCES


