Disaster Management using P-Q controll in PV Inverter

Mayank Pande
PhD Scholar
Jamia Millia Islamia
New Delhi, India
mayank1400@rediffmail.com

Prof Zaheeruddin
Department of Electrical Engineering
Jamia Millia Islamia
New Delhi
zaheeruddin@jmi.ac.in

Abstract— **Disaster Management of distribution line using reactive and active power control by the control of PV inverter is nowadays becoming the most popular method of mitigating the disaster. Simplified Reactive Power Control (SRPC) strategy for single-phase grid-tied Photovoltaic (PV) inverters. The reactive power control or injecting the reactive power into the grid can be efficiently done by the PV inverter By the MPPY algorithm the PV panels draws the power and the need of the active power by the connected loads are met with the help of PV inverter. Simplified power calculation basically calculates the reactive power needed by the grid system to mitigate the occurrence of disaster**

Keywords— Current Mode Asynchronous Sigma Delta Modulation (CASDM), Photovoltaic (PV) Inverter, Reactive Power Control (RPC), Single-Phase, Disaster Management.

I Introduction

In the present scenario it is observed that the energy demand is increasing and it is well obvious that the sources of fossil fuels is depleting day by day. Due to pollution caused by the conventional methods of power production, non conventional energy sources have been explored in the near past and due to excellent R & D ,these have proved to be commercial successful . Photovoltaic power generation is preferred in the residential colonies as the running cost is negligible and the sound pollution is minimum. Inverters have the added advantages that they can inject both active and reactive power into the distribution grid. The injection of reactive power helps in keeping the voltage profile flat. The Current Reference Generation which is commonly known as CRG control the reactive power as the required current reference is set according to the power components which are in demand. A number of Reactive Power Control (RPC) strategies for the single-phase inverter are discussed in several papers (3-10). The direct-quadrature (d-q) transformation 3,4 and the instantaneous reactive power theory (the p-q theory) 5-7 may be regarded as the control schemes which can be used to produce the two orthogonal current references.. In (8) a sinusoidal signal integrator is used to monitor and adjust the voltage distortion. Reactive power control can also be done using the discrete Fourier Transform Phase Lock Loop (9). This paper used the methods as described in (13-15), with the modification as per the Indian power condition and parameters. The calculations are made simplified so that the active and reactive power control can be simultaneously done in the distribution network. This mitigates the chances of happening of disaster in the distribution network. The reactive power demand if exceeds the supply may cause the voltage of the system to fall down and the active power demand if exceeds the supply may cause fall in frequency. Both the situations are dangerous and in cascaded manner may cause disastrous situation in the distribution power sector.

The paper involves a simplified calculation which is used for the smooth tuning of power and may be termed as Simplified RPC.

II Simplified Power Calculation

Assumption is made in this paper for the grid voltage that theoretically it is taken as pure sinusoidal. This assumption gives the liberty that the power output of the PV inverter can be had by the value of the injected sine wave current.

The current component ip which is in phase with grid voltage vac is responsible for the production of the active power P, by The current i which is 90 degree out of phase with the voltage vac determines the reactive power Q . The amplitudes of the currents ip and iq can be expressed

$I_p=I_m\cos\theta i$ (1)

$Iq=Im\sin\theta i$ (2)

where Im and 0i are the amplitude and phase angle of the current iac respectively. By controlling the Im and the θi of the current iac, P & Q can be efficiently adjusted which in turn depends upon the demand. The control of the P&Q in the PV inverter is explained with the help of waveforms of the grid voltage and the waveform of current as illustrated in the Fig 1.

The voltage and current waveforms equation can be expressed as $V_{ac}(t)=V_m\sin\omega t$ (3)

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$I_{ac}(t)=I_m\sin(\omega t-\theta i)$
(4)

where w is the line frequency of the ac radians per second.
At time tp the amplitude of the injected ac current.
It should be mentioned that the current i can be measured

$I_{ac}(tp)=I_m\sin(\pi/2-\theta i)$ (5)

by delaying a quarter of the ac line period when the zero crossing point of the ac mains voltage vac is detected. Equation (5) says that the sampled quantity at time tp is equal to the amplitude of the active current component ip Thus, the active output power of the inverter can be determined as

$P_{out}=1/2V_mI_{ac}(tp)$ (5.1)

Similarly, the amplitude of the injected ac current at time t is

$I_{ac}(tq)=Imsin(\pi-\theta i)=Imsin\theta i$ (6)

When the zero crossing of the Vac is found out, the current iq is measured and thus the Qout of the inverter can be calculated by the following equation.

$Q_{out}=1/2Vm\ I\ sin\theta i=1/2Vmiac\ (tq\ )$. (6.1)

The active and the reactive power of the inverter can be easily calculated by two sampled current values within one ac line cycle. To make the inverter may use a Band Pass filter so that the current ripple distortion which may cause wrong calculation of power may be minimized. Hence, it is necessary to have a suitable current control strategy for reduce the current distortion.

The control by varying the amplitude of injected current not only adjusts the reactive power in the distribution network but also mitigates the possibilities of occurrence of disaster in the distribution network. The current control technique is to be designed in such a way so that the smooth control of the active and reactive power control can be achieved with the great accuracy. Such smooth adjustment of power is discussed in the next section.
The PV inverter is known by its ability of suppling both the active and reactive power to the distribution grid.It is not possible with the conventional grid as P has to be controlled from generation side although Q ca be compensated at the load side also.

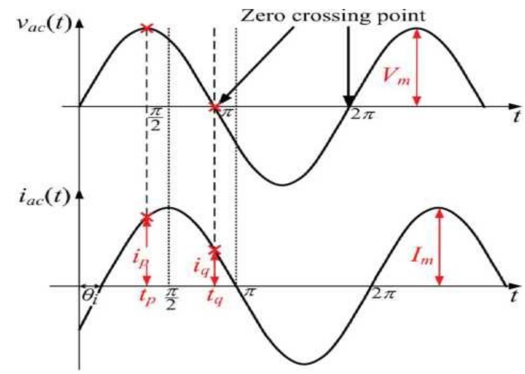

Fig.1 Typical voltage and current waveform of the ac mains

A.*Smooth Power Adjustment*

In order to compensate the power error a well designed controller is needed.Usaually a PID controller is used as its transient response is very fast. As the abrupt variation in the ac output current results in the distortion of current resulting in vague power calculation.

The positive or negative amplitude adjustment AI is determined by the following algorithm:

(a) The current amplitude generator

If $P_{out}>P_{reh}$.I then k=-1;

else if $P_{out}<P_{reh}$.H then k=+1;

else k=0;

$I_m(N+1)=I_m(n)+k\ x\ \Delta I$ (7)

where Im(n) and Im(n+1) are the amplitudes of the injected current reference for the nth and (n+1)th ac mains cycles. As explained earlier the reactive output power Qout is regulated by adjusting the phase angle of the injected current. In the same way, the measured Q is compared with the hysteresis comparator with high bound Qref,H and low bound Q ref,L

.
The positive or negative phase shift adjustment Aθ is determined by the following algorithm:

(b) The current phase angle generator

If $Q_{out}>Q_{reh}$.I then m=-1;

else if $Q_{out}<Q_{reh}$.I then m=+1;

else m=0;

$\theta i(N+1)=\theta i(n)+m\ x\ \Delta i$ (8)

where V(n) and θi (n+1) are the phase angles of the injected current reference for the nth and (n+1)th of ac mains cycles.

It is well obvious that the Pout and Qout vary cosine and sine functions, respectively. Therefore, for θ. close to 90 degree and Pout - Qout, any change in the current will result in the appreciable variation in Qout and any variation in the phase angle results in the appreciable change in the Pout.

It is observed that if ΔI and Δθ are too small the transition of the power consumes more time. Hence it is desirable to keep the value of ΔI and Δθ more during large power change transient and smaller on the value is kept small during steady state, resulting in the noticeable improvement.

Figure 2 illustrates the single phase PV inverter with the help of labeled block diagram of the same. The power stage of the PV inverter consists of a boost converter with the Maximum

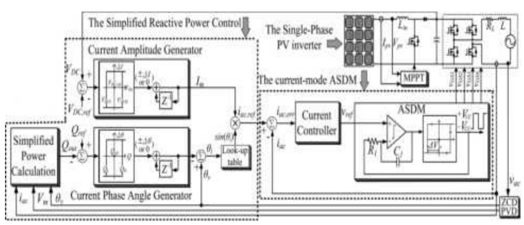

Fig.2 Block diagram of the single-phase grid-connected PV inverter.

Power Point Tracking (MPPT) function its full bridge inverter with both active and reactive power output.

Both, SRPC method and the CASDM control strategy are incorporated in the control algorithm. The main Moto of designing the PV inverter is to draw the maximum power from the PV panels to deliver the required active power to the distribution grid so as to maintain the frequency which otherwise would cause the fall in frequency which may in turn lead to the disaster . Simultaneously, the output reactive power Qout which is had by the simplified power calculation and the reference reactive power Q ref are continuously compared and the phase shift of the current reference θi. The Peak Value Detector (PVD) and the Zero-Crossing Detector (ZCD), are used to know the amplitude and the phase of the voltage at the grid, respectively. The ZCD along with the PVD are the user friendly techniques .We can also use a well designed PLL circuit which appreciably enhance the performance of SRPC method..

B. *Current Control Strategy*

The Current or voltage loop is used in the design of hysteresis controller. In the design of the controller we take the saw tooth carrier, linear modulation and power rejection ratio as infinity.

For the active power control the regulation of V_{dc} is done by the set of hysteresis controller and current amplitude generator.

The algorithm of the current amplitude generator is very simple to understand and the V_{dc} can be varied with the help of this algorithm. The algorithm is well explained in the following few simplified steps.

if $V_{dc} \geq V_{dc}$ H then k = +1

else if $V_{dc} \leq V_{dc}$ L then k = -1

else k = 0

I_m (n+1) = I_m (n) + k x Δ I

Hence it is well obvious that the output current is contineosly compared with the reference current and the error signal is fed to the current controller and the generation of the reference voltage V_{ref} is had which is utilized in the current control PV inverter active power control..

Fig.3 and fig 4 shows the active and reactive power generated by the PV inverter and load angle and inverter output voltage respectively

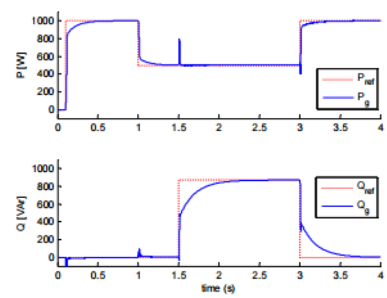

Fig.3 Active and Reactive Power supplied by the inverter with 100%-50%-100% of photovoltaic system.

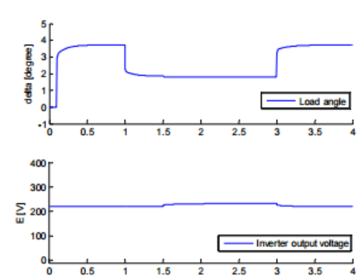

Fig.4 Load angle δ [degree] and Inverter output voltage E [Vrms].

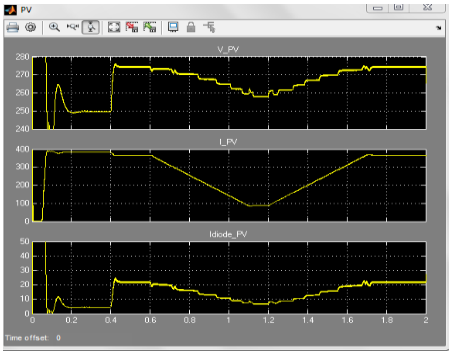

Fig. 5 Showing V I and I diode PV during disaster period and after resume of normal situation of distribution network

III Simulation and Results

The simulation is done with the MAT-LAB / SIMULINK . The P and Q is supplied by the inverter with 100% - 50 % - 100 % of photovoltaic power Fig 3. Graph of Load angle and inverter output voltage is obtained with clearly shows how the active power can be controlled by changing the load angle although the graph is drawn for inverter output voltage but the injection of active power is done by changing the load angle of the inverter. The graphs shows clearly the diode current of the inverter is varied and load angle is also varied depending upon the requirement of active and reactive power Fig 5

(SRPC) strategy for single-phase grid-tied photovoltaic (PV) inverter is applied to the inverter to obtain the desired results. The combination of SRPC and CASDM gives better results with the harmonic distortion at the low current Typical graphs showing the injection of active and reactive power due to the control in the inverter showing the injection of active current to compensate active power demand.

With both the SRPC and CASDM, the single-phase PV inverter can achieve the desired RPC with low current harmonic distortion.

IV Conclusion

This paper used SRPC method and CASDM with RPC applied to a single phase grid connected inverter.. The active and reactive power is supplied by the inverter as per requirement in islanding mode which in turn also to mitigate the occurrence of disaster in the distribution network. The demand of the active and reactive power is met by injecting the required power by the inverter. This adversely affects the power quality If a well designed filter is used and the response time of the change in load angle is done, better results can be obtained. The present trend to meet out the sudden/fluctuating demand both active and reactive with the help of PV inverter is very popular in the countries where abundance of sun energy is available throughout the year. Hence it has become the topic of R & D and everyday more and more solutions are coming to improve the power quality of the PV inverter

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