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Design and Implementation of Photo-Voltaic Inverter for Power Quality improvement in Grid-Connected System using Momentary Cessation operation

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ABSTRACT: There are changes administrated in the power grid, which is being ushered by the entry of more megawatt-scale photovoltaic (PV) power plants and other massive inverter-based power stations to the power grid. In addition to these alterations, new grid code specifications denotes that inverter-based power plants not only maintain timeline set in the event of failure but also offer dyanamic support. Momentary cessation (MC) operation is referred into this paper. This proposed method also improves voltage stability by injecting reactive power. Information from simulations are presented to show that how proposed control scheme works effectively.

Keywords - Photovoltaic generation; Momentary cessation; synchronous machine; voltage stability.

I. INTRODUCTION

The increase of PV generation implies some new technical challenges, such as transient stability [1], which makes the operation of power systems under severe disturbances an important issue. For instance, PV inverters may assist in preserving stability following a system disruption, such as a transmission line short circuit brought on by a lightning strike, which may result in the Fault detection (FD) signal responsible for opening the circuit breakers on the damaged line [2].

The grid code have changed to require Fault ride-through (FRT) capacity from renewable units during disturbances [3],[4]. That means the generation unit must not only remain connected to the power system but also must give support in maintaining synchronism and voltage stability. Phasor measurement unit (PMU) and Phasor data concentrator (PDC) may thus become commodities in this environment, as they provide other functionalities for metering, monitoring and control.

The proposed control scheme improve voltage stability and its post-fault recovery through the delivery of reactive power into the grid.

II. PROPOSED CONTROL SCHEME

The power system configuration shown in Fig. 1 is used for the transient stability analysis presented below. This hybrid power system consists of an synchronous machine operating in parallel with a PV system, both power plants are connected to the grid through two transmission lines. The PV system is composed of PV units (n) as shown in Fig. 2, these units are controlled according to a Maximum power point tracking (MPPT) strategy under normal operation. However, during a fault in one of the transmission lines, the PV inverters can enable Fault ride-through in momentary cessation mode and perform the proposed control action to minimize the synchronous machine load angle. It is well known that in an Active pass filter (APF), the grid currents can be indirectly controlled by making injection of the harmonic components and reactive parts of the load currents. Similarly, the synchrounous machine current components responsible for regulating the torque (or active power) and magnetic flux (or reactive power) can be imposed by controlling the currents injected into the grid by the PV inverters. This can be done because these inverters can act within the fault time frame, whereas the synchronous machine governor usually acts after the fault has ended. The disequilibrium caused by a disturbance can be reduced by maintaining the active power output of the synchronous machine as close as possible to its pre-fault condition. This means that, during the fault, the exceeding active power, that cannot be absorbed by the faulty grid must be delivered to the dc link capacitors of the PV units. Therefore, it should be noted that this strategy depends on the operational limits of the inverter, which must be considered. During the fault, the objective of the proposed control scheme becomes ensuring that the synchronous machine active power remains equal to its pre-fault. To achieve this objective the PV plant reference active power should be:

$$P_{\mathrm{PV}}^{*} = \bar{P}_{\mathrm{g}}^{\mathrm{f}} - P_{\mathrm{SM}}^{\mathrm{pre\text{-}f}}, \qquad (1)$$

where is the average active power injected into the grid during the fault. As determined by (1), the PV plant will require real-time measurements of the synchronous machine and the grid. For this, as shown in Fig. 1, a Phasror measurement unit is installed in the synchronous machine substation to measure the voltage phasor at the Point of common coupling and the current phasors of the transmission lines. Current phasor measurement unit technology can transmit synchrophasor data at up to 120 samples per second to a Phasor data concentrator, which is located at the PV plant substation for the following analysis.

Based on (1), the pre-fault synchronous machine active power must be computed during the disturbance. For that, it can be obtained through the use of a very slow low pass filter, having a time constant of some seconds, which is much longer than the typical duration of a fault. On the other hand, the reduction of the active power consumed by the grid must be considered by the control. Moving average filter (MAF) is used to attenuate the power oscillations caused by the negative-sequence and harmonic components of voltages and currents during the fault. Its cutoff frequency is higher, in order to allow the proposed control scheme to keep tracking the real-time changes of the average power that is being transferred through the grid. On the other hand, the Low pass filter(LPF) with lower cutoff frequency are used to retain the synchronous machine pre-fault active power output, which is used as a reference signal in the proposed control scheme.

The same applies to the PV reactive power reference computation. Since the reference values calculated through (1) are for the PV plant, the power references of each PV unit are calculated dividing those values by the number of PV units (n). The reference (P*) inv value must be limited within the maximum active power (Pinv-max) that can be absorbed during the disturbance for safety purposes, which can be determined by

$$P_{\max}^{\mathrm{inv}} = \frac{C}{2\Delta t}\left(v_{\mathrm{dc}}^{\max^2} - v_{\mathrm{dc}}^{2}\right), \qquad (2)$$

where C is the dc link capacitance, t is the faults maximum duration vdc is the steady state dc link voltage, and vdc-max is the maximum dc voltage during a disturbance (Eq.2).

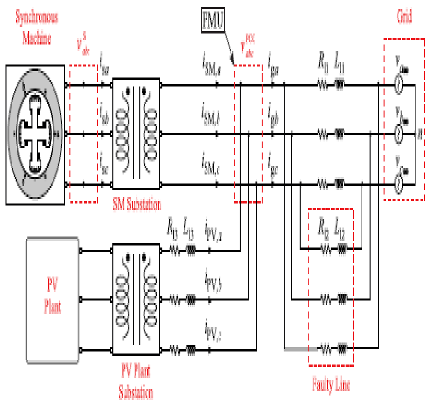

Figure 1. Three-phase diagram of a utility-scale hybrid power system.

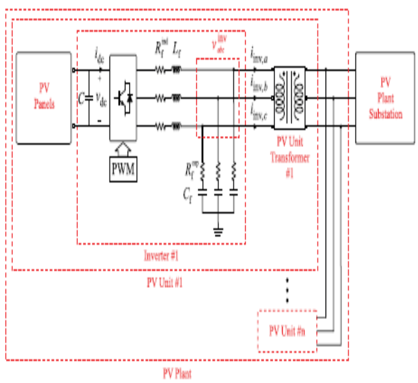

Figure 2. Three-phase diagram of each PV unit.

This imposed limit on the controller prevents the dc link voltage from rising beyond the maximum inverter's dc input voltage, as specified in [5], which is a more restrictive limit than the capacitor's surge voltage of two times its nominal voltage, as in [6].

The reference must also be limited within the maximum reactive power can be calculated as:

$$Q_{max}^{inv} = \sqrt{\left(S_{max}^{inv}\right)^2 - \left(P_{inv}^{*}\right)^2}. \tag{3}$$

As presented in [9], the FRT scheme computes the inverter current references in order to achieve: a)constant power injection (which demands to synthesize all odd harmonic current components) b)oscillatory power injection of frequency (which only demands to synthesize fundamental-frequency positive sequence (FFPS) currents).

When applied to the proposed control scheme, the oscillatory power injection does not impact the average synchronous machine active power output because its mean value is zero, thus it has no influence in the variation of rotor angle . It should also be noted that in comparison to the injection of only fundamental frequency positive sequence currents, injection of all odd harmonic currents can exceed the maximum short circuit withstand capacity of the inverter. For these reasons, In this paper the inverter current references contain only FFPS component. The ``power to current'' block determines the current references using the instantaneous power theory [6]:

$$\begin{bmatrix} i_{+1,\alpha}^{inv^*} \\ i_{+1,\beta}^{inv^*} \end{bmatrix} = M_{\alpha\beta}^{+1} \begin{bmatrix} P_{inv}^{*} \\ Q_{inv}^{*} \end{bmatrix}, \tag{4}$$

$$M_{\alpha\beta}^{+1} = \frac{1}{\left|\vec{v}_{+1,\alpha\beta}^{inv}\right|^2} \begin{bmatrix} v_{+1,\alpha}^{inv} & v_{+1,\beta}^{inv} \\ v_{+1,\beta}^{inv} & -v_{+1,\alpha}^{inv} \end{bmatrix}. \tag{5}$$

In (5), the fundamental frequency positive sequence component of the voltage at PV unit's terminals voltage is obtained using a phase lock loop (a GDSC-PLL was used for obtaining the results presented in this paper due to its better performance characteristics[8].

III. Simulation diagram & Result:

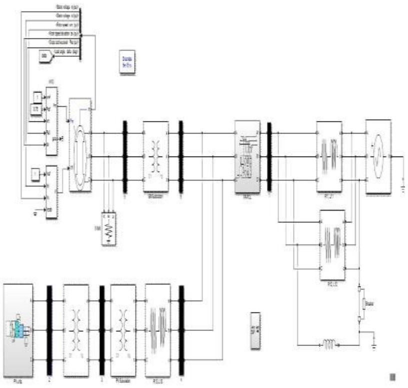

Figure 3. Matlab model

This model consist of three system :PV system, Phasor measurement unit, grid connected system.

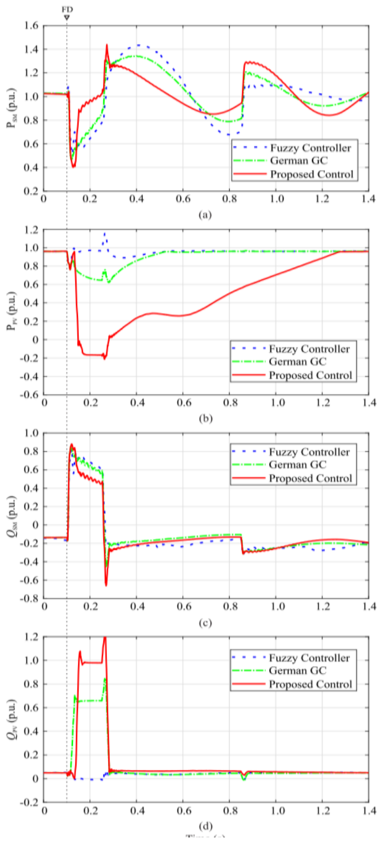

Figure 4. Comparative responses of the hybrid system subjected to a 2LG fault. (a) synchronous machine active power output. (b) PV system active power output.(c) synchronous machine reactive power output. (d) PV system reactive power-output.

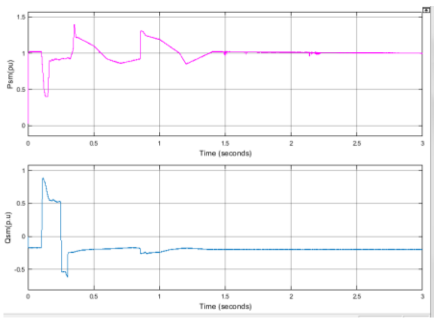

Fig 5: Synchronous machine active and reactive power

When using the proposed scheme, in fig. 5, the synchronous machine active power output is increased close to its pre-fault value, recovering the balance between the SM electrical power and mechanical power. This decelerates the rotor angular speed that, in turn, reduces the rotor angle excursions and ensures transient stability within the first cycles of the disturbance.

IV. Discussion

The synchronous machine active power transient response is shown in Fig.4a. The PV system active power transient response is shown in Fig.4b. Despite the reactive power support from the PV system, the German grid code does not reduce the synchronous machine reactive power output during the fault when compared to the results obtained with the fuzzy logic control (FLC) strategy. However, the proposed control scheme reduced it approximately from 70 Mvar (0.7 p.u.) to 50Mvar (0.5 p.u.), as can be seen in Fig. 4c. The reactive power support is established only in the German grid code and the proposed control strategies. Therefore, as shown in Fig. 4d, the results obtained using the German grid code requirements injected 66 Mvar (0.66 p.u.) of reactive power. Meanwhile, the proposed control scheme allows for higher reactive power support, injecting 98.7 Mvar (0.98 p.u.) into the point of common coupling, which is proved to be useful for the voltage recovery during and after the fault.

V. CONCLUSION

This paper demonstrated that the proposed control scheme can act while the PV system is in momentary cessation operation. This supports the grid to recover stability during and after a disturbance on the transmission grid. The proposed control scheme makes the kinetic energy to be absorbed into the dc link capacitors to ensure transient stability. Besides that, it also enables the injection of reactive power into the grid to support voltage stability.

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