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# Implementation of TIBC for A Photovoltaic Water Pumping System to Drive a 3ϕ Induction Motor

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**ABSTRACT:** This paper proposes a new converter for photovoltaic water pumping and treatment systems without the use of storage elements. The converter is designed to drive a three-phase induction motor directly from PV solar energy. The use of this motor has the objective of presenting a better solution to the standard DC motor water pumping system. 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.

## I. INTRODUCTION

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 . 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 . [2-4]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.

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.[5]

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 fulfil most of the aforementioned features.[6]

## II. PROPOSED SYSTEM

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. The energy produced by the panel is fed to the motor trough a converter with two power stages: a DC/DC stage to boost the voltage of the panels and a DC/AC three-phase

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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.[7-9] The use of this PWM strategy is to improve the output voltage level as compared to sinusoidal PWM. We believe that further analyses on this topology aren't necessary.

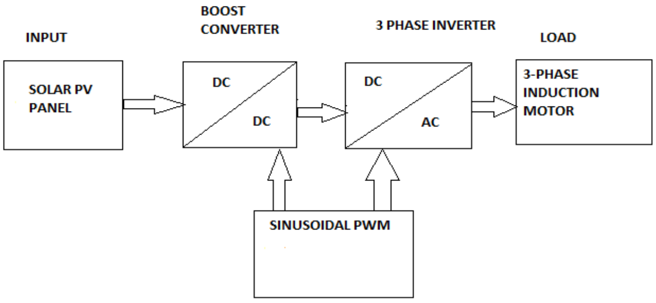


**Fig 1 Simplified block diagram of the system**.

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 makes voltage-fed converters not the best choice for this application.[10]

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.[11]

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 favourably 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).

In its classical implementation the TIBC is hard switched. However it can be modified to a quasi-resonant converter by adding a resonant tank at the transformer's secondary winding . This tank is mainly formed by the magnetizing inductance of the transformer and a capacitor, as show in Fig.1 By adding this capacitor it's possible to achieve ZCS condition for the input switches and output rectifying diodes, which enables the converter to operate at high frequencies with good efficiency.[12]

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: an auxiliary transformer is added in series to the input inductors, and is proposed an implementation of this auxiliary transformer and the two input inductor into one unique core.

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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. 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.

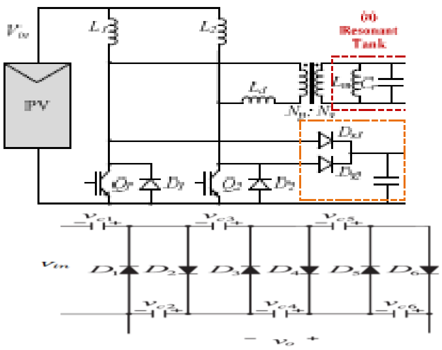

**Fig2 Modified TIBC topology**

In this paper the previously mentioned resonant solution was implemented in the two inductor boost converter along with a voltage doubler rectifier Fig. 2(b), 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.[13]

The regenerative snubber is formed of two diodes and a capacitor connecting the input side directly to the output side of the converter, as showed in 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.[14] 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.[15]For the converter with the previously mentioned modifications the static gain (k) can be calculated from (1), where D represents the duty cycle of each switch and must be higher than 50% to guarantee the necessary overlapping for the correct operation of the TIBC converter.

## III. CONTROL METHOD

Perturb and observe: In one method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases.[16]This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

### Comparison of methods

Both perturb and observe, and incremental conductance, are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the array, and so provide a true maximum power point.[17] The perturb and observe method can produce oscillations of power output around the maximum power point even under steady state illumination. The incremental conductance method has the advantage over the perturb and observe method that it can determine the maximum power point without oscillating around this value.[18] It can

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perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method. However, the incremental conductance method can produce oscillations and can perform erratically under rapidly changing atmospheric conditions. The computational time is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method.

In the constant voltage ratio (or "open voltage") method, the current from the photovoltaic array must be set to zero momentarily to measure the open circuit voltage and then afterwards set to a predetermined percentage of the measured voltage, usually around 76%. Energy may be wasted during the time the current is set to zero. The approximation of 76% as the MPP/$V_{OC}$ ratio is not necessarily accurate though. Although simple and low-cost to implement, the interruptions reduce array efficiency and do not ensure finding the actual maximum power point. However, efficiencies of some systems may reach above 95%.

## IV. SIMULATION RESULTS

Simulation has become a very powerful tool on the industry application as well as in academics, nowadays.[20] It is now essential for an electrical engineer to understand the concept of simulation and learn its use in various applications. Simulation is one of the best ways to study the system or circuit behaviour without damaging it .[19]The tools for doing the simulation in various fields are available in the market for engineering professionals. Without simulation it is quiet impossible to proceed further. [21-22]It should be noted that in power electronics, computer simulation and a proof of concept hardware prototype in the laboratory are complimentary to each other. However computer simulation must not be considered as a substitute for hardware prototype. The objective of this chapter is to describe simulation of impedance source inverter with R, R-L and RLE loads using MATLAB tool[23-28].

**(a)Discharging mode**

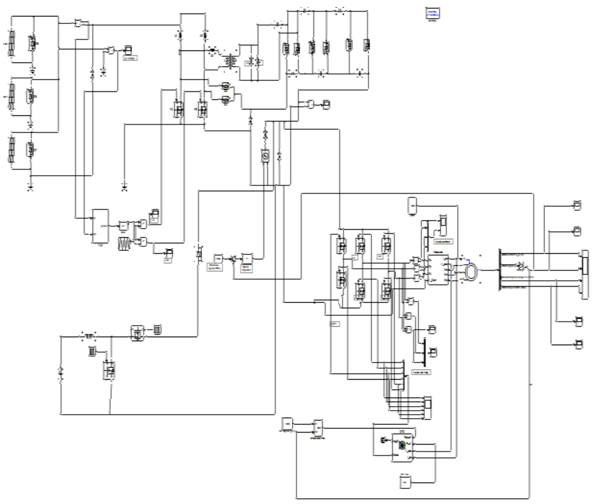

**Figure 3 Circuit diagram during discharging mode Input voltage from the source**

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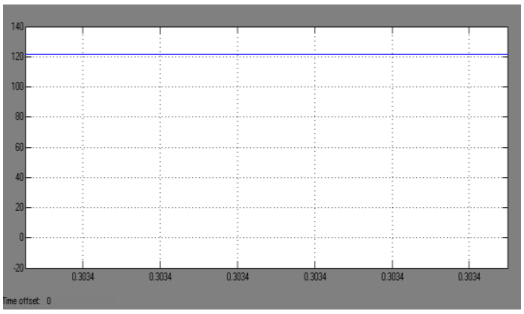

**Fig 4 Input voltage waveform**

**Input Pulse**

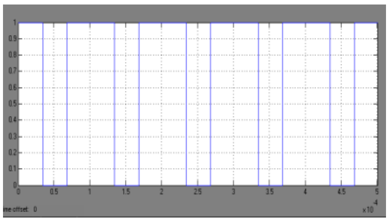

**Fig 5 Pulse wave form**

**DC CAPACITOR LINK VOLTAGE**

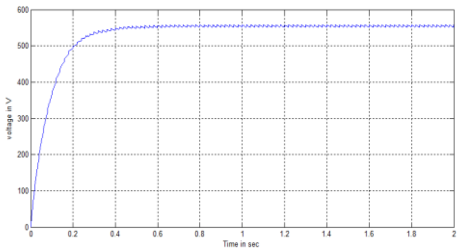


**Fig 6 Dc Capacitor Voltage**

**Motor performance During Discharging mode**
**Stator Voltage**

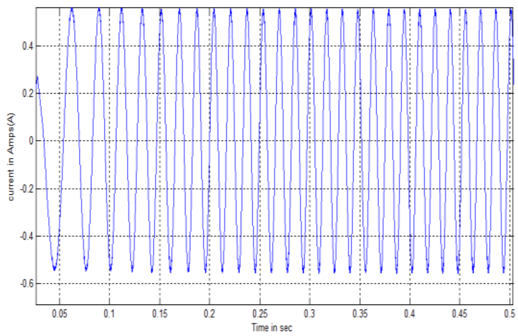


**Fig 7 Stator Voltage wave form**
**Rotor Speed**

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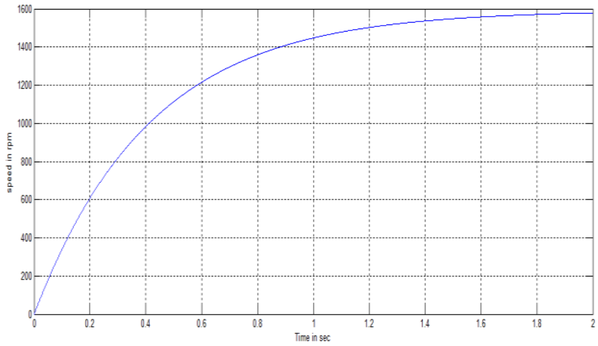


**Fig 8 Speed curve of 3Phase Induction Motor**

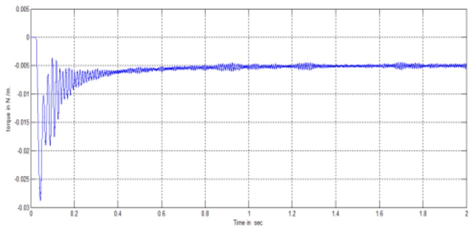

**Fig 9 Torque Curve Of The Induction Motor**

**(b) Charging Mode**

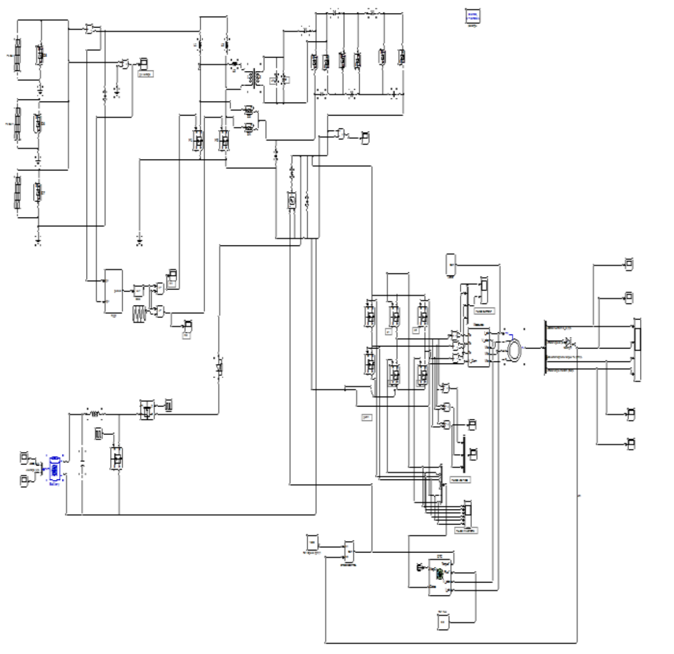

**Fig10 Circuit diagram during the charging mode**

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**DC CAPACITOR LINK VOLTAGE**

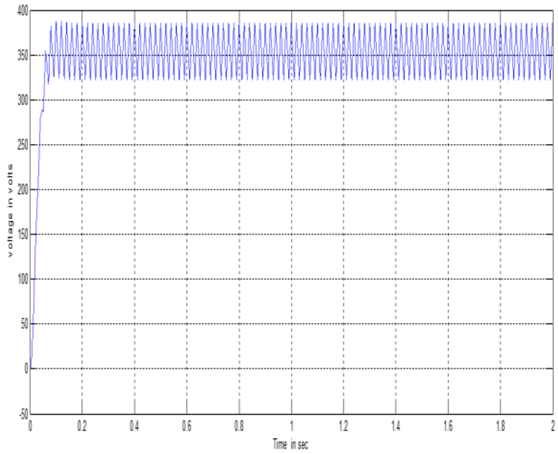


**Fig 11 DC Capacitor voltage during charging mode**

**SOC of the Battery**

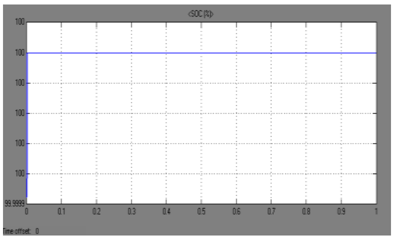


**fig 12 Storage capacity of the battery**

**Battery Voltage**

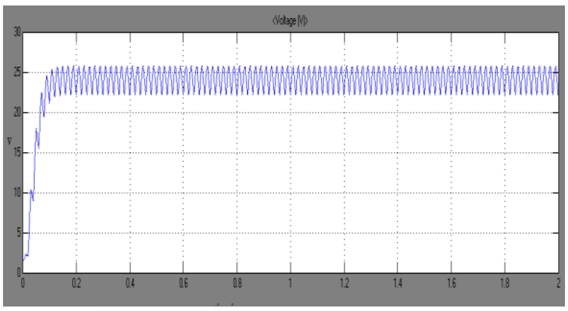


**Fig 10 Battery Voltage**

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**Motor Performance during the Charging Mode**

**Stator Voltage**

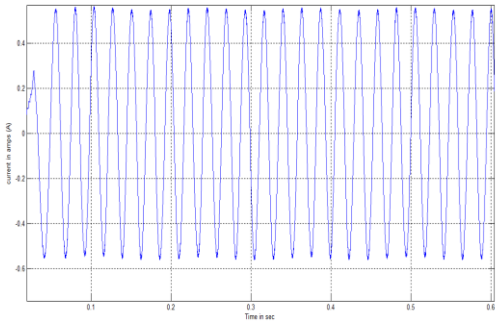

**Fig11 Stator Voltage during charging mode**

**Rotor Speed**

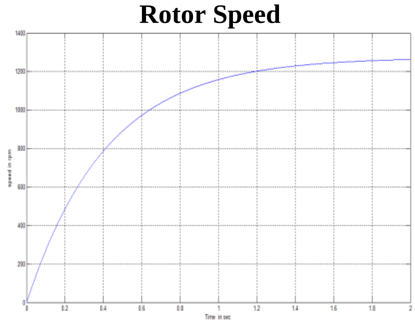

**Fig 12 Speed curve in Charging Mode**

**Torque Of The Motor**

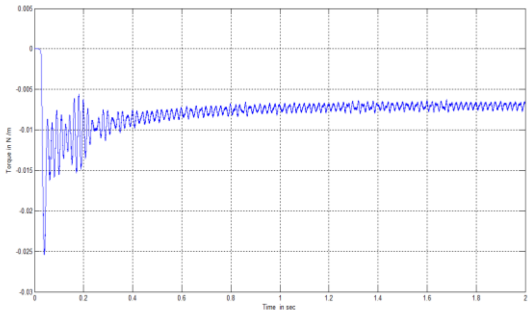

**Fig 13 Torque Curve during Charging Mode**

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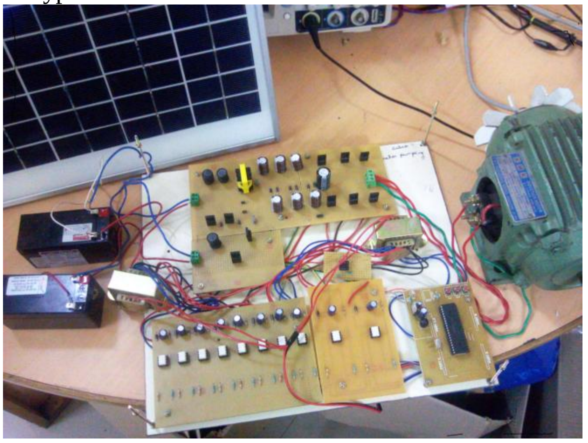
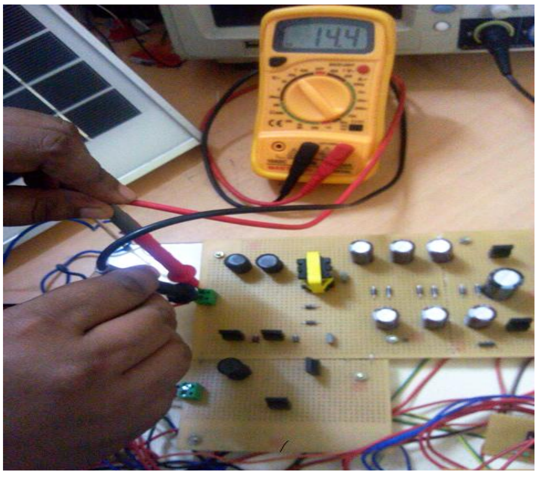
## V. HARDWARE RESULTS

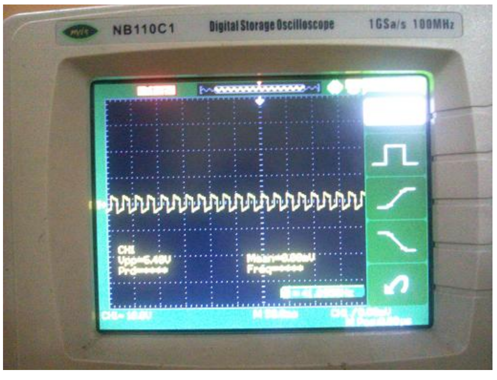
Fig.14 Test-bed hardware prototype



Input voltage that was obtained from the solar panel and stored in the battery obtained latter



**Pulse given to the circuit**

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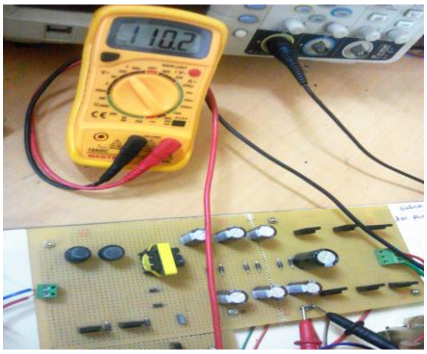
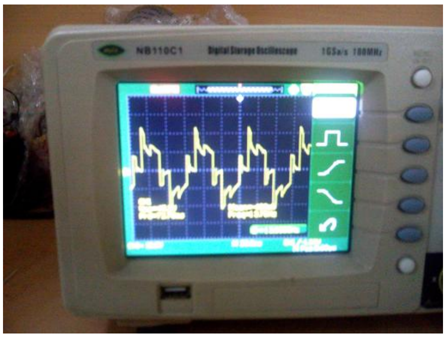
**DC Voltage after the voltage doubler**



**Stator voltage of the motor between two phases**



## V. CONCLUSION

In this project, a converter for photovoltaic water pumping and treatment systems with the use of storage elements was presented. The converter was design 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 tests are performed to guarantee its robustness.

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