Single phase Grid system using single stage connection

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ABSTRACT
The electricity sector in the country have many critical issues regarding the electricity supply, so the renewable energy policies have increased the consumption of solar energy. This paper proposes the single stage inverter with MPPT (maximum power point tracking) and one cycle controlled (OCC) for the grid connected PV system. OCC scheme is predicated on the current adjustment of the output signal. Schemes predicated on OCC do not require the accommodation of a PLL (phase locked loop) for interfacing the inverter to the grid. these schemes are increasingly being used for such applications. As compared to the previous schemes, it requires less number of sensors i.e. only two. The maximum power extracted from the PV array uses Perturb and Observation method.

General Terms
Grid system, single stage connection.

Keywords
One Cycle Control (OCC), Maximum Power Point Tracking (MPPT), Photovoltaic (PV) array, Single phase grid connected inverter, Perturb and observation method.

1. INTRODUCTION
With the rapid increase in the industrial area, the consumption of fossil fuel is increasing day by day. With the rapid increase in the pollution, the environment is incrementing ecumenical warming and is damaging ecological. Due to these, there is a requirement to increase the use of renewable energy in the environment, also there are many renewable energy sources available in the environment such as solar, wind, tidal etc. Among all these renewable energy sources, the solar energy is obtainable on a large scale so that the renewable energy sources can be used to a large extent & there is ordinant dictation for photovoltaic (PV) panel. The output voltage is varied along with current on a PV panel with irradiation, panel temperature and the power loading is nonlinear. Under certain conditions in atmosphere, there exists maximum power point. To extract maximum power from the PV panel, large number of researchers have proposed, maximum power point tracking (MPPT) algorithms which include voltage feedback method [1].

In this paper there are discussions about photo voltaic cell connected to the grid. A grid connected photo voltaic system is very popular because of their application in distributed generation and for utilizing efficiently the PV array potency. The symbolic grid connected PV system is shown in the fig 1. In a grid connected PV system there are many power processing stages [2], [3].The first stage involves dc –dc conversion. It extracts maximum power by utilizing a maximum power point tracking (MPPT) method. The second stage is to invert D.C. to A.C. conversion. It then aliments to the grid.

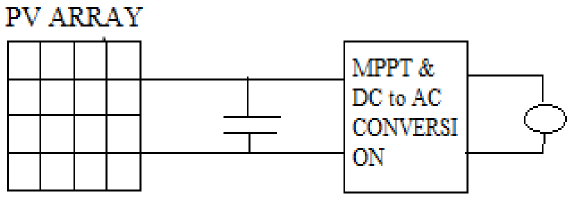


Fig.1 A generic grid connected PV system.

The inverter makes sure that whatever amount of potential energy is extracted from solar array, it is being dumped on the grid. This is achieved by maintaining the dc-link voltage to a set reference value. The single stage inverter performs two functions like two stage systems: 1) to obtain maximum power by utilizing MPPT algorithm. 2) the potencies are distributed to the grid by maintaining the power quality discipline of the utility. The grid connected PV system consist of: two current control loop, an expeditious inner current controller which regulates the current injected to the grid. It also maintains the prescribed total harmonic distortion (THD) and also power factor, while a slow outer current control loop incorporates the MPPT algorithm employed. When PV system is interfacing to the grid, it requires phase lock loop (PLL). Designing a PLL for interfacing with the grid is always difficult to propose considering the non-idealities as of frequency variation and harmonic distortions present in the line voltages [4]. The system based on OCC does not require the accommodation of PLL [5]-[7].

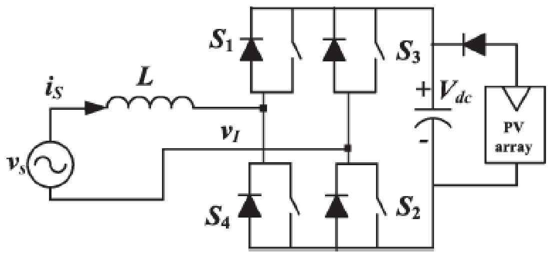


Fig.2 1 phase single stage grid connected PV system

Due to the current controller loop the operations become faster. Single phase Grid system using single stage connection with one cycle control can be operated at maximum power point tracking. For obtaining maximum power, OCC is using perturb and observed method at maximum operating power point.

2. VOLTAGE-SENSORLESS OCC BASED INVERTER for PV SYSTEM
A single stage grid connected photovoltaic system which has a single phase full bridge voltage source inverter (VSI) is shown in Fig. 2. The inverter switches are controlled to give an output voltage whose fundamental component is VI1. By controlling the phase and magnitude of VI1 through a (PWM)

strategy, the continuous flow from the solar array to the grid can be obtained and controlled while maintaining a limit of high power factor and low harmonic distortion in it. Considering the phasor model of the system as shown in fig. 5 and assuming the system to be lossless, the expression for good quality power flow from the inverter to grid can be expressed as under:

$$P = \frac{VI1\ Vs\ sin\delta}{\omega L} \qquad (2.1)$$

where Vs is the grid rms voltage, Is the grid frequency and δ is the phase angle between fundamental component of the output voltage of inverter and grid voltage. The inverter used cannot be controlled with fundamental OCC predicated control technique as the rudimental OCC predicated schemes exhibit instability in the operation when the converter which is involved is operated in an inverting mode of operation [8], [9]. In order to resolve this problem, a modified OCC (M-OCC) predicated scheme has been used. The scheme presented in [9] does not require the use of a PLL, it needs to sense instantaneous grid voltage. In the scheme reported in [9], the grid voltage which is sensed is multiplied by a constant gain to produce a fictitious current signal that is in phase with the grid voltage. The fictitious current signal is integrated to the original current drawn by the inverter. The sum of the two signals is then used by the OCC core controller to produce gating pulses for the inverter switches as shown.

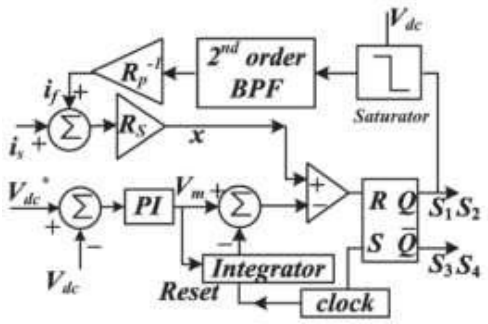


Fig.3. control block diagram of voltage sensor less grid connected PV system

The scheme proposed in the paper does not sense the voltage to produce the fictitious current signal that is required to resolve the issue of instability in OCC predicated inverter. It combines the required fictitious current signal by multiplying the fundamental component of the output voltage of inverter with a constant gain. Information of the inverter output voltage is obtained from switching function used to fire the inverter switches. It is not by sensing the inverter output voltage per sec. The control block diagram of the proposed scheme is as shown in Fig. 3. The dc link capacitor voltage is sensed in the figure and compared with a set reference, and the error so produced is given to a proportional and integral regulator to produce a signal Vm. A sawtooth waveform with constant frequency having peak to peak value of voltage of 2Vm is produced utilizing a resettable integrator. A free-running clock which has a duration of Ts is utilized to reset the integrator, hence, the frequency of the clock T−1s decides the frequency of sawtooth waveform and also the switching frequency of the contrivances. The time constant of integrator Ti is opted to be a part of Ts as expounded in [7]. A fictitious current signal that is proportional to the fundamental component of the voltage output of inverter (if = VI1/Rp) is integrated with source current and proportionally scaled to obtain the modulating signal x.

Where

$$X = Is + If = Is + \frac{V1}{Rp} \qquad (2.2)$$

In order to obtain VI1 and if the inverter switching pulses are passed through the saturator, the output of the saturator moves between the scaled dc link voltage and zero in response with the pulsation of switching sequence between the state one and zero. The signal in proportion to VI1 is obtained by filtering the output of saturator. The harmonic spectrum of saturator output has: 1) a fundamental frequency component (50 Hz); 2) a dc component; and 3) higher frequency components centered about multiples of switching frequency. Hence, a Band Pass Filter (BPF) is required to revive the fundamental component of the signal and remove the dc and higher order components. A second order BPF which has a central frequency identical tantamount to the original frequency (50 Hz) is utilized for the purport. The circuit diagram is shown in Fig. 4. The modulating signal is multiplied by gain Rs and is compared with the sawtooth waveform to produce the switching pulses. At every increasing edge of the clock pulse, S3 and S4 are turned on that leads to the increment in source current Is. When the modulating signal becomes identically similar to the sawtooth waveform, S3 and S4 are turned off and then S1 and S2 are turned on so the modulating signal is decreased. The elevating and falling slopes of Is is given by (Vs + Vdc) / L and (Vs − Vdc) / L, respectively, where Vs is utility voltage, Vdc is the dc link capacitor voltage, L is the magnitude of boost inductor. The modulating signal x is being compared with sawtooth waveform to produce the switching pulses.

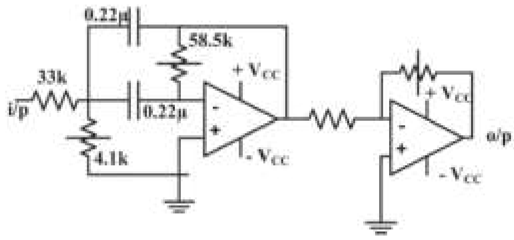


Fig. 4-Circuit diagram of analog implementation of BPF

When x is below the sawtooth waveform, S3 and S4 are on, and output voltage of the inverter is −Vdc. When x is greater than the sawtooth waveform, S1 and S2 are turned on and the output voltage of the inverter is +Vdc. Therefore, the average output voltage of inverter during switching duration (time period of the sawtooth waveform) is

$$Vm = \frac{Vm-X}{2Vm}(-Vdc) + \frac{Vm+X}{2Vm}(-Vdc) = \frac{Vdc\ X}{Vm} \qquad (2.3)$$

Therefore, it can be seen from equation (3) that the average output voltage of inverter in a switching duration is proportional to modulating signal x. Furthermore, the fundamental component of the inverter output voltage will be in phase with modulating signal. By combining (2) and (3), the expression for the output voltage of inverter averaged over a switching time period is gathered as follows:

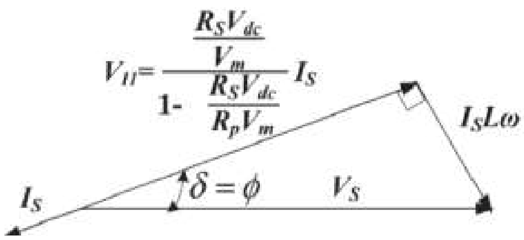


Fig.5.Phasor diagram depicting the steady-statecomportment of the proposed voltage-sensor lesssystem.

$$Vm = \frac{Rs\,Vdc}{Vm}\left(Is + \frac{V1}{Rp}\right) \qquad (2.4)$$

From the above expression, it can be obtained that Vi and Is have a phase shift of either 0◦ or 180◦ in between each other. The phasor diagram showing the grid voltage, the fundamental component of the output voltage of inverter, and the drop along the series filter inductance is depicted in Fig. 5 for the inverting mode of operation.

3. MPPT IMPLEMENTATION USING P&O METHOD

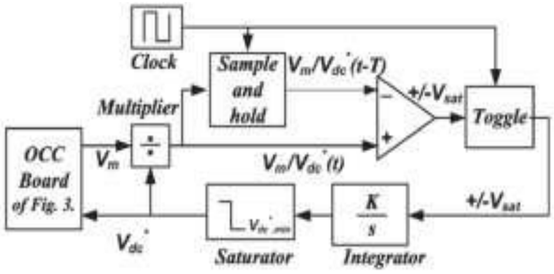


Fig. 6.block diagram of MPPT realization

P&O method is one of popular methods to track the maximum-power point [10]. Implementing MPPT by P&O method is generally done. It is done by utilizing DSP or microcomputer. But digital circuitry and discrete analog can add the utilization for the purport [11]. The following figure shows the analog controller which is proposed in this paper to implement P & O method. In the figure, the controller consists of analog multiplier, sample and hold circuit, a free-running clock, an integrator, and a toggle switch.. The P&O controller receives the Vm signal from the OCC controller of Fig. 3. The output of the controller is Vdc* which sets dc link voltage reference that is required by the OCC controller of Fig. 3. An integrator is connected to the output of a toggle flip-flop which engenders the voltage reference Vdc*. P&O cycle decides the period of a free running clock that sets sampling instants for the sample and hold circuit and also toggling instants for the toggle flip-flop. To understand the working of the MPPT controller, the typical variations of different signals of MPPT controller block are shown in Fig. 9. Depending on the output level of toggle flip-flop, Vdc* can have either an elevating / falling slope. The rate of vicissitude in Vdc* is kept much more small than the control bandwidth of the OCC controller.

4. SIMULATION AND EXPERIMENTAL RESULTS

In order to prognosticate the performance of the proposed study of one cycle controlled (OCC) voltage sensorless grid connected system, detailed simulation studies are worked out on MATLAB– Simulink platform. In order to show that, the proposed voltage sensorless scheme does not have the difficulty of current instability while the operation in inverting mode, a model of the system shown in Fig. 2 is simulated [12]. The parameters which the inverter culled for the purporse of simulation [12] and the controller are as follows:

Table 1: Parameters

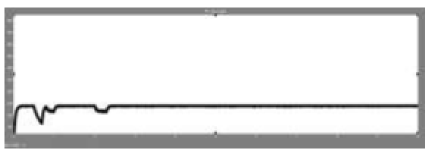
Sr. No.	Parameter	Value
1	Switching Frequency	20 kHz
2	DC-link Capacitor	2200 µF
3	Series Inductor	2 mH
4	Rp	1.5 Ω

The utilization of the designations for the solar array in the simulation study are provided in Table I, corresponding to 1000W/m2 and 800W/m2 insolation levels. The dc link reference is externally set to 220 V. The grid is considered as a 230 Vrms 50-Hz system.

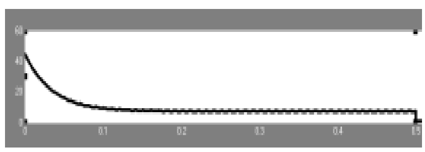
Table 2: Pv Array Specifications

Peak Power (Pp)	2KW	1.5KW
Peak Power Voltage (Vmp)	220V	188V
Current at peak power (Imp)	8.8A	6A
Open circuit voltage (Voc)	230V	195V
Solar isolation	1000W/M^2	800 W/M^2

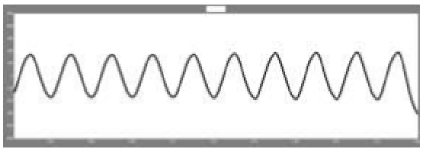
When isolation level abruptly changes from 1000W/m2 to 800W/M^2, the DC link voltage suddenly falls at 188V and current is changed from 8.8A to 6A. And maximum power output of PV array is changed from 2kw to 1.5kw at 3 sec. After 8 sec, the voltage, current, power is settle back to the initial value. Fig. 6 shows the simulation results as the waveforms of the DC link voltage, DC link current, and Grid voltage abruptly transmuted from 1000W/m2 to 800W/m2.



Dc link voltage



Dc link current



Grid voltage

Fig 6. show the a) dc link voltage b) dc link current c) grid voltage

From the simulated performance, it can be concluded that the system supplies the maximum power from the PV array to the grid. The transient performance of the system can be optically found out during the vicissitude in insolation levels. It can also be observed from the simulated performance that vicissitudes in PV current and dc link voltage are smooth during the transmutation which implicatively insinuates a proper transient performance for the system. The steady-state source current, the fictitious current signal, grid voltage, dc-link voltage obtained from the filtered output of the switching pulses of the inverter are shown in Fig. 5.

It can be noted that the grid voltage and source current are virtually 180 out of phase which demonstrates the inverting mode of operation. The quantity qualified harmonic spectrum of the current supplied by the system to the grid, the grid voltage from which it can be inferred is all the low order harmonics to that of the fundamental component. As an OCC predicated scheme has itself an equipollent impedance to the grid, disturbances present in the grid voltage does not appear in the current drawn by the system from the grid.

5. CONCLUSION

An M-OCC predicated single phase grid system using single stage connection has been proposed. The circumscription of using the subsisting OCC predicated inverters, such as, requisite to sense the grid voltage which requires to tackle the instability quandary, is resolved in the proposed scheme. The proposed scheme is functioned on a single stage of potency conversion and is to realize by utilizing less number of sensors compared to that of the conventional schemes. Further, the main controller of the proposed scheme can be realized by designating very simple analog controller. All the mentioned features of this scheme can make it an ideal candidate for very small and distributed single phase grid connected PV systems. Detailed simulation studies have been solved to verify the efficiency of the scheme. The viability of the scheme has been confirmed by performing detailed simulation studies.

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7. REFERENCES

[1] M. Calais, J. Myrzik, T. Spooner, and V. Agelidis, “Inverters for single phase grid connected photovoltaic systems—An overview”, in Proc. IEEE Power Electron. Spec. Conf., June. 2002, pp. 1995–2000.

[2] Z. Salameh, F. Dagher and W.A. Lynch, “Step-Down Maximum Power Point Tracker for Photovoltaic System”, Solar Energy, vol. 46, no. 1, 1991, pp. 278-282.

[3] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, “Power inverter topologies for photovoltaic modules—A review”, in Conf. Rec. IEEE IAS Annu. Meeting, vol. 2, 2002, pp. 782–788.

[4] Dezso Sera,, Laszlo Mathe,, Tamas Kerekes, Sergiu Viorel Spataru, and Remus Teodorescu, “On the Perturb and-Observe and Incremental Conductance MPPT Methods for PV Systems”, IEEE journal of Photo Voltaics, vol. 3, no. 3, July. 2013.

[5] Q. Chongming and K. M. Smedley, “Unified constant frequency integration control of three-phase standard bridge boost rectifiers with power factor correction,” IEEE Trans. Ind. Electron., vol. 50, no. 1, February. 2003, pp. 100–107.

[6] K. Chatterjee, D. V. Ghodke, A. Chandra, and K. AlHaddad, “Simple controller for STATCOM - based Var generators”, IET Power Electron., vol. 2, no. 2, March. 2009, pp. 192– 202.

[7] D. V. Ghodke, K. Chatterjee, and B. G. Fernandes, “Modified one cycle controlled bi-directional high power factor AC to DC converter”, IEEE Trans. Ind. Electron., vol. 55, no. 6, June. 2008, pp. 2459–2472.

[8] K. M. Smedley, L. Zhou, and C. Qiao, “Unified constant frequency integration control of active power filters—Steady-state and dynamics”, IEEE Trans. Power Electron., vol. 16, no. 3, May 2001, pp. 428–436.

[9] B. K. Bose, P. M. Szezesny, and R. L. Steigerwald, “Microcontroller control of residential photovoltaic power conditioning system”, IEEE Trans. Ind. Appl., vol. 21, no. 5, September. 1985, pp. 1182–1191.

[10] D. V. Ghodke, E. S. Sreeraj, K. Chatterjee, and B. G. Fernandes, “One cycle controlled bi-directional AC to DC converter having constant power factor operation”, IEEE Trans. Ind. Electron., vol. 56, no. 5, May 2009, pp. 1499– 1510.

[11] Sreeraj E. S., Kishore Chatterjee, and Santanu Bandyopadhyay, “One-Cycle-Controlled Single-Stage Single-Phase Voltage-Sensorless Grid-Connected PV System”, IEEE Trans. Ind. Electron., vol. 60, no. 3, March 2013.

[12] G. Petrone, G. Spagnuolo, R. Teodorescu, M. Veerachary, and M. Vitelli, “Reliability issues in photovoltaic power processing systems”, IEEE Trans. Ind. Electron., vol. 55, Jul. 2008., no. 7, pp. 2569–2580.