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A Survey on Power Quality Improvement in Grid Integrated Solar Water Pumping System Using PMSM Drives

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ABSTRACT

This paper proposes a standalone two stage solar photovoltaic (PV) water pumping system. This system utilizes a solar PV array, boost dc-dc converter, Utility grid, three-phase voltage source converter; three phase VSI (Voltage Source Inverter), PMSM (Permanent Magnet Synchronous Motor). The boost converter used between PV array and VSI, serves the purpose of MPP (Maximum Power Point) tracking by adjusting the duty ratio using an INC (Incremental Conductance) method in order to extract optimum power from the PV array. In this way, the purpose of effective and efficient water pumping is achieved. The proposed system is modelled using MATLAB/ Simulink environment and its performance is simulated to study its behavior under varying insolation level.

Keywords: PV array; Utility grid; Voltage Source Inverter; Voltage Source Converter; Permanent Magnet Synchronous Motor; Incremental Conductance.

Introduction

With the ever-increasing energy demand and depleting conventional energy sources, renewable energy sources offer a promisable alternative for fulfilling the rapidly increasing gap between demand and supply.

With the advancement of semiconductor technology, the steadfast improvement in PV array technology has improved its efficiency and effectiveness. Amongst various sectors where solar PV energy is being utilized, water pumping for domestic as well as irrigation processes is seemingly one of the best and economically viable applications of PV energy generating system. Two types of topologies are mostly used for utilizing PV energy. The conventional two stage topology has first stage to extract the maximum power and second stage for maintaining DC link voltage. However, a single stage topology is more effective as the first stage DC-DC Converter is completely eliminated and thereby the losses associated with it are reduced. Despite this, two stage topology has better control on DC link voltage even at lower insolation level. Moreover, the presence of DCDC Converter eases the burden on VSI as it has to maintain only the power flow to the load. Mostly induction motors are used to drive the pump with advantages such as low cost, robustness, ability to operate under adverse environment, easy availability and need for low maintenance but some of their limitations like low efficiency, complex control, overheating at lower voltages make them feasible for solar PV pumping. In the last few decades, extensive research in permanent magnet (PM) technology has led to the development of PMs of considerably high energy density. This advancement has contributed to the

development of Permanent Magnet Brushless ac and dc motors. Permanent Magnet ac motors are generally known as PMSM (Permanent Magnet Synchronous Motor) whereas permanent magnet brushless dc motor as BLDCM (Brushless DC Motor). It has an advantage of high efficiency, large torque to weight ratio, long life, low noise, low torque ripples, high reliability and low maintenance and hence best suited for Solar PV array water pumping. A three phase Voltage Source Inverter (VSI) is widely used to feed the PMSM which is controlled using high frequency PWM signals.

Literature Review

M. A. Elgendy, B. Zahawi and D. J. Atkinson, [1] the energy utilization efficiency of commercial photovoltaic (PV) pumping systems can be significantly improved by employing simple perturb and oberve (P&O) maximum power point tracking algorithms. Two such P&O implementation techniques, reference voltage perturbation and direct duty ratio perturbation, are commonly utilized in the literature but no clear criteria for the suitable choice of method or algorithm parameters have been presented. This paper presents a detailed theoretical and experimental comparison of the two P&O implementation techniques on the basis of system stability, performance characteristics, and energy utilization for standalone PV pumping systems. The influence of algorithm parameters on system behavior is investigated and the various advantages and drawbacks of each technique are identified for different weather conditions. S. Jain, R. Karampuri and V. T. Somasekhar [2] In this paper, a single-stage solution for solar photovoltaic (PV) pumping system using a dual-inverter fed open-end winding induction motor drive is presented. The three-level dual-inverter requires a low PV bus voltage compared with its conventional three-level counterpart. This could avoid large string of PV modules and helps in reducing the voltage rating of the capacitors and semiconductor devices used in the system. This may further help in reduction of cost of the system. A. Khiareddine, C. Ben Salah and M. F. Mimouni [3] pumped storage is generally view as the most promising technology renewable energy penetration levels and particularly in small autonomous systems. Combined batter and pump constitute a realistic and feasible option to achieve high penetrations. P. García, C. A. García, L. M. Fernández, F. Llorens and F. Jurado, [4] This paper describes and evaluates an adaptive neuro-fuzzy inference system (ANFIS)-based energy management system (EMS) of a grid-connected hybrid system. It presents a wind turbine (WT) and photovoltaic (PV) solar panels as primary energy sources, and an energy storage system (ESS) based on hydrogen (fuel cell -FC-, hydrogen tank and electrolyzer) and battery. I. Ducar and C. Marinescu, [5] In this paper two operating modes available for permanent magnet synchronous machines (PMSM) are presented. This study aims to increase the efficiency of the motor-pump system. The PMSM is driven at variable speed and the inverter is controlled by space vector modulation theory. A. B. C. S. B. Slama and A. Chrif, [6] In this paper, we propose an efficient design along with modeling and simulation of a small scale water pumping system fed by a hybrid Photovoltaic-Fuel Cell (PV-FC) power system. An overview of the basic theory of such system along with their modeling and simulation package is presented. A switching Maximum Power Point Trucking (MPPT) control algorithm is applied to the proposed configuration. R. Kumar and B. Singh, [7] This paper proposes a solar photovoltaic (PV) fed water pumping system driven by a brushless DC (BLDC) motor. A promising case of interruption in the water pumping due to the intermittency of PV power generation is resolved by using a power grid as an external power backup. The power is drawn from the grid in case the PV array is unable to meet the required power demand, otherwise the PV array is preferably used. A unidirectional power flow control for the same is developed and realized through a power factor corrected (PFC) boost converter. R. Kumar and B. Singh, [8] A solar water pumping system employing a brushless DC motor drive is presented. The utility grid is utilised as a

secondary power source. The total load demand is shared by photovoltaic array and the grid. This results in continuous water pumping. The amount of power shared by each source is controlled through a power factor corrected boost converter. The full utilisation of motor pump is achieved with increased reliability. The power quality is improved at the utility grid side. The simulation and hardware implementation are carried out to exhibit the performance of the system. B. Singh and S. Murshid, [9] This paper deals with an effective power transfer scheme between the solar photovoltaic (PV) array and single-phase grid, feeding a field-oriented-controlled (FOC) permanent-magnet synchronous motor (PMSM) drive applied to a water-pumping system (WPS). Owing to the intermittency associated with solar (PV) system, the requirement of constant water supply is not possible with the standalone system. In order to mitigate this, a grid-intergraded WPS is proposed here. The grid integration enables the consumer an uninterrupted operation of water pump irrespective of solar insolation level. Moreover, the PV power can be fed to the utility grid when water pumping is not required. To make it possible, one voltage-source converter (VSC) and one voltage-source inverter connected to a common dc link are used for utility grid and PMSM control, respectively. The unit vector template theory is utilized to generate switching pulses for VSC to control the bidirectional power flow between the solar PV system and utility grid through the common dc link. E. Radziemska, and E.Klugmann [13] This paper presents the experimental results and discusses the track of the maximum power point on the current-voltage curve of a PV module due to changes of the illumination level and temperature. A time decrease of the voltage and simultaneous temperature increase during the initial stage of irradiation has been observed. Some practical implementation aspects of a maximum power point tracking unit, which match the current and voltage characteristics of the load to the PV module's maximum power point automatically, are also discussed. A linear decrease of the maximum output power P-m with temperature increase has been observed and the temperature coefficient was derivate. Temperature coefficients for V-oc, I-sc, V-mpp, I-mpp, and eta(PV) have been determined for the photovoltaic module. Also the radiation rate coefficient at constant temperature has been calculated. D. P. Hohm and M. E. Ropp, [14] Maximum power point tracking (MPPT) is important in solar power systems because it reduces the solar array cost by decreasing the number of solar panels needed to obtain the desired output power. Several different MPPT methods have been proposed, but there has been no comprehensive experimental comparison between all the different algorithms and their overall maximum power point (MPP) tracking efficiencies under varying conditions (i.e. Illumination, temperature, and load). This paper such a comparison. Results are using a microprocessor controlled MPPT powered by a 250 W photovoltaic (PV) array and also a PV array simulator. Chia-Hsi Chang, Yu-Hui Lin [15] The objective of this paper is to propose a simplified reactive power control (SRPC) strategy for single-phase grid-tied photovoltaic (PV) inverters. With the proposed SRPC strategy, a cost-effective microcontroller can be adopted to achieve an effectively reactive power control. Moreover, the current-mode asynchronous sigma-delta modulation (CASDM) is adopted to enhance the current control's dynamic response and reduce both the current harmonic distortion and electromagnetic interference. In this paper, the operational principle of the proposed SRPC is introduced. Then, the small signal analysis for the PV inverter with the CASDM is presented. Finally, a 1-kVA single-phase PV inverter was built to verify the performance of the proposed control strategy.

Proposed System

The system presented in this work comprises of solar PV array, dc to dc boost converter, three phases VSI, PMSM and a centrifugal pump. An INC method is utilized for extracting optimum power from solar PV array.

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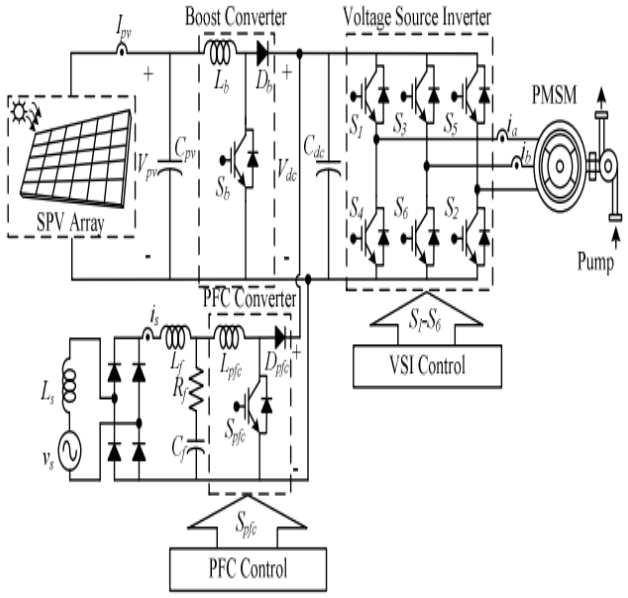

Fig. 1: Proposed System.

Solar cells are fundamental building block of solar PV array. PV cells are combined in order to make a solar PV module. These modules are of standard power rating. Series combination of these PV modules increases the voltage level whereas parallel combination increases the current level. Depending upon the power required, the numbers of solar PV modules are decided. These modules are further arranged in series and parallel depending upon system voltage and current requirement respectively.

A. Design of Solar PV Array

For the design of a solar PV array, the most important aspect to be considered is the load power requirement. The power rating of the solar PV array is selected somewhat higher as compared to the load power. Since the actual system is never lossless, this excess power would feed the losses of converter used for power processing at intermediate stages and load would get rated power at standard solar irradiation.

B. Maximum Power Point Tracking (MPPT)

For the purpose of optimizing the output power from the solar PV array, the MPP tracking techniques are mostly utilized. An INC method of MPP tracking is used in this work for its capability of highly accurate tracking even under rapidly changing insolation conditions. The MPP tracking method adjusts the duty ratio of dc-dc boost converter in small step size. Smaller step size gives good MPP tracking. The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcomes by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculates using the relationship between Di/Dv and –i/v. This relationship is derived from the fact that dp/dv is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P and O in that it can determine when the MPPT has reached the MPP, where P and O oscillates around MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance condition with higher accuracy than P and O.

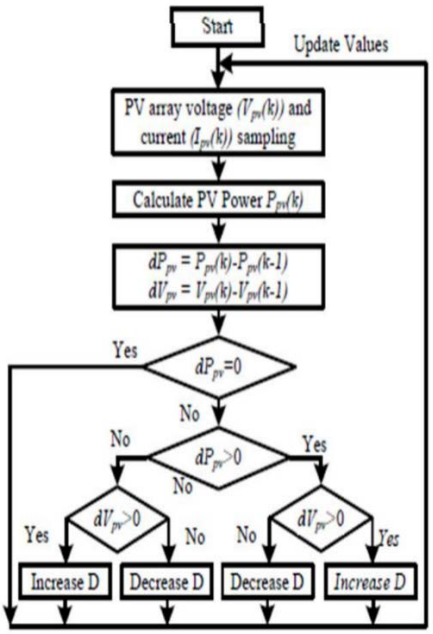

Fig.2: Flowchart.

Conclusion

A solar PV water pumping system driven by PMSM has been studies many paper in literature. The performance of the system will be analyze under wide range of insolation. If PI controller is updated by fuzzy logic controller. it can be considered that the proposed system with fuzzy controller will be more stable. The grid integration has improved the WPS reliability. The pump is fully utilized regardless of varying weather conditions. The INC based MPPT algorithm has effectively extracted the maximum power from the solar PV array. Hence the proposed system gives a simple, reliable, economical, efficient, robust and compact solution which is highly feasible for solar water pumping.

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