A Solar Powered PV Based Induction Motor Drive in Water Pumping System Using Flc

P.Abarnaa[1], Mrs.S.P.G.Bhavani[2]

Abstract— This project introduces a current fed converter for a photovoltaic water pumping system. The converter is designed to drive a three-phase squirrel induction motor directly from photovoltaic (PV) energy source. The use of three-phase induction motor presents a better solution to the commercial DC motor water pumping system. A Two Inductor Boost Converter (TIBC) for the first stage is along with a voltage doubler rectifier is modified into an Energy Storage Management (ESM) system to overcome the problem when there is less availability of solar energy. This converter has high voltage gain, in addition the input current having its current ripple amplitude halved and minimizes the oscillations at the module operation point. A Fuzzy Logic Controller (FLC) is used as a speed control for Induction Motor. A three phase Induction motor connected to Voltage Source Inverter(VSI), which in turn runs the centrifugal pump. The whole system is controlled using Matlab Simulink environment. The dynamic performances of an Induction Motor(IM) drive is controlled in the presence of fuzzy logic controller, which increases the overall efficiency of the system. The effectiveness of fuzzy system and energy storage management in water pumping system are demonstrated and implemented.

Index Terms—Induction Motor, Photovoltaic Source, Two Inductor Boost Converter, Three Phase Six Switch Inverter, Fuzzy Logic Controller.

IJSER

1 INTRODUCTION

This is primarily about DC powered pumps, as used in typical solar electric systems. Information is also provided on using AC powered pumps on systems that have an inverter available. DC powered pumps are used for deep and shallow well pumping, stock tanks, irrigation, water pressure systems, and many other areas. This is usually recommended for installers, users, and well drillers - especially those that are new to solar electric pumping systems.
DC pumps are different in many ways from the AC pumps that many people are used to.

1.1. Capabilities & Limitations

DC pumps come in a variety of types. One of the most common is the small pressure booster pumps commonly used to supply water from the on board water tank or storage tank. Others include diaphragm and piston positive displacement pumps for wells, booster (pressurizing) pumps, circulating pumps, ground water sampling pumps etc.[1]

a. Advantages

These low power pumps allows to build a solar pumping system for a deep well at a modest cost. They are cheaper than windmills, and pump the most water during dry, sunny weather, when it is need most. They can be installed and pulled by hand. They work in wells of very low yield that conventional pumps may suck dry in minutes. Pumps are available that pump as low as 1/2 gallon per minute.

b. Pump Controllers & storage system

Many of these solar pumps require a special controller if they are to be powered directly by PV modules (without batteries). The controller, or linear current booster (maximum power point tracker) acts like an automatic transmission, allowing the pump to start and run in low light conditions, such as overcast or early morning & evening.

With a battery power source, the controller may not be required at all or a special controller may convert 12 Volt battery power to 30 Volts. Because of the low flow capacity of these pumps, water must be accumulated in a tank so that it can be released on demand. There are three ways to do this:
(1) pumping directly to a pressure tank,
(2) using storage tank with a booster pump and pressure tank,
(3) using an elevated storage tank with gravity flow.
Therefore an energy storage system along with high converters are implemented in this paper to ensure overall performance of the system.[2]

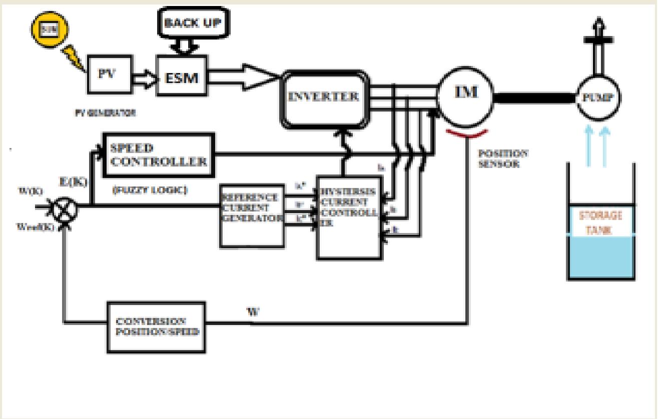

Fig1: Block Diagram Of Water Pumping System

2 INTRODUCTION TO SOLAR INVERTERS

Solar inverter is a critical component in a solar energy system. It converts DC power output into AC current that can be fed into the grid and directly influences the efficiency and reliability of a solar energy system. In most occasions, 220VAC and 110VAC are needed for power supply. Because direct output from solar energy is usually 12VDC, 24VDC, or 48VDC, it is necessary to use DC-AC inverter in order to be

---

1. P. Abarnaa, M.E Research scholar
Meenakshi College of Engineering,
2. S.P.G. Bhavani, Assistant professor
Meenakshi College Of Engineering,

able to supply power to 220VAC electronic devices. Inverters are generally rated by the amount of AC power they can supply continuously. [3]

In general, manufacturers provide 5 second and ½ an hour surge figures which give an indication of how much power is supplied by the inverter. Solar inverters require a high efficiency rating. Since use of solar cells remains relatively costly, it is paramount to adopt high efficiency inverter to optimize the performance of solar energy system.High reliability helps keep maintenance cost low. Since most solar power stations are built in rural areas without any monitoring manpower, it requires that inverters have competent circuit structure, strict selection of components and protective functions such as internal short circuit protection, overheating protection and overcharge protection. Wider tolerance to DC input current plays an important role, since the terminal voltage varies depending on the load and sunlight. Though energy storage batteries are significant in providing consistent power supply, variation in voltage increases as the battery's remaining capacity and internal resistance condition changes especially when the battery is ageing, widening its terminal voltage variation range. In mid-to-large capacity solar energy systems, inverters' power output should be in the form of sine waves which attain less distortion in energy transmission. Many solar energy power stations are equipped with gadgets that require higher quality of electricity grid which, when connected to the solar systems, requires sine waves to avoid electric harmonic pollution from the public power supply.[3]

How Inverters Work:

There are three major functions an inverter provides to ensure the operation of a solar system:

2.1. Inversion:

The inversion process converts DC power generated by the PV array to AC power. Except for the use in small off-grid systems, directly using DC power from PV array is not practical. Although many home appliances use DC power, large loads and the electrical network use AC power to allow long distance power distribution and minimize the energy loss.

2.2. Maximum Power Point Tracking:

Maximum power point tracking is a technique solar inverters use to allow modules to produce all the power they are capable of. Sunlight intensity varies significantly depending on the time and location, and therefore variation in cell temperature and solar irradiation, temperature and total resistance all affect the design of inverter as well as system.[7]

2.3. Grid Disconnection:

As required by the safety standard UL 1741 and system intersection standard IEEE 1547, all inverters used in systems tied to grid must disconnect from the grid if the AC line voltage or frequency reaches above or below stated limits in the standards. The inverter must also activate and execute a shutdown protocol on the system when the grid is no longer present. These protections eliminate a hazard caused by continuous injection of voltage into the disconnected wire or switch gear.

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. 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. 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. 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 are not suitable. For such applications 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. These requirements make necessary use of a converter with features high efficiency; low cost; autonomous operation; robustness; and high life span.[5]

3 IMPORTANCE OF HIGH VOLTAGE CONVERTERS

Global energy consumption tends to grow continuously. To satisfy the demand for electric power against a background of the depletion of conventional, fossil resources the renewable energy sources are becoming more popular. According to the researches despite its fluctuating nature and weather dependency the capacity of renewable resources can satisfy overall global demand for energy. The designing of high gain DC/DC converters is imposed by severe demands. Designers face contradictory constraints such as low cost and high reliability. First of all the inverters must be safe in terms of further maintenance as well as in relation to the environment. Since the renewable sources can be utilized for many years the converter designers cope with long time reliability issues. The main problem for the operator is to maximize the energy yield and to minimize the maintenance. For these reasons the converters must be distinguished by high efficiency over wide input power and voltage range. High voltage gain is required to produce sufficient DC bus voltage level. Additionally they should operate at wide temperature range expressing low EMC emission and be immune to environmental conditions. Such demands create severe constraints for DC/DC boost converter designing which are key parts in terms of efficiency of overall renewable energy systems. Although the European standard EN

IJSER

61000-3-2 discusses mainly the power quality issues, it influences designing of all power supply equipment. Since single phase converter can be connected to low-voltage AC public mains distribution system (grid) it should be complied with that standard.[4]

According to that standard the electric and electronic equipment can draw up to 16 A of current from the mains thus its maximum rated power is at the level of 3.7 kW (i.e. 230 V of AC line voltage times 16 A). That is why this investigation will be focused on the area of DC/DC boost converters with the maximum power of 3.7 kW. The majority of commonly used renewable energy sources deliver electric power at the output voltage range of 12 VDC to 70 VDC. To adjust it to the electric grid standards that voltage should be boosted to the system DC Bus voltage of around 200 VDC or 400 VDC depending on the grid requirements. Power conditioning can be accomplished by high efficiency high voltage gain step-up DC/DC converters.[19]. In this paper, two major topology types of step-up converters will be reviewed. However topologies presented in this paper can work with all low voltage renewable energy sources the review will cover the converters working with PV (photovoltaic) systems.

In the past one centralized inverter was responsible for connecting several modules or other renewable energy sources into the grid.[21]

4 PROPOSED SYSTEM

IJSER

In the proposed system, 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.[8] 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.2 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.

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: in an auxiliary transformer is added in series to the input inductors, and in is proposed an implementation of this auxiliary transformer and the two input inductor into one unique core. These solutions make the converter able to operate at almost no load. Here the resonant solution was implemented in the two inductor boost converter along with a voltage doubler rectifier, an innovative recovery snubber, 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.. 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, which have no undesirable effect in the photovoltaic motor driver application.[10]

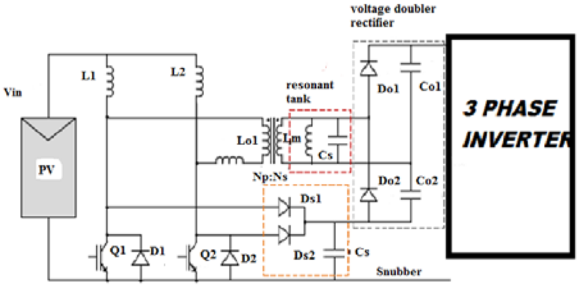

Fig2: Circuit Diagram Of Two Inductor Boost Converter

For the converter with the previously mentioned modifications the static gain (K) can be calculated 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[10]:

$$V_{out}/V_{in} = K = 1/(1-D)*\{2N_s/N_p+1\}$$

Where,
K- Static gain
D- Duty cycle
Ns-Secondary turns ratio of transformer
Np-Primary turns ratio of transformer

5 MODIFIED ENERGY STORAGE SYSTEM

Energy storage is accomplished by devices or physical media that store energy to perform useful operation at a later time. A device that stores energy is sometimes called an accumulator. All forms of energy are either potential energy (e.g. Chemical, gravitational, electrical energy, temperature differential, latent heat, etc.) or kinetic energy (for e.g. momentum). Some technologies provide only short-term energy storage, and others can be very long-term such as power to gas using hydrogen or methane and the storage of heat or cold between opposing seasons in deep aquifers or bedrock. A wind-up clock stores potential energy (in this case mechanical, in the spring tension), a battery stores readily convertible chemical energy to operate a mobile phone, and a hydroelectric dam stores energy in a reservoir as gravitational potential energy. Ice storage tanks store ice (thermal energy in the form of latent heat) at night to meet peak demand for cooling.

Similarly, here the energy storage system operates at normal and backup mode. At normal mode, the supply is from solar panel, but during backup mode the battery supplies to operate the whole water pumping system even during unavailability of sun rays. This is an additional advantage of the system.[21]

Energy storage as a natural process is as old as the universe itself – the energy present at the initial formation of the universe has been stored in stars such as the Sun, and is now being used by humans directly (e.g. through solar heating), or indirectly (e.g. by growing crops or conversion into electricity in solar cells). As purposeful activity, energy storage has existed since pre-history, though it was often not explicitly recognized.A more recent application is the control of waterways to drive water mills. Complex systems of reservoirs and dams were constructed to store and release water (and the potential energy it contained) when required.

Storing energy allows humans to balance the supply and demand of energy. Energy storage systems in commercial use today can be broadly categorized as mechanical, electrical, chemical, biological and thermal.[6]

6 SIMULATION RESULTS

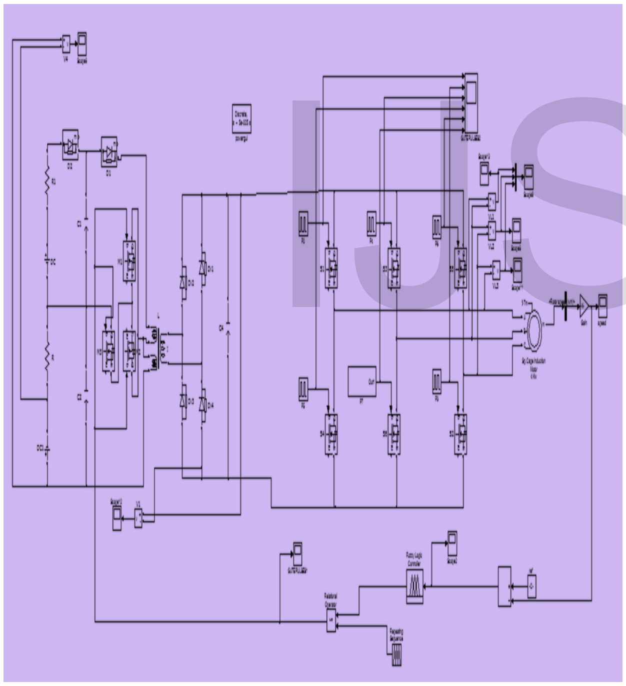

Fig 3: Modified Energy Storage System With Closed Loop Induction Motor As Load

6.1. Input voltage to the system from pv source (normal & backup mode)

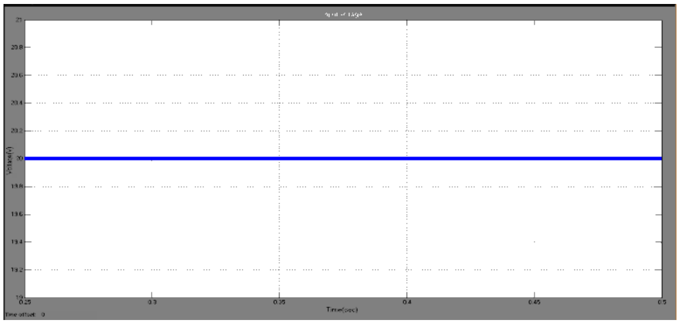

Fig 4: Input Voltage For System During Normal & Backup Mode (Vi=20V)

6.2. Modified energy storage system

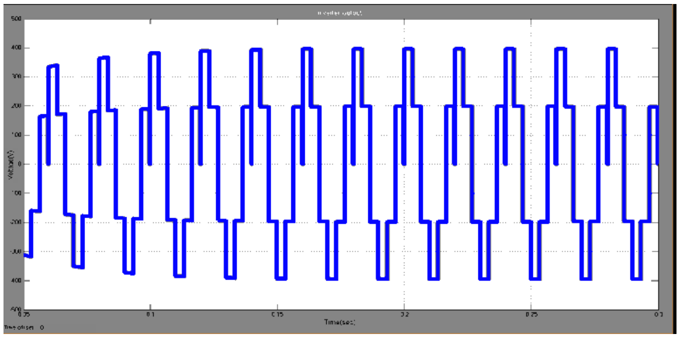

Fig 5: Inverter Output Voltage Of Modified Energy Storage System With Closed Loop Motor As Load

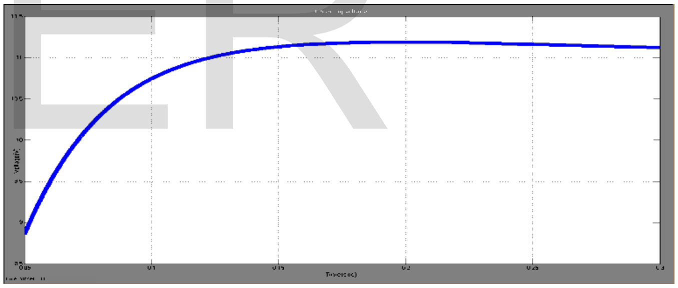

Fig 5: Charging Voltage at normal mode of energy storage system

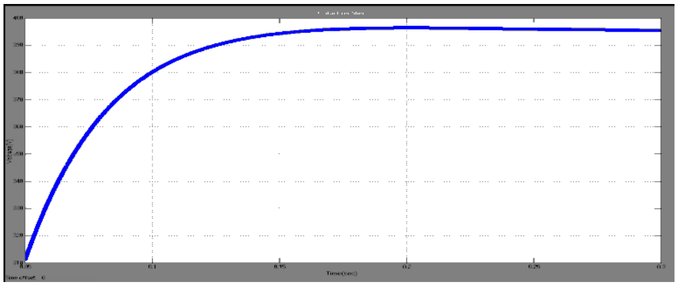

Fig6: Rectifier Output Voltage at normal mode of energy storage system

IJSER

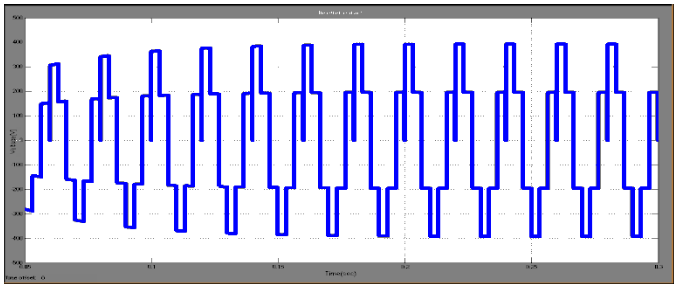

Fig7: Inverter Output Voltage at Backup Mode

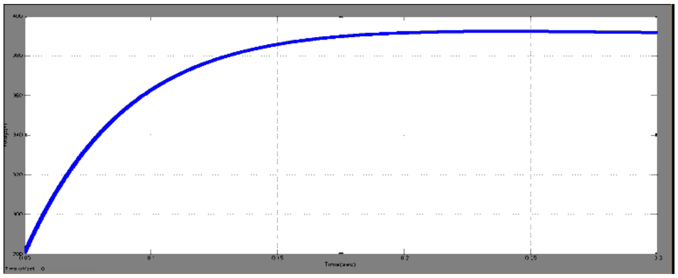

Fig8: Rectifier Output Voltage at Backup Mode

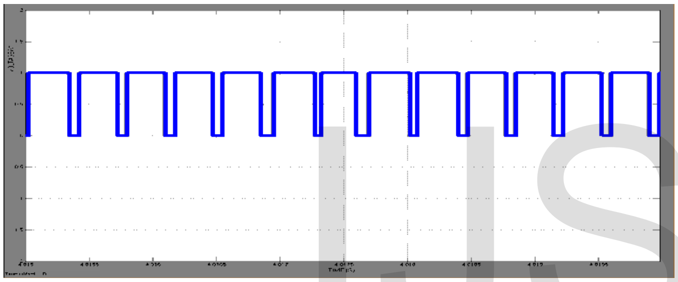

Fig 10: Triggering pulse for switch M1 M2 M3

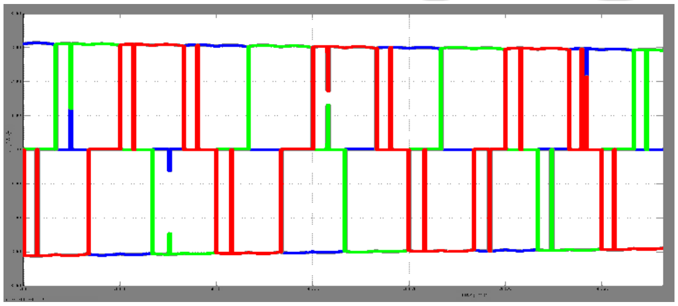

Fig9: Three phase inverter output voltage of closed loop induction motor load using fuzzy logic controller

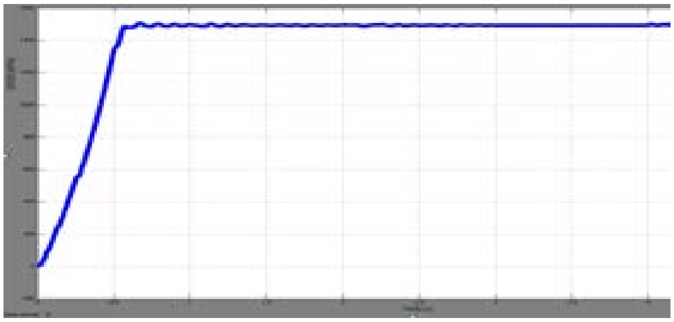

Fig10: Speed Curve of 1500rpm at 0.5sec time Using Fuzzy Controller in Closed Loop Motor Load(Vi=20V)

TABLE I
Rating Parameters of Each Component

RESISTOR, R	0.00005 Ω
CAPACITOR, C1	100e^-6
CAPACITOR, C2	1000e^-6
CAPACITOR, C4	900e^-6
DC INPUT VOLTAGE	20 V
SPEED	1500 rpm
TRANSFORMER	Three winding
WINDING 1	[400 0.40909 0.0052088]
WINDING 2	[20,0.016364,0.00020835]
WINDING 3	[20 0.016364 0.00020835]
INDUCTION MOTOR	5.4hp(4kw),400v,1450rpm
POWER,FREQUENCY	[100 25e^3]

IJSER

7 CONCLUSION

This paper introduces a modified Two Inductor Boost Converter along with an energy storage system that ensures continuous power supply even during unavailability of source from sun, during which the supply is from backup of energy storage system. The converter was designed to drive a three phase induction motor directly from PV solar energy, and was conceived to be a commercially best solution having low cost, high efficiency, and robustness. The experimental results suggest that the proposed solution could be a viable option after more reliability tests are performed to guarantee its robustness. The modified energy storage system with fuzzy logic controller provides reliable performance and it provides better and quick response than any other controllers. Also, the speed can be controlled through fuzzy system very efficiently.

REFERENCES

[1] a.terki*, a. Moussi, a.betka & n. Terkki, “the effectiveness of fuzzy logic control system for photovoltaic pumping system”electrical engineering department, university of biskra, algeria, october 2011.

[2] ms. Sunitha undrajavarapu, m. Srinivasa rao,mr. L.uday kiran, “pv fed boost spwm inverter driven single-phase induction motor”, international journal of engineering research and applications (ijera), vol. 2, issue4, july-august 2012.

[3] andrea tilli & alberto tonielli,“design of hysteresis current controller for 3ph inverter”, associatemember, ieee transaction on industrial electronics, vol. 45, no. 5, october 1998.

[4] sheng-yu tseng * and hung-yuan wang, “a photovoltaic power system using a high step-up converter for dc load applications”, department of electrical engineering, chang-gung university kwei-shan tao-yuan, taiwan, 21 february 2013.

[5] mohan kashyap & saurabh chanana, jai singh arya,“solar powered permanent magnet dc motor drive”, member ieee,conference on advances in communication and control systems 2013 (cac2s).

[6] dr. A. Moussi , a. Saadi, a. Betka, g.m. Asher,“photovoltaic pumping system technologies and trends”, larhyss journal, issn 1112-3680, june 2003.

[7] b.chitti babu, r. Sudharshan kaarthik, nayan kumar dalei, r.vigneshwaran, rabi narayan das,“pv energy conversion system for water pump applications– modeling & simulation”, department of electrical engineering, nit, 13th january 2013.

[8] victor caracas, guilherme de carvalho freitas, louis felipe, “implementation of a high efficiency, lifetime, and low cost converter for an autonomous pv water pumping system”students member ieee, louisantonio de souza, member ieee, 2013 ieee.

[9] v.chitra and r.s.prabhakar, “induction motor speed control using fuzzy logic controller”, world academy of science, engineering and technology 23, 2006.

[10] fuzzy logic toolbox-design and simulations in fuzzy logic systems usingfuzzy logic toolbox(.pdf), www.mathwork.com.

[11] jaime fonseca*, joa˜o l. Afonso, ju´lio s. Martins, “fuzzy logic speed control of an induction motor”, carlos couto,department of industrial electronics, minho university, largo do paco, 4709-braga codex, portugal, received 30 january 1998; received in revised form 31 august 1998; accepted 7 october 1998.

[12] b.chitti babu, r. Sudharshan kaarthik, nayan kumar dalei, r.vigneshwaran, indian institute of technology , kanpur,rabi narayan das,“photovoltaic energy conversion system for water pumping applications, modeling and simulation”, department of electrical engineering, nit, rourkela, india.

[13] osama s. Ebrahim, member, mohamed a. Badri, ali s. Elgendy, and praveen k. Jain, ieee, “optimal energy control of induction motor drive in pumping applications”, ieee transaction energy conversion, vol. 25, no. 3, sept2010.

IJSER