



CONTROL OF PHOTOVOLTAIC INVERTERS FOR TRANSIENT AND VOLTAGE STABILITY ENHANCEMENT

¹Shinde kishor Machhindra, ²Amol Narayan Sonawane, ³Vishal Lahanu Parbhane, ⁴Amol Jagdish Mishra
¹kishorshinde2292@gmail.com, ²amolsonawane192@gmail.com, ³vishalparbhane98608@gmail.com

¹UG Scholar, Department of Electrical Engineering, Adsul Technical Campus Chas, Ahilyanagar

²UG Scholar, Department of Electrical Engineering, Adsul Technical Campus Chas, Ahilyanagar

³UG Scholar, Department of Electrical Engineering, Adsul Technical Campus Chas, Ahilyanagar

⁴Assistant Prof., Department of Electrical Engineering, Adsul Technical Campus Chas, Ahilyanagar

ABSTRACT - The way the power grid is run is changing as more megawatt-scale photovoltaic (PV) power plants and other big inverter-based power plants are added to the power system. In reaction to these modifications, new grid code regulations stipulate that inverter-based power plants must offer dynamic support in addition to maintaining grid connectivity during malfunctions. The literature refers to this characteristic as temporary cessation operation. The influence of these systems on the overall power system stability issue has not been well-explained by the few published research on brief halt operating for PV power plants. In an effort to In order to increase the transient stability of a synchronous generator linked to the grid, this research suggests a control strategy for PV inverters. The research demonstrates how the suggested control technique causes the dc link capacitors of the PV inverter to absorb a portion of the kinetic energy stored in the synchronous machine during a brief stoppage. Additionally, by injecting reactive power, the suggested approach can enhance voltage stability. The efficiency of the suggested control method is demonstrated through the presentation of simulation and experimental findings.

Index terms- Photovoltaic generation, synchronous machine, transient stability, voltage stability.

I. INTRODUCTION

RE sources, which are often connected to the power grid through power converters (such as inverters), have become much more prevalent in power systems in recent years. Transient stability is one of the new technological issues brought about by the growth of PV production [1], which makes power systems' capacity to function during extreme disruptions crucial. This new system design reduces the total system inertia and governor reaction, which might have a detrimental effect on the transitory reaction of SMs' rotor angle. However, the inverters used in PV generation offer SMs additional options, such as supplementary services. For example, PV inverters can assist in preserving stability following a system disruption, such as a short circuit brought on by a lightning strike on a transmission line, which can produce an FD signal to open the circuit breakers on the faulty line. The significant changes in the power system layout with relation to power inverter operation were not anticipated by the GCs of the previous 20 years. Even now, it is challenging to understand and project future RE generation possibilities. As a result, GCs have mandated that the RE sources be removed as soon as a disruption is discovered during the past ten years [3]. In order to avoid the loss of synchronism, this condition is acceptable as long as the RE penetration level is not substantial. Nevertheless, during disruptions, the GCs now demand FRT capacity from RE units [4]. This implies that the generating unit must not only be connected to the power system but also provide assistance in preserving voltage stability and synchronization. Certain nations have set regulations requiring PV plants linked to the medium voltage transmission grid and PV inverters used in dispersed generating units to have extra capabilities. A few of these requirements permit to increase voltage stability, momentarily halt the flow of active power to the grid while prioritizing reactive power support [5]–[7]. As demonstrated in [5], [6], and [8], some GCs set up APRRR for post-fault operation. The FRT capability of PV systems in compliance with the GCs has been extensively studied in the literature. For instance, [9] suggests a FRT system that allows the power quality to change based on a trade-off between power ripple and current harmonics in order to sustain the grid by injecting reactive power, as required in the German GC [6]. The effects of the following PV systems' operation modes are examined in [10]: FRT in blocking mode; disconnection from the grid

II. METHODOLOGY PV INVERTER

The transient stability study that follows is based on the power system configuration depicted in Fig. 1. An SM and a PV system run in tandem in this hybrid power system, which is linked to the grid via two transmission lines. As seen in Fig. 2, the PV system is made up of n PV units, which are normally regulated using an MPPT method. However, in the event of a transmission line failure, the PV inverters can activate FRT in MC mode and carry out the suggested control

action to reduce the SM load angle (δ_r). It is commonly known that an APF may be used to indirectly influence grid currents by injecting the harmonic

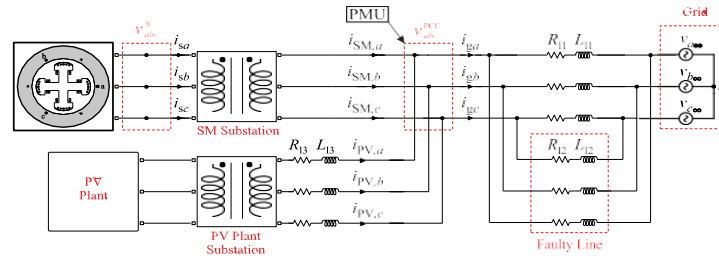


Fig. 1- Three-phase diagram of a utility-scale hybrid power system

components and the load currents' reactive portions. Similarly, by managing the currents that the PV inverters inject into the grid, the SM current components that regulate torque (or active power) and magnetic flux (or reactive power) may be enforced. This is possible because, in contrast to the SM governor, which often acts after the fault has finished, these inverters can function within the fault time period. By keeping the SM's active power output as near to its pre-fault state as feasible, the disequilibrium brought on by a disturbance can be minimized. This implies that the PV units' dc link capacitors must receive the excess active power during the failure that cannot be absorbed by the malfunctioning grid.

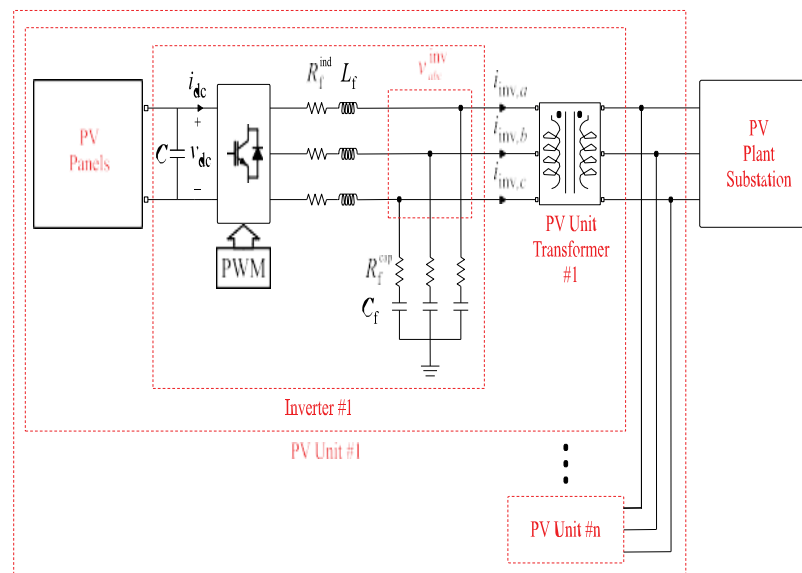


Fig. 2.- Three-phase diagram of each PV unit.

depicts the suggested FRT method to be applied to the PV inverters. Once the PMU data are sent to the PDC of the PV plant substation, the power references for each PV unit (Fig. 2) may be calculated. It is necessary to calculate the pre-fault SM active power during the disturbance

based on (1). For that, an extremely slow LPF with a time constant of a few seconds—much longer than the average fault duration—can be used.

III. EXPERIMENTAL VERIFICATION

The prototype depicted in which consists of an SM-flywheel-primary motor assembly with the flywheel mounted on the axis coupling the SM and the primary motor to make its inertia resemble the operation of a conventional hydroelectric power plant, is used to experimentally verify the suggested control scheme. As seen in Fig. 6, an inverter runs in parallel to the SM; however, in every experiment, the dc link of the inverter is not linked to any RE source. The complete suggested FRT strategy was built using a dSPACE platform (model DS1005 with a CPU operating at 1 GHz) as a real-time processing tool. Because of the increased danger to the facilities and operators, it is not recommended to apply a real fault in a laboratory. Because of this, equation c is connected to the SM terminals (phases b and c) when the FD signal is activated, simulating a two-phase failure. As seen in the FD signal also disconnects the SM's phases b and c from the grid. Because the SM is linked in Δ and is not connected to the grid's neutral, the SM's active power output falls to zero in these circumstances. Similar to what occurs during an actual failure, the low impedance inductive load generates large currents and a high SM reactive power output.

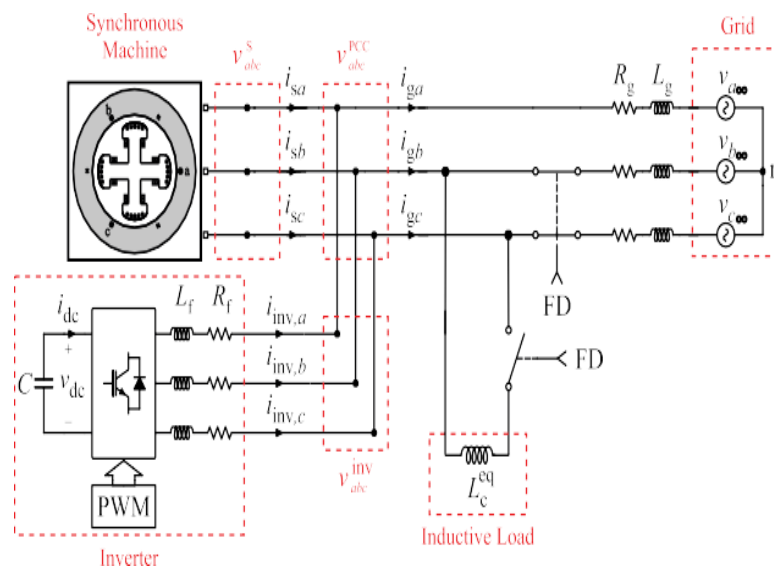


Fig. 3- Experimental system configuration – Two-phase inductive load.

IV. UTILITY-SCALE HYBRID POWER SYSTEM SIMULATION

This part uses Simulink/Matlab to simulate a utility-scale photovoltaic facility in order to test the suggested control method. The simulation results of the suggested control system are compared with those obtained taking into account: (i) the FRT constraints imposed by the German GC [6]; and (ii) the insertion of a VR-FCL, where an FLC's action determines the effective resistance [17]. Fig. 1 depicts the simulated power system's architecture. An SM of 120 MVA and a PV plant of 100 MVA that produces 100 MW and 0 Mvar (operating at the maximum power point) were taken into consideration in the configuration in order to acquire the simulation results. The PV plant is capable of This section is composed of $n = 50$ PV units, each with a nominal apparent power of 2 MVA. The PMU unit sends 60 samples of data per second to the PDC, and the

V. RESULTS

The simulation results in Figs. 8 and 9 correspond to a comparison of the transient response of the following FRT schemes: the PV plant that complies with German GC regulations; the suggested control scheme; and the FLC with a VR-FCL installed between the PCC and the transmission grid through an isolation transformer as in [17], with a resistance having a nominal value of 1.6 p.u. the SM active power transient response. Electrical and mechanical power get out of balance during the fault, as indicated by the FLC and German GC data. During the problem, the suggested control performs better, increasing Only during the PMU communication delay is the SM active power near to its pre-fault value displays the active power transient response of the PV system. The FLC strategy shows no significant variation during and after the fault. In order to provide reactive power assistance during the failure, the German GC reduces its active power output. On the other hand, using the suggested control scheme,

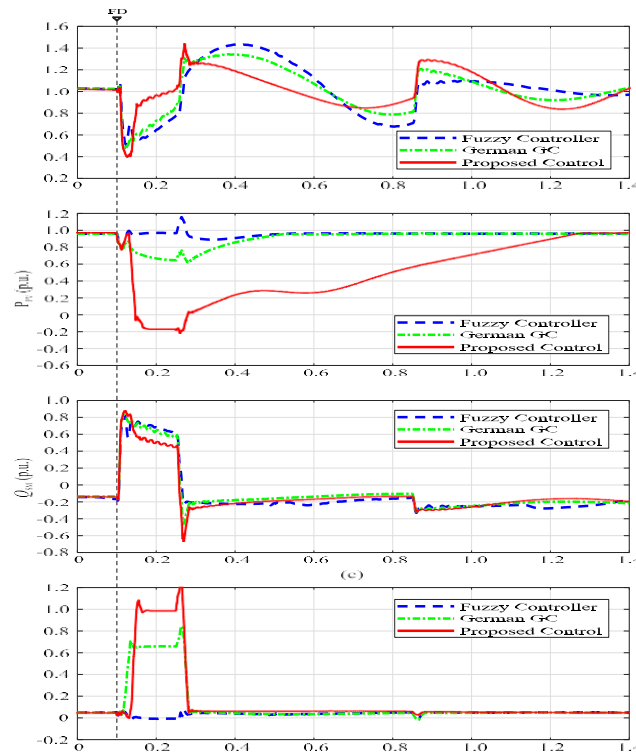


Fig. 8- Comparative responses of the hybrid system subjected to a 2LG fault. (a) SM active power output. (b) PV system active power output. (c) SM reactive power output. (d) PV system reactive power output.

VI. CONCLUSION-

This paper proposes a control mechanism for PV inverters to respond to faults that may jeopardize a hybrid power system's transient and voltage stability. The investigation showed that the suggested control strategy can help the grid's recovery of stability both during and after a transmission grid disruption when the PV system is operating in MC. To guarantee transient stability, the suggested control strategy causes the SM kinetic energy to be absorbed by the dc link capacitors. In addition, it makes it possible to support voltage stability by injecting reactive power into the grid.

The suggested control strategy may effectively ensure the SM's transient stability by reducing the rotor angle oscillations within the initial few cycles of the fault, according to experimental and modeling data. In contrast to previous FRT control techniques, it has also demonstrated improvements in the grid voltages throughout the fault period and a very quick post-fault voltage recovery.



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