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Study on Enhancement of Output of Grid Tied PV Systems under Symmetrical and Asymmetrical Faults

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Abstract: High performance grid-tied inverters have stringent control requirements both under steady-state and under transient conditions. Many different control systems can be applied to grid-tied inverters. High quality voltage and current are required when PV generator is connected to grid utility. To this, multilevel inverters can be used as connection interface. Efficiency enhancement scheme of a multilevel grid-connected inverter for renewable energy generation systems is researched in detail. This paper has widely reviewed the existing MLIs came to under the categories of Symmetric, Asymmetric, Hybrid and Single DC source based structures, realizing high-quality output waveform being specially designed for medium to high-power applications. Thereby a detailed investigation have been done for each topology and category. Further enhancement can be done by using MPPT algorithms.

I. INTRODUCTION

Nowadays, an increase in demand for energy brings about some problems such as grid instability, outage, etc. for power distribution [7]. Using distributed power generation system (DPGS) is a reasonable solution for these problems, because it causes more flexibility, balance, and stability for the grids. Also, it can improve the management of distribution networks and reduce the released Carbon [8]. Photovoltaic systems, wind turbine systems, and energy storage systems like battery bank, fuel cell, and active filter are examples of DPGS.

The output voltage of this system is usually DC, but it should be converted to AC before being discharged into the grid or used by

various loads. Therefore, in the grid connected DPGS, inverters play a key role in enabling the DPGS to convert the DC voltage and current to AC and deliver them to the grid. The delivered energy enjoys special properties and standards, so it should be controlled before delivering. Thus, it is necessary to use a suitable controller for inverters modifying the type of energy and power. In fact, the inverter and its controller are an interface between DPGS and the grid to transfer the high quality power. Since the grid wave shapes are AC and sinusoidal, the DPGS output should be sinusoidal as much as possible. Connecting DPGS to the grid is very important since it results in numerous problems including the grid instability and disturbance if no suitable controller is designed for it. That is why these systems should be able to overcome the grid distortions. Thus, a high-speed controller along with a compatibility algorithm is needed in this regard.

Also, the design of the controller is fundamental and considerable. Instability and failure taking place on the grid are the result of an inappropriate design for the controller. Only an applicable controller can contrast to grid distortion [7]. Fig. 1 illustrates a general structure for distributed systems.

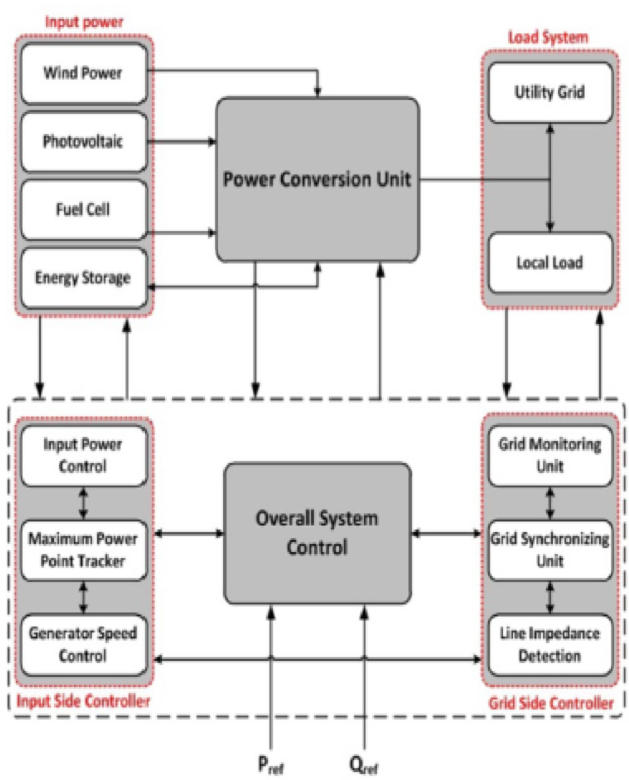

Fig. 1: General structure of DPGS with different power sources

Depending on the connection of the generation system to the utility network or to local loads, the power produced can be delivered to one of them [7].

A power conversion unit includes a single-phase inverter with an Lfilter which is an interface unit between the power generating system and the grid or local loads as shown in Fig. 2.

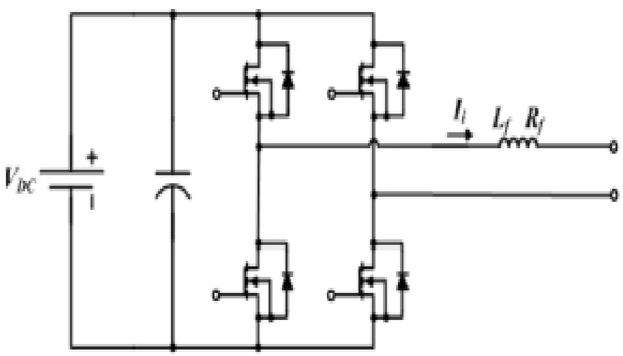

Fig. 2: An example of power conversion unit in DPGS.

Controlling the distributed system is an important issue that can be
divided into two major parts.

1) Input-side controller: The main property of this controller is the extraction of the maximum power that comes from the input
source. Also, input-side converter must be protected by this controller.

2) Grid-side controller: This controller can perform the following tasks:

• control of the active power delivered to the grid;
• control of the reactive power transfer between the grid and the DPGS;
• control of the DC-link voltage;
• assuring high quality of the injected power; and
• grid synchronization.

Furthermore, the grid operator may request ancillary services like voltage harmonic compensation, active filtering or local frequency, and voltage regulation [7].

1.1 PV Generator:

The electrical equivalent circuit of PV module is composed of a current source, a diode, a parallel connected resistor, and a serial resistor which results in the circuit as seen in Fig. 3 [1, 2].

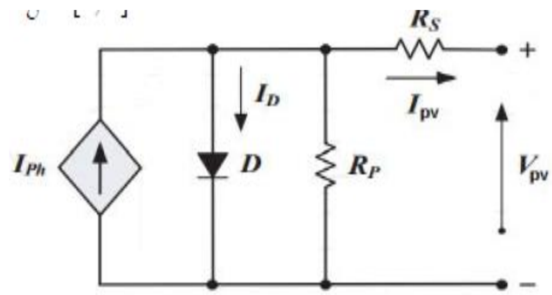

Figure 3: Electrical equivalent circuit of PV cell.

The mathematical model that predicts the current production of the PV cell becomes an algebraically simply model, being the current-voltage relationship defined in Eq. (1).

$$I = I_{pv} - I_s\left(e^{\frac{V+I.R_s}{V_t}} - 1\right) - \frac{(V+I.R_s)}{R_{sh}} \quad ..(i)$$

Where:

Ipv : PV cell output current, A
Vpv : PV cell output voltage, V
Iph : the photocurrent due to incident sunlight, A
Is: The reverse saturation or leakage current of the diode, in A
Vt: thermal voltage
Rs, Rp,a, Ns: series resistance, shunt resistance, ideality factor and number of series PV cells.

1.2 PV Control Structure

Fig. 4 shows the structure of the grid-tied single-phase inverter for PV maximum power point tracking.

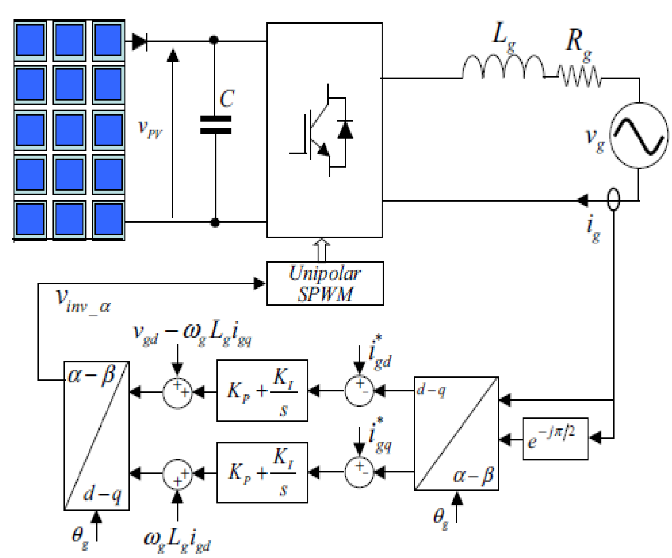

Fig. 4: Control structure of the single-phase grid-tied inverter.

The voltage power characteristic curves of the array for two temperatures and three levels of irradiance are shown in Fig. 5.

The shaded area shows the possible operating zone for the inverter. That is, the zone where the inverter input voltage is higher than the grid peak voltage plus the voltage drop in the inductance.

A synchronous reference frame phase-locked loop (SRF-PLL) is used for extraction of grid voltage phase, frequency, and amplitude

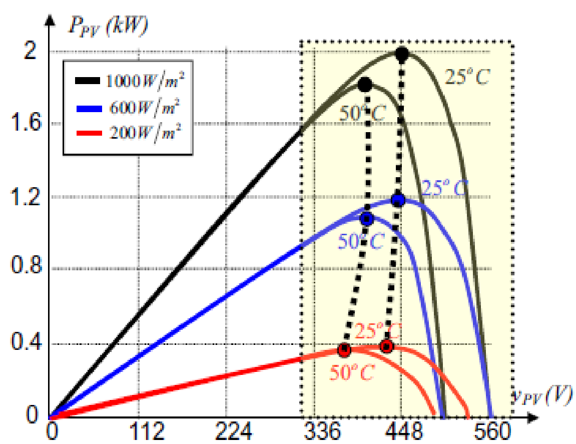

Fig. 5 Used PV array power characteristic curves

The PLL PI controller gains are adjusted as indicated in [3] with a natural frequency of 628 rad/s and a damping factor of 1 (Ghartemani et al., 2012, [4]).

In the DC/AC inverter, the Sinusoidal Pulse Width Modulation (SPWM) unipolar switching technique is implemented. This way, the output voltage high frequency main harmonics appear at twice the switching frequency, improving the current ripple for a given inductance. The inverter DC voltage is measured for feedback purposes with the HCNR201 High-Linearity Analog Optocoupler. However, the low-frequency DC ripple, due to energy fluctuations inherent in a single-phase system (Zhong et al., 2012; Wang et al., 2011, [5]), in PWM converters used in photovoltaic applications shifts the operating point of a panel away from the desired maximum power point tracking condition (Harb et al., 2013,[6]). To remove this ripple in the feedback signal a band-stop filter (BSF) or notch filter is implemented with a reject frequency of 100 Hz and a quality factor of 10.

The PI current controllers have and anti windup scheme to prevent integration wind-up. The controller gains are adjusted to have a bandwidth of 1100 rad/s and a damping ratio of 1. The measured grid voltage and current are delayed 90_ to work in a virtual bi-phase system. This is realized with an all-pass filter where the phase shift is _90_ to the grid frequency.

1.3 VSC DC-Side Model

The schematic diagram of a single stage, three-phase grid connected PV system under study is shown in Fig. 1.6.

The converter is connected to the distribution network (13.8 kV) through a step up Y-D transformer, where the distribution system is modeled using an ideal voltage source vs in series with an impedance Zs. Other loads connected to Bus 1 are also fed by the mains. Based on the power balance between the converter's AC and DC sides, the VSC DC-side voltage dynamics can be written as:

$$\frac{1}{2}C\frac{dV_{DC}^2}{dt} = P_{PV} - \frac{V_{DC}^2}{R_p} - P_{DC}$$ ..(ii)

where C is the DC-side capacitance; V DC is the voltage across the capacitor bank; PPV is the active power converted by the PV panels; Rp is a resistance which models the DC-side losses; and PDC is the active power at converter's DC-side.

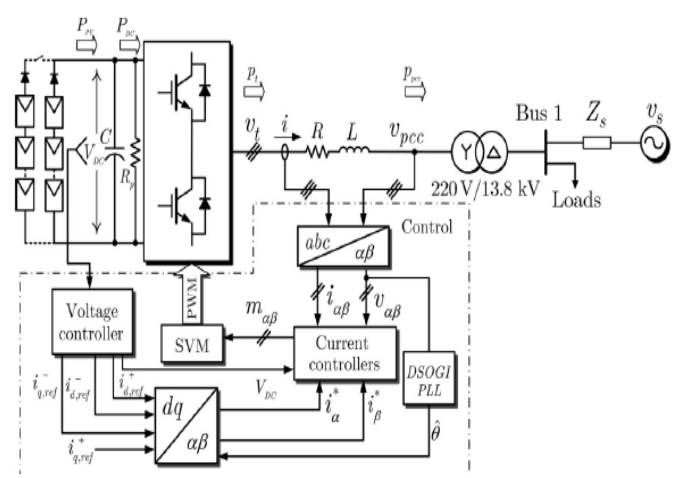

Fig. 6: Schematic diagram of a grid-connected PV system with DC side model

As the switches on losses can be incorporated on the output filter resistance, the power balance between the DC and AC side can be written for a lossless converter. That is, P_{DC} ¼ P_t. Where P_t is the instantaneous active power on the converter's AC-side, which is given by:

$$p_t = p_{pcc} + p_R + p_L;$$ ..(iii)

where P_{pcc}; P_R and P_L are the instantaneous active power at the point of common coupling (PCC), dissipated on the output filter resistors and absorbed by the output filter inductances, respectively.

II. LITERATURE REVIEW

[1] The paper presents a new maximum power point tracking method based on Golden-Section Optimization technique for photovoltaic systems. The proposed method converges to the Maximum Power Point by interval shrinking. At given iteration the algorithm has a new narrowed interval bounded by the new point and one of the initial points according to the evaluation results. The algorithm stops iterating (interval shrinking) when the interval becomes small enough and the photovoltaic system is forced to operate at the average value of the last found interval without perturbing either the voltage or the duty cycle. This makes the photovoltaic sys-tem converges rapidly to the maximum power point without voltage or power oscillations around the maximum power point thereby lower energy waste.

[2] This chapter presents a new algorithm for Maximum Power Point Tracking in PVS. The algorithm uses the Golden Section method to search for the point at which the derivative of the input power versus voltage is zero. The power versus voltage characteristics of the photovoltaic system is a unimodal function making the Golden Section Search technique very suitable. The process of searching uses a variable step to shrink the search space, hence helping to reach the optimum point of the function, the maximum power point, within a small number of iterations. The basic advantage of this search technique is the reduction of tracking convergence time, in comparison with classical techniques with slow convergence time that can lead to instability.

[3] In this paper, the transfer function describing the actual input-output relationship of the conventional SRF-PLL is presented. Using this transfer function, it is shown that the conventional SRF-PLL is a first-order adaptive complex band pass filter. The accuracy of this transfer function is confirmed through numerical results.

[4] An adaptive phase-locked loop (PLL) structure is proposed which offers fast and smooth tracking of phase-angle jumps. Correlatively, it offers soft startup stage and avoids undesired frequency swings caused by phase jumps. The adaptive mechanism adjusts the gain of frequency estimation loop in order to mitigate large transients of frequency during sudden phase angle variations. This reduces the coupling of phase and frequency variables and allows tremendously faster and smoother estimation of both variables.

[5] In this paper, a single-phase PWM-controlled rectifier is taken as an example to analyse the ripple energy that causes the voltage ripples on the DC bus. Moreover, a ripple-current compensator is proposed to absorb/inject ripple energy from/to the DC bus so that the voltage ripples are reduced actively. The compensator is a boost/buck converter with an auxiliary capacitor having a voltage higher than the DC-bus voltage. A repetitive controller is then proposed to compensate the ripple energy on the DC bus instantaneously, with a fixed switching frequency.

III PROBLEM IDENTIFICATION

- Second-order voltage oscillations on the converter's DC-side voltage leads to several unwanted consequences, therefore a control strategy should be incorporated into the classical control to overcome these drawbacks.
- Also change in environmental conditions can lead to variations in the incoming radiations on the PV module which can change the output. This has to optimized in order to maximize the output from the PV module under all environmental problems

IV. CONCLUSION

Integration of dynamic grid support is required for distributed power systems that are interconnected with medium voltage grids. This study proposes a comprehensive control solution to enhance fault ride through (FRT) capability for utility-scale photovoltaic (PV) power plants. Based on positive and negative sequence control schemes and PV characteristics, the approach alleviates dc-bus double-line-frequency ripples, reduces voltage stress on inverter power switches and DC-link capacitors, and minimizes undesirable low-order voltage and current harmonics that are presented on the ac side.

Improving the output of the PV grid various methods can be applied. The improvement in the grid tied inverter topology with controlling on DC side converter can serve the purpose. Along with this, using MPPT algorithm for the improvement can lead to further improvement in symmetrical as well as asymmetrical fault conditions.

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