RIPPLE CORRELATION CONTROL OF MAXIMUM POWER POINT TRACKING ON PV SYSTEM

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ABSTRACT

This work presents a comparison of ripple correlation control maximum power point tracking (MPPT) technique and the modified version of the same MPPT applied to single-phase, single-stage, grid-connected photovoltaic (PV) system, as the technique is fast and suitable for fast changing environmental conditions. Both the techniques are compared on the basis of the time taken to reach (track) the MPP, operating point oscillations about MPP and the dependence of the algorithms, if any, on array configuration and parameters. An LCL-Filter based grid connected inverter with proportional resonant (PR) current controller is suggested to provide power to the line with unity power factor and the inverter offers much less total harmonic distortion. The focus is on presenting a systematic design procedure for AC current, DC voltage controllers for the VSI and low complexity grid synchronization method. The complete system is numerically simulated in MATLAB and the results are presented for rapidly changing irradiation levels.

***Index Terms:* Micro Grid, Photovoltaic System, Power Conditioning, Single-Phase Grid-Connected Inverter.**

I INTRODUCTION

Renewable energy is currently widely used. One of these resources is solar energy. The photovoltaic (PV) array normally uses a maximum power point tracking (MPPT) technique to continuously deliver the highest power to the load when there are variations in irradiation and temperature. The disadvantage of PV energy is that the PV output power depends on weather conditions and cell temperature, making it an uncontrollable source. Furthermore, it is not available Combining multiple renewable resources via a common dc bus of a power converter has been prevalent because of convenience in integrated monitoring and control and consistency in the structure of controllers as compared with a common ac type. There are some previous works on similar hybrid systems [2]–[11]. Dynamic performance of a stand-alone solar system with battery storage was analyzed [3]. A Several methodologies for optimal design or unit sizing of stand-alone or grid-connected systems have been proposed using steady-state analysis [4]–[7]. In addition, the steady-state performance of a grid-connected wind- and photovoltaic (PV)-power system with battery storage was analyzed [8]. This paper focused on system engineering, such as energy production, system reliability, unit sizing, and cost analysis, based on long terms of data hourly, daily, and yearly recorded. A simulation package was developed for a PV power system [9]. Most applications are for stand-alone operation, where the main control target is to balance local loads. A few grid-connected systems consider the grid as just a back-up means to use when there is insufficient supply from renewable sources [4], [5], [8]. They are originally designed to meet local load demands with a loss of power-supply probability of a specific period. Such systems, focusing on providing sustainable power to their loads, do not care much about the quality or flexibility of power delivered to the grid. From the perspective of utility, however, a system with less fluctuating power injection or with the capability of flexibly regulating its power is more desirable. In addition, users will prefer a system that can provide multiple options for power transfer since it will be favorable in system operation and management. Control strategies of such a system should be quite different from those of conventional systems. This paper addresses dynamic modeling and control of a grid-connected PV–battery system with versatile power transfer. i this system, unlike conventional systems, considers the stability and dispatch-ability of its power injection into the grid. The system can operate in different modes, which include normal operation without use of battery, dispatch operation, and averaging operation. In order to effectively achieve such modes of operation, two modified techniques are applied; a modified hysteresis control strategy for a battery charger/discharger and a power averaging technique using a low-pass filter. The concept and principle of the system and its supervisory control are described. Classical techniques of maximum power tracking are applied in PV array using MPPT control. Dynamic modeling and simulations were based on Power System Computer Aided Design/Electromagnetic Transients Program for DC (PSCAD/EMTDC), power-system transient-analysis software. The program was based on Dommel's algorithm, specifically developed for the simulation of high-voltage direct current systems and efficient for the transient simulation of power system under power-electronic control of inverter and its control system were developed.

II.MODELLING OF P.V SYSTEM

Generally, a PV module comprises of a number of PV cells connected in either series or parallel the classical equation of a PV cell describes the relationship between current and voltage of the cell (neglecting the current in the shunt resistance of the equivalent circuit of the cell) as

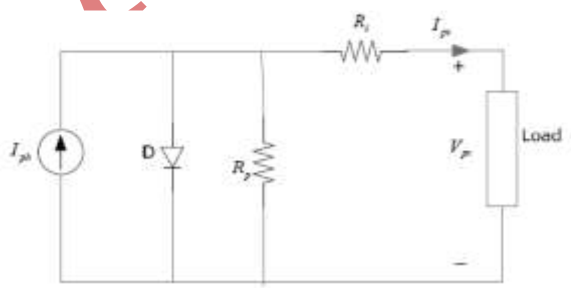


Fig.1. Equivalent circuit of PV cell

$$I_{ph} = I_L - I_O \left[\exp\left(\frac{V_{ph} + R_{se} I_{ph}}{A} \right) - 1 \right]$$

$$I_O = n_p I_{ph} - n_p I_{rs} \left[\exp\left(\frac{K_o V}{n_s} \right) - 1 \right]$$

Where *I*o denotes the PV array output current, *V* is the PV output voltage, is the cell photocurrent that is proportional to solar irradiation, is the cells reverse saturation current that mainly depends on the temperature, is a constant, *n* and are the numbers of series strings and parallel strings in the PV array, respectively.

III SYSTEM STRUCTURE AND CHARACTERISTICS

The power circuit topology includes an LCL filter as a interface between the inverter and grid. Sinusoidal pulse width modulation (SPWM) with unipolar switching, LCL filter is employed to achieve decreased switching ripple with only a small increase in filter hardware as compared to that of the L or LC filter with bipolar switching [6]. The voltage controller produces the gird current reference by comparing the actual dc link voltage with the maximum power point voltage given by the MPPT algorithm, which is then multiplied with the grid voltage template provided by the grid synchronizer. The control voltage produced by the injected grid current regulator is used to generate pulses for the grid connected PV inverter.

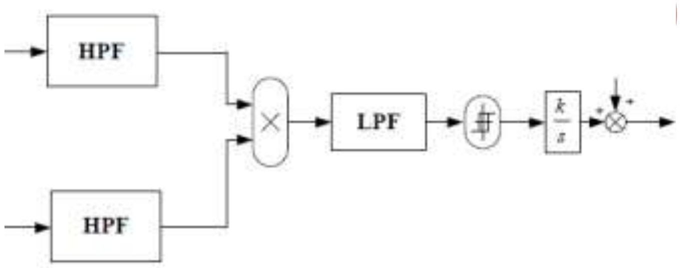


Fig 2.Block diagram of RCC-MPPT and Vmpp, ref generator

Assuming that the voltage and power oscillation frequency is known, RCC-MPPT uses filtering approach to extract the alternative components of PV power and voltage for reaching MPP. Fig. 3 shows the structure of MRCC-MPPT in which mean value function is used to overcome the complications in selection of filter time constants and to generate faster response in tracking MPP.

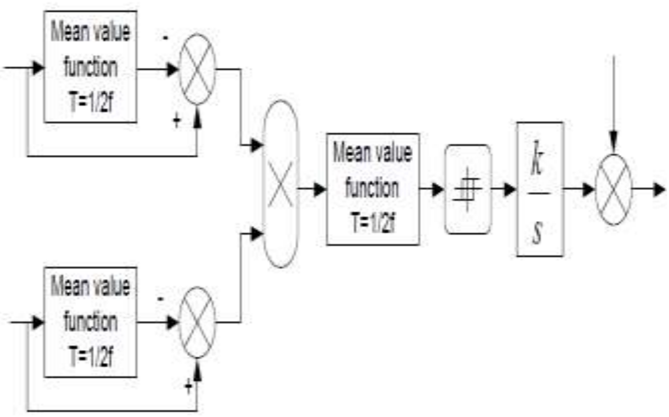


Fig 3: Block Diagram of MRCC-MPPT and Mpp, Refgenerator

The lowest order harmonics that appears in the harmonic spectrum of the output voltage of the full-bridge VSI are at the sidebands of 2mf, where mf is the frequency modulation index. Since the inverter switching frequency is set to 20 kHz, the lowest order of the harmonics of the inverter is (2mf −1) = 799. According to the standard IEEE-1547, any current harmonic with an order greater than 35 must have a magnitude that is no greater than 0.3% of the rated current of the distributed resource output. Thus, the primary design guide for the inverter output filter is to make the magnitude of the major harmonic current of the inverter less than 0.3% of the rated current. LCL filter values are chosen based on these guidelines.

IV CONTROL SCHEME OF SINGLE PHASE GRID CONNECTED VSI

The design of the control system for the inverter can be divided into three parts: 1) current controller, 2) grid synchronization and 3) DC link voltage controller. A current controller regulates the sinusoidal AC current injected into the grid and a voltage controller regulates the DC link voltage at adesirable level as indicated by the MPPT algorithm.

4.1 Current Controller

There are three major output current control techniques for the single phase VSI: hysteresis band, predictive and sinusoidal pulse width modulation (SPWM) control. The traditional method of SPWM control uses a proportional-integral (PI) compensator in the feedback loop to regulate the output current. However, while PI compensators have excellent performances on regulating DC quantities, tracking a sinusoidal current reference would lead to steady state magnitude and phase errors [7]. The recently introduced proportional-resonant (PR) controllers are very much suitable for single phase grid-connected converters. Compared with PI compensator, PR compensator can provide larger gain at the fundamental frequency to eliminate the steady state error [8]. Using the PR controllers, the converter reference tracking performance can be enhanced and previously known shortcomings associated with conventional PI controllers can be alleviated. These shortcomings include steady-state errors in single-phase systems and the need for synchronous d–q transformation in three-phase systems. The mathematical model of the current controller and the plant are as shown in Fig. 4.

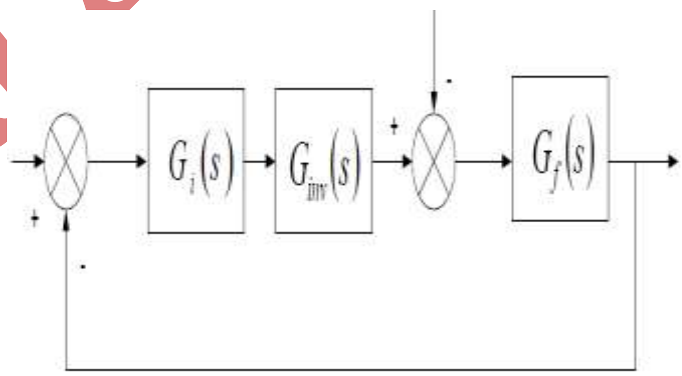


Fig 4: Block Diagram of Inner Current Loop.

The plant G (s) f is the transfer function of the LCL filter, which is of the form:

$$G_S(S) = \frac{R_d C_f S + 1}{\left(L_i L_g C_f S^3 + \left[L_i + L_g\right] C_f R_d S^2 + \left[L_i + L_g\right]\right)}$$

The controller $G_i(S)$ is responsible for reference signal tracking. It consists of a damped generalized integrator tuned to resonate at the grid frequency W_0 . The structure of PR controller is as follows. Where the proportional gain is tuned in the same way as that for a PI controller, and it basically determines the dynamics of the system in terms of bandwidth, phase, and gain margin. According to the analysis proposed in [9] it seems reasonable to select a high value resonant gain K_{ir} in order to obtain a high attenuation of current harmonic, a low value of ξ in order to get a low bandwidth so that the selective harmonic compensation is effective for PR structure shown in (2). G_{inv} (s) is the transfer function of the inverter bridge, which is modeled as a first order lag system with time constant equal to 1.5 times the switching period. Fig. 5 shows the Bode plot of the inner current loop with and without Current controller.

4.2 Grid Synchronizer

The grid synchronizer consists of two parts: 1) a grid voltage estimator, and 2) an amplitude identifier [11]. The grid voltage estimator takes the grid voltage as the input and outputs two signals. One is aligned with the grid voltage (parallel component), and second signal that leads the grid voltage by (orthogonal component). The state space form of the estimator

4.2.1 Dynamic Modeling of Boost Converter

The main objective of the boost converter is to track the maximum power point of the PV array by regulating the solar panel terminal voltage using the power voltage characteristic curve.

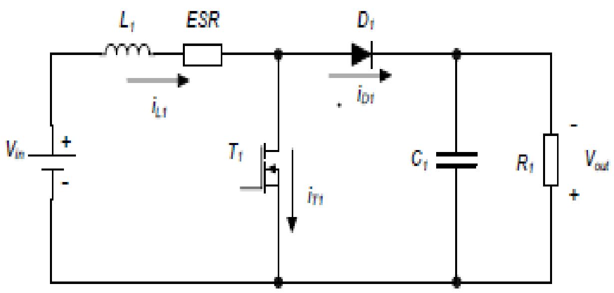


Fig.4. Boost Converter

$$Vin - L\frac{di_1}{dt}(1-D)V_C - ESRi_1 = 0$$

$$i_{D1} = i_{C1} + i_{L1}$$

$$\begin{bmatrix} \dot{i}_{L_1} \\ \dot{v}_{C_1} \end{bmatrix} = \begin{bmatrix} \dfrac{-ESR}{L_1} & \dfrac{-(1-D)}{L_1} \\ \dfrac{1-D}{C_1} & \dfrac{-1}{R_1 C_1} \end{bmatrix} \begin{bmatrix} i_{L_1} \\ v_{C_1} \end{bmatrix} + \begin{bmatrix} \dfrac{1}{L_1} \\ 0 \end{bmatrix} \left[V_{in}\right]$$

$$\left[V_{Out}\right] = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_{L_1} \\ v_{C_1} \end{bmatrix} + [0]\left[V_{in}\right]$$

V MODELING OF BATTERY

Battery acts as a constant voltage load line on the PV array and is charged both by PV array and induction generator .the battery is modeled as a nonlinear voltage source whose output voltage depends not only[8-9] on the current but also on the battery state of charge(SOC), which is non linear function of the current and time :

$$V_b = V_O + R_b i_b - K \frac{Q}{Q + \int i_b dt} + A \exp\left(i_b dt\right)$$

VI SIMULATION RESULTS

In order to predict the comparative performance of the MPPT techniques, simulation studies of the single phase grid connected PV system shown in Fig. 1 are carried out on MATLAB/SIMULINK platform. The specifications for the solar module used in the simulations study, corresponding to two different irradiation levels (1000 and 600W/m2) are The grid connected PV inverter system is subjected to a rapid irradiation level is changed from 1000 to 600W/m2 at t=2s and reverted back to 1000W/m2 at 3s as shown in Fig. 8. The temperature is considered to be constant (25 0 C) during the simulation.

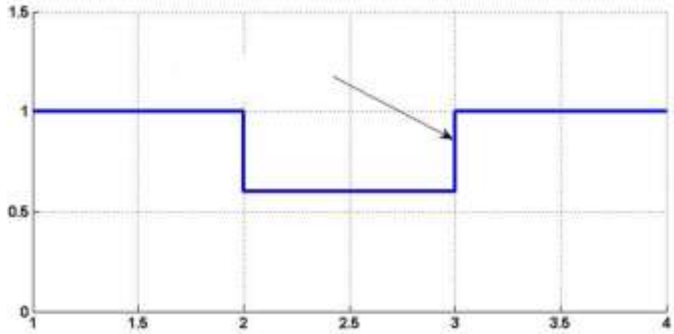


Fig.8. Step change in Irradiation level

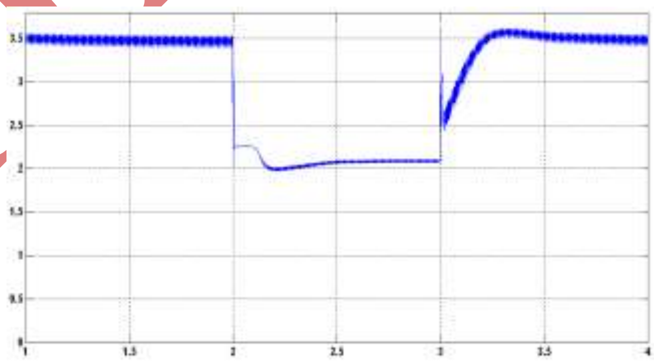


Fig.9.(a) Current (Ipv) Waveform of PV module with RCC-MPPT.

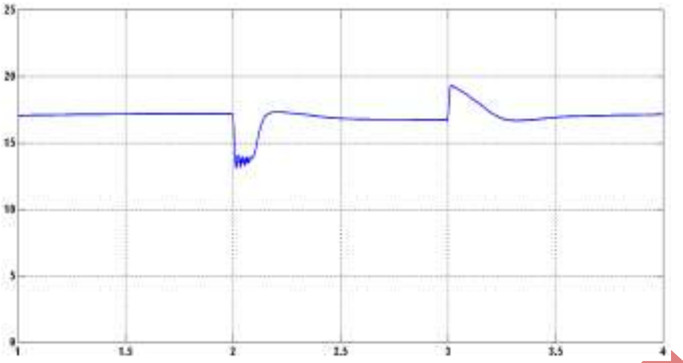
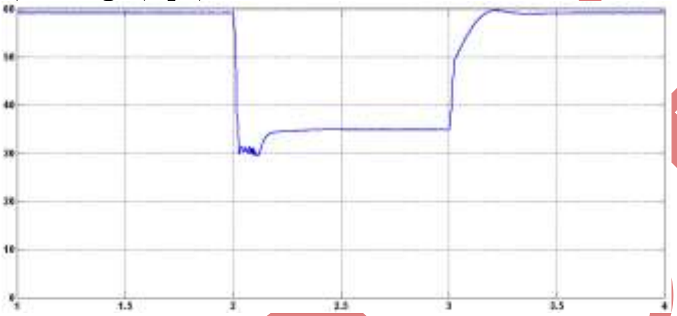


Fig.9.(b) Voltage (Vpv) Waveform of PV module with RCC-MPPT



PV Power (Ppv) Waveform of PV module with RCC-MPPT.

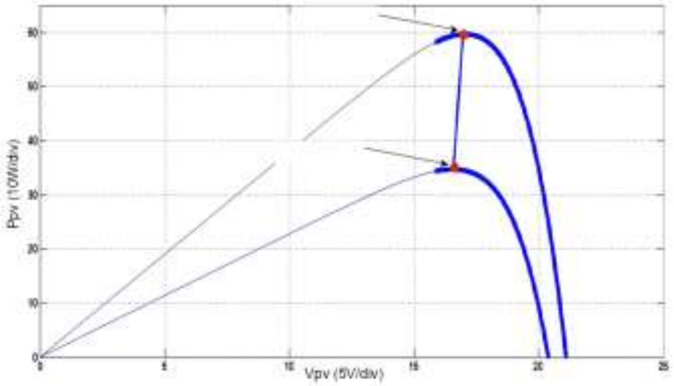


Fig.10. PV Power Ppv versus Vpv for step change in Irradiation.

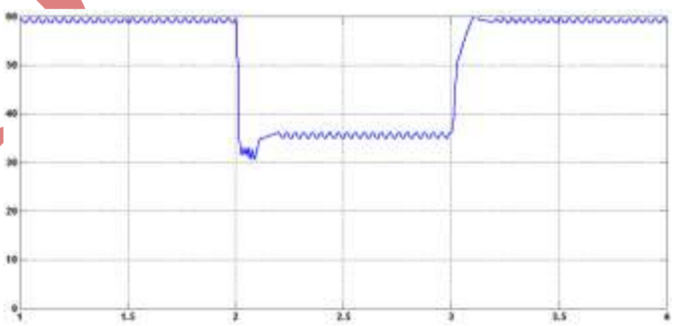


Fig 11. PV Power(Ppv) Waveform of PV module with MRCC- MPPT.

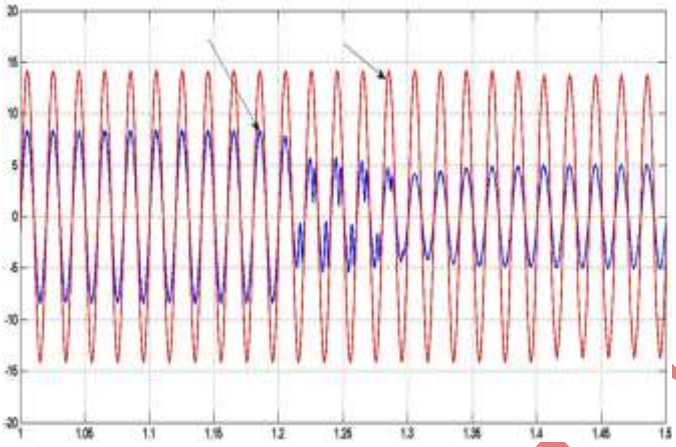


Fig.12. Transient Response of Grid Current.

VII PARAMETERS FOR PHOTOVOLTAIC PANEL

TABLE:1

Parameter	Symbol	Value
Grid voltage(rms),frequency	V_g, f_g	10V,50Hz
Rated output current(rms)	I_g	6A
Nominal DC link voltage	V_{dc}	21.1V
DC link capacitor	C_{dc}	3300µF
Grid side inductor	L_g	60µH
Inverter side inductor	L_i	460µH
Filter capacitor	C_d	2µF
Filter damping resistor	R_d	1.5Ω
Switching frequency	f_{sw}	20kHz
Proportional gain of current controller	K_{pi}	6
Resonant gain of current controller	K_{ri}	100
Damping ratio of current controller	ξ	0.01
Proportional gain of voltage controller	K_p	0.5
Integral gain of voltage controller	K_i	10
Filter time constant(sec)	τ	0.05

VIII. CONCLUSION

In this paper, design of controllers, LCL filter for a singlephase grid connected inverter system are presented. By employing unipolar switching scheme for the inverter with LCL filter, the current injected into grid is sinusoidal and ripple free. Further, LCL filter can provide good grid synchronization without knowledge of grid impedance. Performance comparison of MRCC-MPPT and RCC-MPPT are done as applied to single-phase single-stage PV inverter. From the results, it is guaranteed that MRCC algorithm results in higher accuracy, faster response as compared to the RCC algorithm for generating the MPP reference voltage. A low complexity grid synchronization method ensures that the VSI is well synchronized and the grid current is in phase with the grid voltage even under grid disturbances ensuring unity power factor operation of the inverter.

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