JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Review of Solar PV Array Fed Motor Drive-Based Water Pumping System

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Abstract : Solar energy such as photovoltaic is the most promising energy of the non-conventional energy sources which is capable to satisfy the energy needs of the isolated rural areas. Solar photovoltaic-powered water pumping systems are becoming very successful in regions where there is no opportunity for connecting the electric grid. This paper presents the discussion of various research works on photovoltaic based water pumping system, scope and limitations. Components and functioning of PV solar pumping system are also described.

***IndexTerms* - Water Pumping System, Photovoltaic, Solar, Sustainable Solution, Irrigation Technology.**

I. INTRODUCTION

The photovoltaic technology converts solar energy into electrical energy for operating direct current (DC) or alternating current (AC) motor-based water pump. Irrigation is a well established procedure on many farms and is practiced on various levels around the world. It allows diversification of crops, while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel. Photovoltaic water pumping system is one of the best alternative methods for irrigation. The variation of spatial and temporal distribution of available water for irrigation makes significant demand on water conservation techniques. Hence solar powered Automated Irrigation System provides a sustainable solution to enhance water use efficiency in the agricultural fields using renewable energy system removes workmanship that is needed for flooding irrigation.

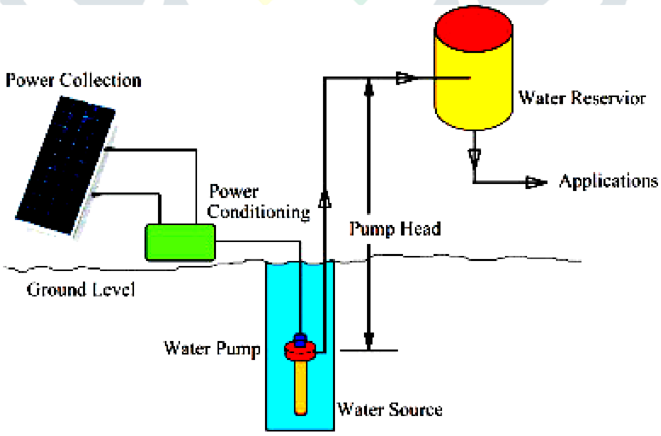

Figure 1: Solar power water pumping system

Environmental pollution is prevented with renewable energy and energy production from local resources is encouraged. The use of this photo-irrigation system will be able to contribute to the socio-economic development. It is the proposed solution for the present energy crisis for the Indian farmers. This system conserves electricity by reducing the usage of grid power and conserves water by reducing water losses. Proposed system is easy to implement and environment friendly solution for irrigating fields. The system was found to be successful when implemented for bore holes as they pump over the whole day. Solar pumps also offer clean solutions with no danger of borehole contamination. The system requires minimal maintenance and attention as they are self-starting. Solar energy is the most abundant source of energy in the world. Solar power is not only an answer to today's energy crisis but also an environmental friendly form of energy. Photovoltaic generation is an efficient approach for using the solar energy. Solar panels (an array of photovoltaic cells) are now a day extensively used for running street lights, for powering water.

The cost of solar panels has been constantly decreasing which encourages its usage in various sectors. One of the applications of this technology is used in irrigation systems for farming. Solar powered irrigation system can be a suitable alternative for farmers in the present state of energy crisis in India. Nowadays, as the increasing shortage of water resources, promote water saving irrigation technology and has become the inevitable choice to fill the water crisis. Today the generation is heading towards ultra-technologies. Water pumping has a long history; so many methods have been developed to pump water. People have used a variety of power sources, namely human energy, animal power, hydro power, wind, solar and fuels such a diesel for small generators.

The most common pumps used in remote communities are:

- Hand pumps
- Direct drive diesel driven borehole pumps
- Electric submersible pumps with diesel generator
- Solar submersible pumps

II. BACKGROUND

A. Varshney et al.,[1] provides rated water discharge throughout the day despite change in atmospheric conditions and feeds the surplus power to the three-phase utility grid. Moreover, during fault in any of the sources, the performance of the water pump remains unaffected. A high efficiency RSM drive without position/speed sensor is utilized here to drive the water pump. An intelligent power sharing concept, between the PV array and the grid, is used here, in which, automatic switching among all operating modes happens according to the availability of the PV array power and the grid supply. Moreover, the preference is given to the PV array power over the grid supply because of its availability at no cost.

I. Akhtar et al.,[2] The energy utilization of different electrical appliances in operation and their operating parameters like temperature, humidity, efficiency and energy consumption etc. are taken into consideration for the analysis. The objective of this work is to use a fuzzy logic controller for the energy consumption reduction analysis in Kasganj city of Uttar Pradesh state in India, by employing the utilization hours of the solar powered system and the required load demand using the time for which the different appliances are in operation. This analysis has been started with the survey of different buildings in order to get the information on present energy utilization. The energy audit presented in this work only concentrated in the 5 buildings in the Kasganj in order to take the real life conditions. Whereas, the fuzzy controller can set a threshold of power from grid and solar energy system that could not be exceeded as well as controlling the working hours of different appliances, otherwise it will affect the energy efficacy of the smart buildings.

A. A. Stonier et al.,[3] presents the design and implementation of Modular Multilevel Inverter (MMI) to control the Induction Motor (IM) drive using intelligent techniques towards marine water pumping applications. The proposed inverter is of eleven levels and has the ability to control the speed of an IM drive which is fed from solar photovoltaics. It is estimated that the energy consumed by pumping schemes in an onboard ship is nearly 50% of the total energy. Considering this fact, this work investigates and validates the proposed control design with reduced complexity intended for marine water pumping system employing an induction motor (IM) drive and MMI. The analysis of inverter is carried out with Proportional-Integral (PI) and Fuzzy Logic (FL) based controllers for improving the performance.

M. Kashif et al.,[4] In this work, a reverse saliency (RS) spoke-type permanent magnet (PM) synchronous motor (PMSM) besides its hybrid adaptive notch filter (HANF) based self-sensing for driving a solar photovoltaic water pump system (WPS) is presented. The conventional spoke-PMSM driven WPS experiences two types of problems. Firstly, the motor is operated with a flux-weakening current to produce positive reluctance torque, thereby increasing the PM demagnetization risk. Secondly, an encoder is used to sense the rotor angle, which in turn affects the cost and reliability. To solve the first problem, the RS-PMSM is presented, which operates with a flux-intensifying current to produce positive reluctance torque. While second issue is resolved by using the HANF based rotor angle estimation. Although conventional methods give an estimate of rotor angle, they do not eliminate both the DC-offset and dominant harmonics..

S. Angadi et al.,[5] research towards AC motor based Water Pumping Systems (WPS) has received a great emphasis owing to its numerous merits. Further, considering the tremendous acceptance of renewable sources, especially solar and wind, this work provides a detailed review of single-stage and multi-stage WPS consisting of renewable source powered AC motors. The critical review is performed based on the following figure of merits, including the type of motor, power electronics interface and associated control strategies. Also, to add to the reliability of solar PV WPS, hybrid Wind-PV WPS will be discussed in detail.

H. Rezk et al.,[6] provide detailed feasibility, a techno-economic evaluation, and energy management of stand-alone hybrid photovoltaic-diesel-battery (PV/DG/B) system. The proposed system can be applied to supply a specific load that is far away from the utility grid (UG) connection, and it is located in Minya city, Egypt, as a real case study. The daily required desalinated water is 250 m^3. The total brackish water demands are 350-500 m^3 and 250-300 m^3 of water in summer and winter seasons, respectively. Two different sizes of reverse osmosis (RO) units; RO-250 and RO-500, two energy control dispatch strategies; load following (LF) and cycle charging (CC); two sizes of DG; 5 kW and 10 kW are considered in the case study. The cost of energy, renewable fraction, environmental impact, and breakeven grid extension distance are the main criteria that have been considered to determine the optimal size of PV/DG/B to supply the load demand. HOMER ® software is used to perform the simulation and optimization. For this case study, the minimum cost of energy and the minimum total present cost are 0.074 /kWhand207676, respectively.

R. Rai et al.,[7] focuses on an efficient and robust speed sensorless control for a solar water pumping system consisting of solar photovoltaic (PV) array fed submersible induction motor drive (SIMD). The speed estimation and sensorless control of SIMD are quite demanding tasks. Additionally, the motor parameter variations lead to deteriorate sensorless control. Therefore, a sensorless control of submersible induction motor (SIM) requires accurate and robust stator current control. The sliding mode based dc link voltage regulator is adopted for regulating the motor power and the speed for single stage solar PV topology.

S. Shukla et al.,[8] deals with a photovoltaic-grid integrated system operating an induction motor (IM) coupled to a water pump. A simple dc-link voltage regulation approach is adopted for the power transfer. This system is utilized to primarily feed the induction motor-driven water pump and when water pumping is not desired, the power is delivered to the utility. This system requires two current sensors and two voltage sensors in total for sensing and estimation purpose. Induction motor phase currents are estimated from dc-link current by modified space vector modulation (SVM) technique.

S. Murshid et al.,[9] presents a single stage standalone solar photovoltaic (SPV) array fed water pumping system using a permanent magnet synchronous motor (PMSM). The vital contribution of this work includes: 1) development of the novel modified vector control, which improves the torque response of the system, 2) development of a novel single stage variable step size incremental conductance technique, which provides a fast maximum power point tracking and eliminates the need of intermediate stage dc–dc converter, and 3) introduction of SPV power feed-forward term, which accelerates the overall response of the system under dynamic conditions. This system includes a SPV array, a three-phase voltage source inverter (VSI), a PMSM and a pump.

K. Khan et al.,[10] a predictive current controller (PCC) is designed and implemented to control a voltage-source inverter of the proposed system comprising of the single-stage topology of solar photovoltaic (PV) array fed an improved designed fractional kilowatt induction motor drive (IMD) coupled to a water pump. The currents, in a synchronous reference frame, are fed as inputs to the PCC after transforming it to (α–β) stationary frame. The IMD is fed from PV array, which operates at a maximum power point (MPP) using a peak power tracking perturb and observe scheme. The PCC is implemented for this system to achieve better control of motor speed, fast dynamic response, inherent decoupling between current components, and improvement in torque dynamics. The optimized design of an induction motor is investigated using the combined approach of the design of experiment and quasi-Newton algorithm for efficiency maximization, minimization of starting current, and maximization of starting torque. Initially, an analysis of the induction motor is performed with the classical approach to design machine and this method is verified by an explanation on the contemporary design using RMxprt and design optimization technique.

A. Varshney et al.,[11]an adaptive d -axis current control of a reluctance synchronous motor (RSyM) drive for a photovoltaic (PV) water pumping system has been presented, which incorporates impacts of the cross saturation in realtime to compensate the errors in the speed estimation. The response of the RSyM drive is optimized by adaptive d -axis current estimation. A real-time assessment of the d -axis inductance is carried out to include the cross magnetization into consideration for improving the efficiency of the motor. The d -axis current is varied for minimum value to provide the maximum output torque. Here, a two-stage solar energy conversion system is used to drive the centrifugal pump coupled to an RSyM drive. A boost converter is used to optimize the PV power using an incremental conductance based maximum power point tracking technique. The boost converter supplies power to a dc–ac, an insulated gate bipolar transistor based inverter through a capacitor connected across the dc link.

S. Rahman et al.,[12] presents the design and implementation of solar-powered V/f controlled single-phase capacitor-start induction motor. Multilevel quasi impedance source inverter controls the power flowing from the photovoltaic (PV) array to a single-phase induction motor. In solar powered drive systems, the main concern is stable intended operation of drive when subjected to variations in power generation of the PV array. For same environmental conditions, the PV power extraction is different at different torques for constant speed application. Due to this, the extraction of maximum power with an MPPT algorithm is not achieved with only motor load. To address this concern, concept of the battery storage system is introduced in the system that helps in achieving maximum power when the PV power generation capability exceeds rated motor input power. In addition to this, battery storage system can supply power to the load when the PV power generation is less than the rated motor input power.

III. PHOTOVOLTAIC SYSTEM COMPONENTS

Photovoltaic cells are devices which 'collect the light and convert it into electricity. The cells are wired in series, sealed between sheets of glass or plastic, and supported inside a metal frame. These frames are called solar modules or panels. They are used to power a variety of applications ranging from calculators and wrist-watches to complete home systems and large power plants. PV cells are made of thin silicon wafers; a semi-conducting material similar to that used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the "photovoltaic effect".

Photovoltaic Applications Solar panels are used in a variety of applications. The applications vary from small simple lanterns to large elaborate power plants.

- Rural and urban households for domestic purposes like lighting.
- Communities, small industries and institutions like schools, for lighting as well as for powering television sets, computers, etc.
- Water pumping systems.
- Telecommunications, as these systems are often installed in isolated places with no other access to power.
- Health center vaccine refrigeration in rural areas. Such solar refrigerators are also utilized to store blood plasma. WHO supports programmers that install solar power for medical purposes.

System Components

The whole system of solar pumping includes the panels, support structure with tracking mechanism, electronic parts for regulation, cables, pipes and the pump itself.

(i) Solar Panels or Modules

Solar panels are the main components used for driving the solar pump. Several solar panels connected together in arrays produce DC electricity, interconnections are made using series or parallel combinations to achieve desired voltage and power for the pump.

(ii)Solar Pump

Centrifugal or submersible pumps are connected directly to the solar array using DC power produced by the solar panels. Solar pumps are available in several capacities depending upon the requirement of water.

(iii)Support Structure and Tracking Mechanism

Support structure provides stability to the mounted solar panels and protects them from theft or natural calamities. To obtain maximum output of water, a manual tracking device is fixed to the support structure. Tracking increases the output of water by allowing the panels to face the sun as it moves across the sky.

(iv)Foundations (Array and Pump)

Foundations are provided for support structures and pump.

(v)Electrical Interconnections

A set of cables of appropriate size, junction boxes, connectors and switches are provided along with the installation.

(vi) Earthing Kit

Earthing kit is provided for safety in case of lightning or short circuit.

(vii) Plumbing

Pipes and fittings required to connect the pump come as part of the installation.

IV. APPLICATION AND LIMITATION

Advantages of PV Pumping System

PV pumping system has many advantages which are summarized as following:

(i) Low operating cost: One of the important advantages is the negligible operating cost of the pump. Since there is no fuel required for the pump like electricity or diesel, the operating cost is minimal.

(ii) Low maintenance: A well-designed solar system requires little maintenance beyond cleaning of the panels once a week.

(iii) Harmonious with nature: Another important advantage is that it gives maximum water output when it is most needed i.e. in hot and dry months.

(iv)Flexibility: The panels need not be right beside the well. They can be anywhere up to 20 meters away from the well, or anywhere you need the water. These pumps can also be turned on and off as per the requirement, provided the period between two operations is more than 30 seconds.

Limitations of PV Pumping System

PV pumping system has its various limitations which are as following:

(i) Low yield: Solar pumping is not suitable where the requirement is very high. The maximum capacity available with solar is very low. However, the output of the solar DC pump is more than a normal pump.

(ii) Variable yield: The water yield of the solar pump changes according to the sunlight. It is highest around noon and least in the early morning and evening.

(iii) Theft: Theft of solar panels can be a problem in some areas. So the farmers need to take necessary precautions. Ideally, the solar system should insured against theft as well as natural hazards like lightning.

V. CONCLUSION

A solar irrigation pump system methods needs to take account of the fact that demand for irrigation system water will vary throughout the year. Peak demand during the irrigation system seasons is often more than twice the average demand. This means that solar pumps for irrigation are under-utilized for most of the year. Attention should be paid to the system of irrigation water distribution and application to the crops. The irrigation pump system should minimize water losses, without imposing significant additional head on the irrigation pumping system and be of low cost.

REFERENCES

1. A. Varshney, U. Sharma and B. Singh, "An Intelligent Grid Integrated Solar PV Array Fed RSM Drive-Based Water Pumping System," in IEEE Transactions on Industry Applications, vol. 57, no. 2, pp. 1818-1829, March-April 2021, doi: 10.1109/TIA.2020.3045952.
2. I. Akhtar, S. Kirmani, M. Suhail and M. Jameel, "Advanced Fuzzy-Based Smart Energy Auditing Scheme for Smart Building Environment With Solar Integrated Systems," in IEEE Access, vol. 9, pp. 97718-97728, 2021, doi: 10.1109/ACCESS.2021.3095413.
3. A. A. Stonier et al., "Fuzzy Logic Control for Solar PV Fed Modular Multilevel Inverter Towards Marine Water Pumping Applications," in IEEE Access, vol. 9, pp. 88524-88534, 2021, doi: 10.1109/ACCESS.2021.3090254.
4. M. Kashif and B. Singh, "Solar PV Fed Reverse Saliency Spoke-Type PMSM with Hybrid ANF Based Self-Sensing for Water Pump System," in IEEE Journal of Emerging and Selected Topics in Power Electronics, doi: 10.1109/JESTPE.2021.3084129.
5. S. Angadi, U. R. Yaragatti, Y. Suresh and A. B. Raju, "Comprehensive review on solar, wind and hybrid wind-PV water pumping systems-an electrical engineering perspective," in CPSS Transactions on Power Electronics and Applications, vol. 6, no. 1, pp. 1-19, March 2021, doi: 10.24295/CPSSTPEA.2021.00001.
6. H. Rezk, M. Al-Dhaifallah, Y. B. Hassan and H. A. Ziedan, "Optimization and Energy Management of Hybrid Photovoltaic-Diesel-Battery System to Pump and Desalinate Water at Isolated Regions," in IEEE Access, vol. 8, pp. 102512-102529, 2020, doi: 10.1109/ACCESS.2020.2998720.
7. R. Rai, S. Shukla and B. Singh, "Sensorless Field Oriented SMCC Based Integral Sliding Mode for Solar PV Based Induction Motor Drive for Water Pumping," in IEEE Transactions on Industry Applications, vol. 56, no. 5, pp. 5056-5064, Sept.-Oct. 2020, doi: 10.1109/TIA.2020.2997901.
8. S. Shukla and B. Singh, "Single-Stage PV-Grid Interactive Induction Motor Drive With Improved Flux Estimation Technique for Water Pumping With Reduced Sensors," in IEEE Transactions on Power Electronics, vol. 35, no. 12, pp. 12988-12999, Dec. 2020, doi: 10.1109/TPEL.2020.2990833.
9. S. Murshid and B. Singh, "Single Stage Autonomous Solar Water Pumping System Using PMSM Drive," in IEEE Transactions on Industry Applications, vol. 56, no. 4, pp. 3985-3994, July-Aug. 2020, doi: 10.1109/TIA.2020.2988429.
10. K. Khan, S. Shukla and B. Singh, "Improved Performance Design Realization of a Fractional Kilowatt Induction Motor With Predictive Current Control for Water Pumping," in IEEE Transactions on Industry Applications, vol. 56, no. 4, pp. 4575-4587, July-Aug. 2020, doi: 10.1109/TIA.2020.2968014.
11. A. Varshney, U. Sharma and B. Singh, "Adaptive d-Axis Current Control of RSyM for Photovoltaic Water Pumping Incorporating Cross Saturation," in IEEE Transactions on Industrial Informatics, vol. 16, no. 10, pp. 6487-6498, Oct. 2020, doi: 10.1109/TII.2020.2964905.
12. S. Rahman et al., "Design and Implementation of Cascaded Multilevel qZSI Powered Single-Phase Induction Motor for Isolated Grid Water Pump Application," in IEEE Transactions on Industry Applications, vol. 56, no. 2, pp. 1907-1917, March-April 2020, doi: 10.1109/TIA.2019.2959734.