A Novel Mppt Technique Based On Ripple Correlation Control For A Single-Stage Pv System Supplies Dual-Inverter-Fed Open-End Winding Im Drive For Pumping Applications

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Abstract— ripple and correlates this with switching function to control the operating point of PV array is called ripple correlation control (RCC). For single-phase, single-stage grid connected photovoltaic (PV) systems a maximum power point tracking (MPPT) technique is proposed in this paper. Compared to multistage topology single-stage topology reduces the cost and complexity of the system and such systems are reliable because of the reduced component count. In single-phase single-stage system, by the instantaneous power oscillations PV array voltage is subjected to 100 Hz ripple (double the grid frequency) is introduced in this paper. By using the simulation results the effectiveness of the proposed method has been verified . In this paper using Real time digital simulator (RTDS) the real time simulation results of the proposed scheme are presented.

Index terms— Photovoltaic (PV), maximum power point tracking (MPPT), ripple correlation control (RCC), real time digital simulator (RTDS)

I. INTRODUCTION

To transfer maximum available power from PV cells to the grid, Maximum Power Point Tracker (MPPT) algorithms have been developed and implemented. The method which makes use of such ripple and correlates this with switching function to control the operating point of PV array is called ripple correlation control (RCC). To generate power and also sell the excess power to the utility grid the concept of distributed generation has enabled any individual single-phase consumer [1]. Because of this, small single phase photovoltaic (PV) generating units are becoming more and more popular.

In distributed generation a grid connected PV system has become very popular because of their application and for efficaciously utilizing the PV array potency. The symbolic grid –connected system is shown in fig 1. Such distributed units should be operated reliably without much maintenance and should be cost effective. The inverter ascertains that whatever amount of potency is extracted from the solar array is being dumped on the grid which is achieved by maintaining the dc-link voltage at a set reference. Like two stage systems, the single stage inverter performs two functions: 1) obtaining maximum power by utilizing congruous MPPT algorithm .2) these potencies are distributed to the grid by maintaining felicitous power quality discipline of the utility. By employing a single-stage topology the cost and complexity of the system can be reduced. Moreover, such a system can be more reliable, because of the reduced component count.

The schematic of a typical single-stage PV system is shown in Fig. 1 in which the output of PV array is connected to the dc-link of the inverter, and the output of the inverter is fed to the grid. Various maximum power point tracking (MPPT) techniques such as Perturb and Observe, Hill-climbing, incremental conductance have been reported in the literature.

Fig. 1. Single-phase, single-stage PV system

The dc-ac inverter present in single-stage systems performs the function of extracting the peak available power as well as dumping the extracted...
power to the grid. Since PV cells show nonlinear v-i characteristic which is dependent on solar irradiation and temperature [3], there is a need to track the maximum power point (MPP). All these MPPT techniques make sure that in order to achieve this, the PV array is operating around the MPP, small perturbation is given to the PV array voltage. Usually, in more steady state oscillations around operating point these methods use fixed step size in which larger step size gives faster dynamics whereas it results.

And smaller step size gives slow dynamics with reduced steady state oscillations. Therefore for satisfactory performance of MPPT PV system compromises between dynamics and steady state oscillations. When these methods perturb and observe and incremental conductance methods have their own disadvantages such as (i) poor tracking performance during sudden increase in solar irradiance, (ii) need of choosing an effective perturbation size [3].

In single-phase single-stage systems where the PV array voltage is inevitably subjected to 100 Hz ripple (double the grid frequency) because of the oscillating nature of the power fed to the grid [5]–[10], according to the perturbation size given the dc-link voltage perturbs around the MPP. And the 100 Hz ripple is superimposed on these perturbing operating points. To determine the MPP of the PV array the 100 Hz ripple is inevitable in single-phase single stage systems, this can be effectively used, and such techniques are reported [5]–[10]. Since the RCC uses inherently available ripples, when sudden change in solar irradiance no artificial perturbation is needed to track MPP which improves the tracking performance [11]. To the PV array voltage making MPPT faster RCC is parameter insensitive and do not induce perturbations [11]. However, the schemes given in requires the service of a phase locked loop (PLL), whose implementation is computationally intensive.

A novel MPPT method based on modified RCC has been proposed in this paper. In this method the drawbacks of perturb and observe, incremental conductance method and the RCC based MPPT methods presented in [5]–[10] are addressed. To synchronize with the grid Some pulse width modulation techniques used for grid connected inverters do not require the service of PLL, and the MPPT schemes given in cannot take advantages of such schemes. Based MPPT algorithm for the implementation of ripple correlation control given service of four filters, two high pass filters and two low pass filters (LPF) are required. This slows down the response of the system, and also makes implementation computationally intensive. Moreover, to determine the MPP only the sign of the power derivative signal, and not its magnitude is used, thereby making the system respond slowly if the operating point is far away from MPP. This method uses the product of power ripple and voltage ripple available in PV array as error signal to track the MPP.

According to distance of operating point from the MPP the MPPT block uses this error to generate a control signal whose magnitude vary. If the operating point is far and will be less. If the operating point is near to MPP, from the MPP the magnitude of control signal will be more. Therefore to ripple content of the PV array voltage which is unavoidable this method gives faster dynamics and the steady state oscillations around the MPP will be limited. Moreover using only two LPFs this scheme is implemented, to respond faster thereby avoiding the use of two HPFs, which reduces the computational complexity and helps the system. To prove the efficacy of the proposed MPPT scheme extensive numerical simulations are carried out and verified using Real-Time Digital Simulator (RTDS) hardware.

Fig. 2. Current and power of the PV panels versus voltage.
II. OPERATING PRINCIPLE AND IMPLEMENTATION OF MPPT ALGORITHM

The efficiency of solar cell is very low. In order to increase the efficiency methods should be undertaken to match source and load properly. One such method is the MPPT. MPPT technique used to obtain the maximum possible power from a varying source. In PV systems V-I characteristics is non linear, thereby making it difficult to be used to power a certain load.

For a single-phase system, the value of instantaneous power \( p(t) \) injected into the grid pulsates at twice the grid frequency. The PV array current, \( i(t) \) and the power fed by the PV array, \( p(t) \) also contains a ripple. This causes the dc-link voltage to oscillate at 100 Hz. For the single-stage system given in Fig. 1, the terminals of the PV array is directly connected across the dc link capacitor, and therefore the output voltage of the PV array, \( v(t) \) also oscillates at 100 Hz. The ripple content of a general time varying quantity, \( x(t) \) can be expressed as

\[
\tilde{x}(t) = x(t) - \bar{x}(t)
\]  

where \( \tilde{x}(t) \) represents the ripple content, and \( x(t) \) represents the moving average component. The general quantity, \( x(t) \), can be PV array voltage, \( v(t) \); current, \( i(t) \); or power, \( p(t) \).

Expressing \( v(t) \) and \( i(t) \) as in (1) and substituting them in (2), we get the PV array power as

\[
p(t) = \bar{v}(t)\bar{i}(t) + \tilde{v}(t)\tilde{i}(t) + \bar{v}(t)\tilde{i}(t) + \bar{v}(t)\tilde{i}(t)
\]  

Hence, the power ripple can be written as

\[
\tilde{p}(t) = \bar{v}(t)\tilde{i}(t) + \tilde{v}(t)\bar{i}(t) - \bar{v}(t)\tilde{i}(t) - \tilde{v}(t)\bar{i}(t)
\]

The product of \( v(t) \) and \( i(t) \) can be expressed as

\[
\tilde{p}(t)\tilde{v}(t) = v_{r}^{-2}\left[\tilde{i}(t) + \tilde{v}(t)\frac{\bar{i}(t)}{\bar{v}(t)} + v_{r}^{-2}\tilde{i}(t)\right]
\]

Also, the PV power derivative can be expressed as

\[
\frac{dp(t)}{dv(t)} = \frac{\bar{i}(t)}{v(t)} + \frac{d\bar{i}(t)}{dv(t)}
\]

Linearization of v-i curve shown in Fig. 2 at a point \((v_{0},i_{0})\) yields

\[
\frac{d\bar{i}(t)}{dv(t)} = \frac{\bar{i}(t)}{v(t)}
\]

Using (6) and (7), \( p(t) \) and \( v(t) \) can be expressed as

\[
\tilde{p}(t)\tilde{v}(t) = v_{r}^{-2}\left[\tilde{i}(t) + \tilde{v}(t)\frac{\bar{i}(t)}{\bar{v}(t)} + v_{r}^{-2}\tilde{i}(t)\right]
\]
Ripple correlation control (RCC) was first proposed by Midya et al. (1996) for MPPT and motor efficiency optimization purposes. Inexpensive and robust controllers utilizing an analog RCC technique have also been developed by Esram et al. (2007), Il-Song & Myung-Joong (2004) and Lim & Hamill (2000, 2001). RCC makes use of converter ripple as an alternate source of perturbation. The maximum power point is usually located by correlating the derivative of the array power with the voltage or current ripple waveform. For example, the product of power and voltage derivatives with respect to time is zero at the MPP, but yields a positive and negative sign when the operating point is to the left or right (respectively) of the MPP (Esram & Chapman 2007, Kimball & Krein 2007, Midya et al. 1996). As Midya et al. (1996:1710) note, a major benefit of RCC is that it ‘keeps [DC–DC] converter operation at the optimum point’ while avoiding the ‘inconvenient, slow, and fundamentally sub-optimal’ perturbation process.

### III. SIMULATION RESULT

The proposed MPPT algorithm has been numerically simulated using Matlab/Simulink. The details of the PV system considered is summarized in Table I. Both in steady state and transient conditions by varying solar irradiance the performance of the system connected to the photovoltaic array has been evaluated. Fig. 5 shows the simulated power versus voltage characteristics for the PV system considered in Table I.
the operating point from MPP, the operating point can be controlled by passing the average error signal through a PI controller. The implementation of the proposed MPPT algorithm is shown in Fig. 4. The ripples $\sim v(t)$ and $\sim p(t)$ can be obtained by subtracting the average values from the respective signals using LPFs. The product of these ripples is used as input to a PI controller. The output of the PI controller is considered as reference signal, $V(t)$ to control the dc-link voltage. The reference signal thus obtained is compared with PV array voltage and the error obtained is passed through another PI controller to obtain the load angle. This angle is used to generate the control signals to operate the inverter switches.

IV. REAL TIME SIMULATION RESULTS

The generated switching pulses are given to a photovoltaic inverter system simulated using real time digital simulator (RTDS) in order to further verify the proposed method. To implement the aforementioned system the RTDS hardware which consists of host computer and FPGA based target is used [15]. Fig. 9 shows the photograph of RTDS OP4500 test set up, where OP4500 is the compact real time power grid digital simulator from OPAL-RT technologies.

Using RTDS hardware with a real time simulation time step of 10 s the grid connected PV system through inverter system has been implemented. The details of the PV generation system are given in Table I. It has been verified that from both numerical simulation and real time simulation results, the proposed method is able to track the desired MPP under varying irradiation levels effectively. The PV array voltage and power is settled at 434 V and 900 W which corresponds to MPP for irradiation level of 600 W/m$^2$.

CONCLUSION

Generating electrical power from PV panels has become popular in recent years. In the literature, two stage complex structures are commonly used. For single-phase single-stage grid connected PV systems a novel MPPT technique based on ripple
correlation control is proposed. In the proposed technique, single stage structure is used and it does not require any complex circuitry and modulation technique. A 175 Watt prototype system is designed. The MPPT block uses the product of voltage and power ripple to drive the operating point towards MPP. Under different environmental conditions, MPPT controller adjusts the delay angle successfully. In the simulation, after tuning the delay angle for the new environmental condition by the controller, the system starts generating 136 W instead of 96 W. The proposed algorithm is working satisfactorily under dynamic irradiance conditions. The efficacy of the proposed algorithm has been proved through simulations and real time simulation results using RTDS hardware.

REFERENCES

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