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Photovoltaic-grid hybrid power fed pump drive operation for curbing the intermittency in PV power generation with grid side limited power conditioning

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ABSTRACT

Existing pump drive systems are fed from the grid. In case grid fails, it takes time to restart the pump drive, and unnecessarily power is wasted in restarting. Moreover, to reduce the burden on the grid and also to curb the intermittency a hybrid configuration is proposed in which PV system is integrated with grid to cater the pump load operation. Even if the grid fails, the PV system works in islanded mode to cater the pump load at the permissible limit depending on the generation by PV system alone in the absence of storage systems. To establish a bidirectional power flow a voltage source converter (VSC) based grid coupling is considered which also provide limited power conditioning to utilize the capacity of VSC at maximum to solve Grid power quality issues like unbalance current, harmonics, etc. The synchronous reference frame (SRF) method is used for current decomposition for determining the limited compensation to be provided by the grid coupled VSC, based on its unutilized capacity. MATLAB based simulation and experimental results show the efficient working of hybrid configuration in both grid connected mode and islanded mode with limited power conditioning.

Introduction

The larger part of the electrical energy is utilized by continuous duty pumps used in industrial, agricultural, and household sectors. In the majority of these pumps are fed by power drawn from the distribution systems, and for isolated cases, these are fed by diesel generation sets. To reduce the dependence on the grid renewable energy source needs to be proposed [1]. Out of the all available renewable sources, solar Photovoltaic (PV) energy is suitable for all aforementioned applications [2].

PV panels, exhibits a typical non-linear *I-V* and *P-V* characteristics. This varies with varying irradiance and temperature condition. With the high cost of PV panels, there is a need to extract maximum available power from PV panels to avoid heating of the panel due to circulating current and in turn, enhance the total conversion efficiency. In literature different approaches have been proposed for maximum power point tracking (MPPT) such as the lookup table method, perturb and observe method (P&O), and incremental conductance method (IC) [3–5]. For fast tracking and efficient control author has also suggested fuzzy logic base MPPT controller [6]. Amongst different algorithm P&O is very simple to implement, but suffers from oscillations at the MPP point, and the same is overcome by more advanced algorithm such as an incremental conductance method (IC).

Most of the earlier reported literature advocated the use PV pumping system in standalone mode [7]. In literature DC motor driven pump load control based on artificial neural network have been advocated [8] Though PMDC motors are operationally most suitable due to their direct control with charge controller, but due to the ruggedness and absence of brushes in induction motors (IM) are more widely accepted even with additional DC-AC converter. In literature mainly V/f control and slip optimization techniques are reported for induction motor used in PV based pumping application to realize the increase in efficiency. With the advancement in embedded systems and power electronics the sensorless field oriented control (FOC) is considered suitable most for an IM drive for pump application especially with PV applications [9,10].

In standalone operation DC link capacitor voltage experience variation with change in isolation levels, which puts the IM drive out of FOC, if the change is significant. Thus, for smooth operation of the IM drive in FOC the MPPT must operate with some storage system. Such systems are devoid of expansion of PV infrastructure and cost high due to battery capacity storage system. Since the

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major part of the industrial, agricultural, and household sectors are connected with the grid the storage can be grid based. In grid connected mode DC link voltage can be maintained easily without any battery source. Excess power from PV unit can be transferred to the grid and similarly deficit may be drawn from the grid. Such PV system is connected to the grid through transformer for providing isolation for voltage source converter (VSC) [11]. In literature many control algorithms for PV grid integration have been proposed [12]. Control derives using instantaneous reference theory has been proposed by author [13], but the algorithm lacks in the estimation of current reference generation due to corrupt PCC point. Modifications and improvements are suggested based on power balance or *p-q* theory using unit template [14–16]. Even these methods, though are very easy to implement, but prone to malfunction under noisy operation at PCC and there exists no decoupling of real and reactive components [17]. To have decoupled control in literature SRF based control have been proposed. In the current proposed system SRF based Indirect current control of grid coupling is advocated, as it gives better control and dynamics as compare to voltage control and other control discussed above. The control apart from transacting the excess/deficit power to/from the grid, utilizes the remaining available capacity of VSC for compensating power quality (PQ) problems on priority such as reactive power compensation, negative sequence compensation, and harmonic compensation [18,19]. In literature many controls have been discussed for alleviating harmonics problems and power quality problems [20,21]. For estimating different PQ problems in load current, synchronous reference frame (SRF) is used for decomposing load current into positive sequence fundamental real reactive power current, negative sequence fundamental current, and harmonic current [22]. VSC's are operated such that its first priority is the transaction of real power and the remaining capacity can be used for selective compensation of PQ problems based on priority and severity of the problems at the load side [23–25].

The paper presents the technique which evacuates maximum available power from solar PV panels, maintains a near constant DC bus voltage to ease the FOC of IM drive for pump applications, transact excess/deficit power required by the pump load and provides limited compensation to power quality problems (PQ) on the distribution grid. Apart from utilizing the VSC resource through PQ compensation, the proposed system also helps in reducing the total cost of operation as pump load operates in continuous duty cycle without need to shut down the pump even if the grid fails due to hybrid configuration. In the proposed scheme indirect vector control scheme is used for IM drive in grid connected mode. The effectiveness of the proposed system is evaluated through simulation under grid connected mode and varying insolation conditions. Moreover, to track the fast changing insolation condition an effective incremental conductance (IC) MPPT method is used for maximum evacuation of power from the PV panel.

The proposed hybrid photovoltaic pumping system with power conditioning capability (HPVPSPCC) is simulated under the MATLAB simulink environment. The contents are dealt in the following sections: (II) System architecture (III) PV array modeling, (IV) IC method based MPPT techniques, (V) Control, (VI) MATLAB based simulation, (VII) Performance evaluation (VIII) Hardware implementation.

System configuration

Fig. 1 shows the block diagram of HPVPSPCC comprising of indirect vector controlled induction motor (IM) pumping system connected across the tank capacitor (C_r) which is fed by both PV generation and grid in grid tied mode and PV generation in off grid mode. The grid based loads are varying types and in the present case, these are balanced RL load, unbalanced R load, thyristor converter type load, etc. PV system consists of PV panels, DC-DC boost converter with MPPT operation. A large tank capacitor (C_r) is

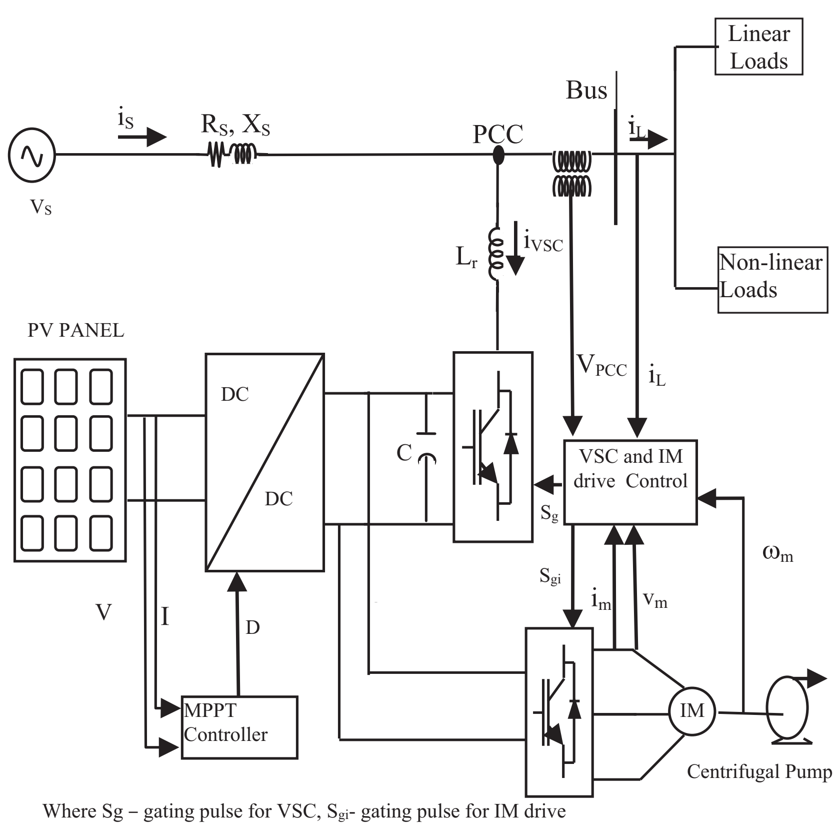

Fig. 1. Block diagram for system configuration of HPVPSPCC.