# Research on Low Voltage Ride Through Control of PV Grid-connected Inverter Under Unbalance Fault

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***Abstract*—In order to solve a series of problems caused by photovoltaic (PV) off-grid, PV must have the low voltage ride through (LVRT) capability ensuring grid-connected operation and outputting reactive power to power grid within a certain time range. At present, the control strategies of PV grid-connected inverter under balance fault have been used effectively. However, the strategy of keeping the inverter stable under unbalance fault is still immature. In view of this situation, the requirement of LVRT is introduced in this paper, and reactive power is firstly output when the power grid is faulty. The negative sequence double current loop control strategy of PV inverter is analyzed to suppress the negative sequence current based on unbalance fault characteristics, and the control strategy is improved combined with LVRT requirements and the constraint of maximum short-circuit current of inverter. Then, a new LVRT control strategy is proposed in this paper, which can not only output reactive power but also suppress negative sequence current. In the end, it was verified that the control strategy proposed in this paper is rational and feasible by PSCAD/EMTDC.**

***Keywords—Photovoltaic (PV) grid-connected inverter, unbalance fault, positive and negative sequence double current loop control, Low Voltage Ride Through (LVRT)***

## I. INTRODUCTION

As a pollution-free and new renewable energy, PV system has more and more penetration in the grid, which has an important influence on the stable operation of the grid [1], [2]. In the case of grid failure, to prevent that the power shortage caused by PV power station off-grid leading to the tripping of adjacent power station, new grid-connected regulation requires that the photovoltaic power station has LVRT capability to ensure grid-connected operation within a certain voltage sags and time range [3]. At the same time, PCC voltage sags will cause a series of harms to photovoltaic devices, such as over current and power fluctuation [4]. 95% of the faults that lead to voltage sags are unbalance faults, according to statistics [5]. Therefore, it is necessary to study the LVRT strategy of PV inverter under unbalance fault to maintain the safe and stable operation of power system with high permeability PV and reduce the damage to PV equipment.

In recent years, many domestic and foreign scholars have studied the LVRT strategy of PV. When the power grid fails, the dynamic resistance is installed on the AC side of the inverter to limit the PV output current in paper [6]. A LVRT strategy with a priority output reactive current is proposed in [7]-[8], but only balance fault is considered and unbalance fault isn't mentioned in it. A grid-connected inverter control strategy that can effectively restrain the negative sequence component of PV output current under unbalance fault, but can't consider the latest PV grid-connected regulation is proposed in [9]. When the network voltage is slightly unbalanced, the control strategy of the inverter is studied in [10]-[11]. A LVRT strategy that the inverter outputs different active and reactive power according to the PCC voltage sags is proposed in [5], this strategy can effectively restrain the two octave fluctuation of the active power which PV outputs, but the PV output current is unbalanced and contains negative sequence components, which affects the power quality of the grid. Up to now, there are few literatures about the LVRT control strategy of PV inverter under unbalanced fault, so it is

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necessary to study the LVRT control strategy of PV inverter under unbalanced fault.

State Grid Corporation of China (SGCC) has not made specific demands for reactive current, thus, according to the new standard of German PV LVRT capacity, considering the constraints of the maximum short-circuit current of PV inverter, a LVRT control strategy based on positive and negative sequence double current loop control under unbalance fault is proposed in this paper. The proposed strategy is that the PV inverter adopts positive and negative sequence double current loop control to restrain the negative sequence component of the PV output current and ensure the three-phase balance of the output current; and the inverter outputs the different reactive power according to the sags degree of the positive sequence component of PCC voltage, so as to support the system voltage under an unbalance fault. It was verified that the LVRT control strategy proposed in this paper is rational and feasible by PSCAD/EMTDC simulation software.

## II. PV LVRT REQUIREMENTS

The State Grid published the technical rule for PV power station connected to power grid in 2011, in which LVRT technical requirements are shown in Fig. 1. When the power grid fails, if PCC voltage remains the value above the voltage curve shown in Fig. 1, and the PV power station should be ensured grid-connected operation, if PCC voltage is below the value of voltage curve shown in Fig. 1, PV should be removed from the grid. The values of $T_1$ and $T_2$ are obtained according to the actual situation of power grid. The value of $T_1$ is 1s, and the value of $T_2$ is 3s in the ordinary way.

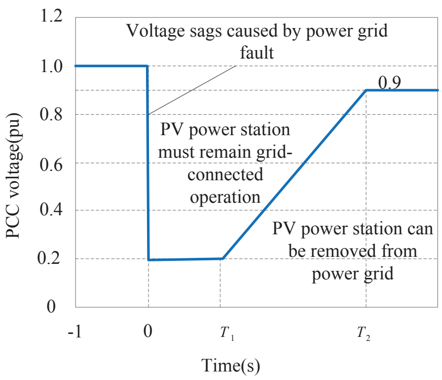


Fig. 1. Requirements of PV station' LVRT ability

The LVRT control strategy proposed in this paper is to control reactive power through reactive current, but SGCC hasn't made specific requirements for reactive current compensation. However, Germany issued detailed requirements for PV LVRT capability in 2008 [12], which specify the relationship between the depth of PCC voltage sags and reactive current compensation, as shown in Fig. 2.

As depicted in Fig. 2, when PCC voltage drops to 90% and above the rated voltage, the PV power station needn't output reactive current. When PCC voltage drops to 50%-90% of the rated voltage, 2% of the reactive current will increase with 1% voltage drops. When PCC voltage is less than 50% of the rated voltage, the PV inverter needs to provide 100% reactive current.

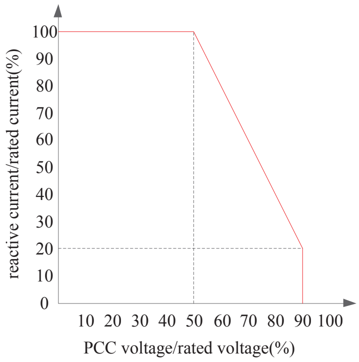


Fig. 2. the required percentage of reactive current during the LVRT

## III. CONTROL STRATEGY OF PV INVERTER

Most of the PV is connected to a neutral non-direct grounded power system. When the grid occurs an unbalance fault, only the positive sequence component and the negative sequence components are in output current of the PV, the zero sequence component is not considered. But the negative sequence current will make AC current of the PV inverter unbalance, make DC side voltage of the PV inverter generate harmonic components, and AC side current of the PV inverter generate odd harmonic components, and it will affect the power quality seriously [13]. Therefore, the positive and negative sequence double current loop control method is introduced, which can suppress the negative sequence current component of PV inverter.

It is necessary to detach the positive and negative sequence components of PCC voltage and the output current of PV inverter in positive and negative sequence of double current loop control method. T/4 delay algorithm can separate positive and negative sequence components only through the arithmetic operation, without increasing the order of the control system so that the stability of the control system is basically not affected. So T/4 delay algorithm is used to separate positive and negative components in this paper. $U_\alpha$ and $U_\beta$, the voltage components in αβ two-phase stationary coordinate system can be obtained through $U_a$, $U_b$ and $U_c$, the instantaneous value of the PCC voltage by Clark conversion.

$$\begin{cases} U_{1\alpha}(t)=\frac{1}{2}\left(U_\alpha(t)-U_\beta\left(t-T/4\right)\right) \\ U_{1\beta}(t)=\frac{1}{2}\left(U_\alpha\left(t-T/4\right)-U_\beta(t)\right) \\ U_{2\alpha}(t)=\frac{1}{2}\left(U_\alpha(t)+U_\beta\left(t-T/4\right)\right) \\ U_{2\beta}(t)=\frac{1}{2}\left(U_\beta(t)-U_\beta\left(t-T/4\right)\right) \end{cases} \tag{1}$$