JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

PHOTOVOLTAIC SYSTEM CONTROL TO IMPROVE THE STABILITY OF MULTI-MACHINE POWER SYSTEMS

[1]M.Mnunuswami,[2]T.Rahulkrishna,[3]M.Dhileepkumar,[4]G.Manipavan,[5]SK.Rouf
[1,2,3,4,5]Electrical and Electronics Engineering,
[1,2,3,4,5]Gokula Krishna College of Engineering, Sullurupet, India

ABSTRACT: A increasing variety of sources, including solar systems, are linked to electrical grids through inverters in an effort to achieve decarbonized operation of power systems in response to climate change. Because synchronous machines' transient operations differ from theirs, power system stability problems can arise. Most grid regulations demand that fault ride-through operating requirements be enabled in the event of severe transmission network requirements, giving reactive power delivery to the power system priority in order to maintain voltage stability. In order to utilize a fault ride-through control method for PV inverters in a multi machine power system, this study modifies one that was recently. It shows that the scheme can effectively preserve transient and voltage stability even under adverse voltage.

I. INTRODUCTION:

The use of renewable energy sources (RES) to produce electricity has gained attention due to the detrimental environmental effects of burning fossil fuels for energy conversion, a process that emits massive volumes of carbon dioxide and other greenhouse gases into the atmosphere.

Conventional fossil fuels are often non-renewable, which raises the possibility of resource depletion. The most advanced RES to be extensively incorporated with electrical grids and is a trend in contemporary energy systems. Photovoltaic solar energy is one of the most important and promising renewable energy sources.

Due to their increasing penetration into electrical networks, photovoltaic (PV) power plants are now considered a potential source of stability and reliability issues. when they experience major faults and are cut off from the network

For the operation of RES, the International Electro Technical Commission (IEC) in Switzerland and the United States have established and updated a number of standards, rules, and regulations.

Fault Ride-Through (FRT) is the ability of the grid to continue operating even in the case of a grid breakdown. With a FRT capability, the PV inverter will function similarly to a traditional synchronous generator, able to withstand voltage drops brought on by grid faults or disturbances, stay connected to the grid, and either supply or absorb the reactive power specified by the GC during the disturbance. *One of the leaders in this field, Germany, implemented two GCs in 2008 to address the rising penetration of renewable energy sources (RES), such as solar and wind power. The specifications described in these GCs have been used as a guide for other nations' code development efforts as well as the integration of more RES into grid systems. The German GC announced in January 2015 that every renewable energy facility must be able to provide dynamic grid support

Similar to Germany, Spain is implementing new guidelines in its GC. Italy recently upgraded their CEI 0-16, (2012) and CEI 0-21, (2014) standards, which included PV generation, and approved a new version of their GC for distributed on the incorporation of RES and the suggested control mechanisms to act during network outages, Inertial and frequency management solutions in power networks with a high penetration of renewable energy sources (RES), especially wind and photovoltaics, However, the study does not address the requirements imposed by various GCs.

The purpose of this study is to evaluate the effectiveness of the control method in a meshed power system as suggested in reference The outcomes are contrasted with those attained when the German GC's conditions are satisfied During a significant disruption in the transmission network, both approaches are employed to regulate the inverters of a photovoltaic (PV) system in a modified 9-bus power system designed by the Western System Coordinating Council (WSCC)

The suggested control method for the PV inverters modified for usage in a meshed power system is Section II. In Section III, the difficulties that a power system now faces when RES are connected to the grid via inverters are discussed, along with potential modeling strategies for future FRT schemes that would enhance power system stability.

II. A MULTIMACHINE POWER SYSTEM'S PROPOSED FRT CONTROL SCHEME FOR PV INVERTERS

For one SM and one PV system linked to a power system, the FRT control technique suggested in changed in this study to enable the control system to function in a meshed electrical system that has many transmission lines, loads, and SM load sand transmission lines

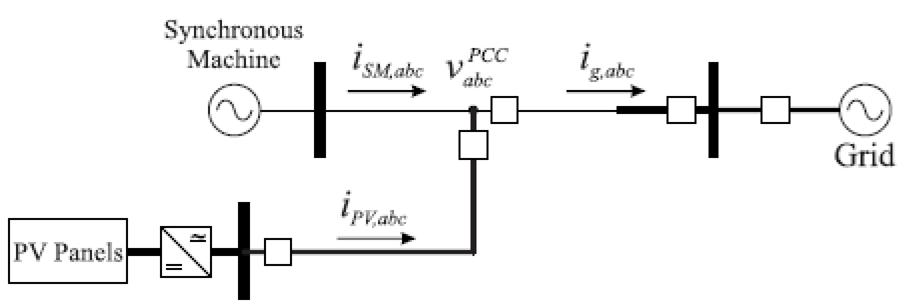


Fig 1: The Control Strategy Was Designed Using a Radial Power System.

This is accomplished by the PV system's dc-link capacitors absorbing the kinetic energy contained in the SM's rotating mass during the fault. The ability to take in energy is restricted by the maximum direct current (dc) bus voltage of the inverter.

This limit sets the maximum amount of active power that the dc-link capacitors can absorb, allowing some power to be released in the form of reactive power, which is needed by some GCs. The control scheme has two main benefits: it enhances voltage stability during a significant disturbance and transient stability, which helps the electrical system function.

On the other hand, the majority of GCs just need support for voltage stability. Nonetheless, as illustrated in the control scheme was developed with a radial power system in mind, consisting of a single SM linked to an infinite bus via a transmission network and the PV system connected to the grid in parallel to the SM. This power system configuration is not realistic; rather, it is unique. Typically, a real power system consists of multiple SMs, loads, and transmission lines that are mesh connected**.**

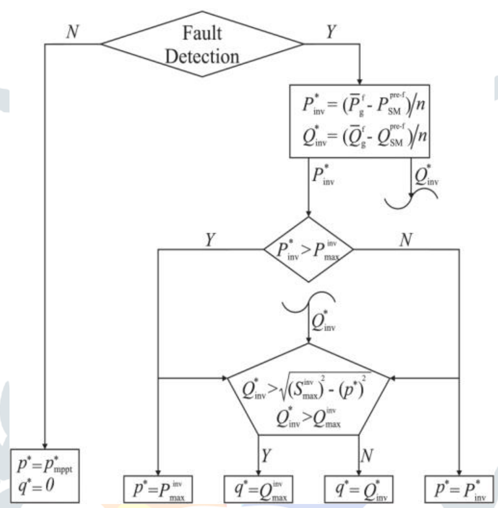


Fig 2: Computation of Inverter Power References Based on the Control Scheme

Through the absorption of active power into the PV system's dc-link capacitors, the inverter power reference required to maintain each transmission line's power flow at its pre-fault value is calculated and adjusted for into the PCC. Likewise the maximum dc bus voltage of the inverter limits the capacity.

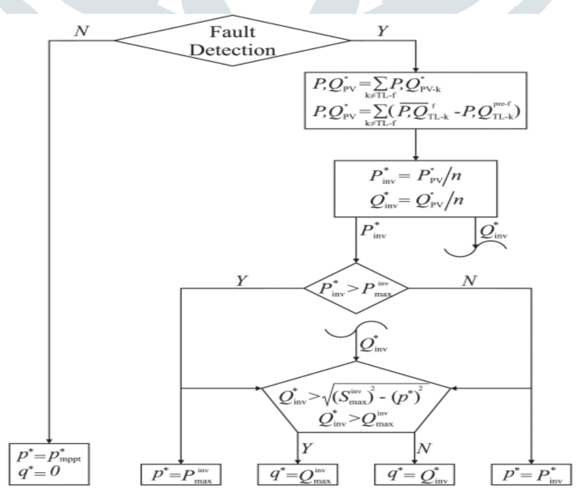


Fig 3: Computation of Inverter Power References Adapted for Use in a Multi Machine Power System.

III. THE DIFFICULT OF SETTING UP A FRT CONTROL SCHEME IN A MULTIMACHINE POWER SYSTEM FOR A PV POWER PLANT

A power system using sources linked to the grid via inverters is subject to both new and old issues with voltage, frequency, and angular stability. Due to these difficulties, the majority of GCs now have FRT requirements. This means that PV system inverters must respond to fault conditions both during and after they occur, giving priority to power system voltage stability by boosting reactive power and lowering or halting the system's active power supply.

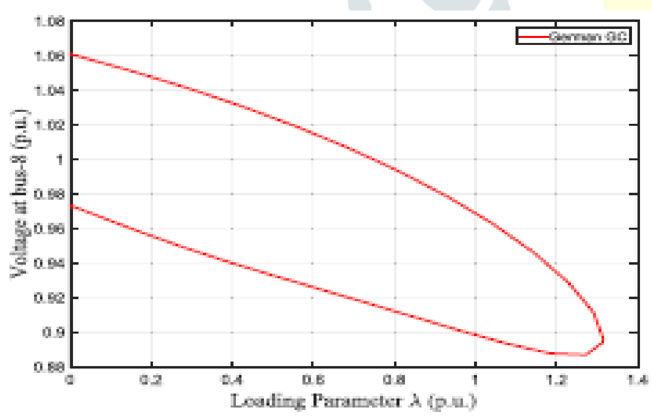
A. WSCC 9-BUS TEST SYSTEM STABILITY:

Bus-8, which is regarded as the PCC, in the modified WSCC 9-bus test system seen in Fig. 5 is connected to a PV system. Twenty-five 2 MW PV units make up the PV system, which has a nominal apparent power of 50 MVA (full technical information for each PV unit is available. MATLAB/Simulink was utilized to execute the simulated cases on the modified WSCC 9-bus test system depicted. The test system is intended to demonstrate how well the suggested PV inverter control method works in a meshed power system with several SMs in the event of a transmission.

IV. SIMULATION OF WSCC 9-BUS TEST SYSTEM

The test system aims to show how well the suggested PV inverter control method works in an attached power system with several SMs in the event of a transmission network contingency.

The findings for both fault scenarios utilizing the suggested control scheme will be displayed in the following subsections, along with a comparison with the outcomes obtained with the control mandated by the German GC. Because it has the highest FRT criteria, the German GC's requirements were chosen to be compared with the suggested control strategy. variations in the rotor angles of the synchronous machines between the suggested control technique and some of the most recent grid codes in use.



Fi 4: The WSCC 9-bus test system's bus-8 power vs. voltage nose curve

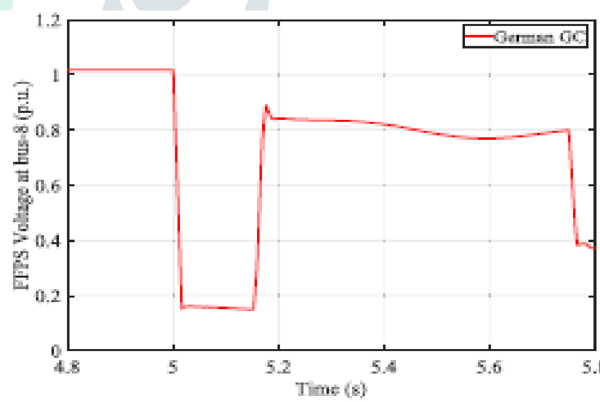


Fig 5: Voltage simultaneously during and after the breakdown at bus-8 of the WSCC 9-bus test system.

CASE 1 SIMULATION RESULTS

the active power flow in the transmission line between buses 7 and 8, based on simulation findings, between the usage of the suggested control system and PV inverters acting in accordance with the German GC. Both control techniques respond in extremely similar ways, practically simultaneously achieving an operating point that was comparable to the one that occurred prior to the defect.

The active power output of every generator. As would be predicted from the prior research, all of the generator curves exhibit comparable behavior both during and after the fault. Power flows that are feasible in the transmission lines entering the PCC. Following the fault, the active power output of both control methods increases at the 20%/s Active Power Recovery Ramp Rate (APRRR) set by the German GC.

the outcomes of the control measure in accordance with the guidelines given in the German GC. The system receives reactive power as soon as a voltage drop less than 0.9 p.u. is noticed. according to For this reason, reactive power support is continued for a brief while after the fault has passed.Showing the voltage profile is substantially similar to that achieved using the suggested control system, even with the reactive power assistance given by the control strategy based on the German GC. In this instance, both solutions have maintained voltage stability, and their respective performances have not differed significantly.

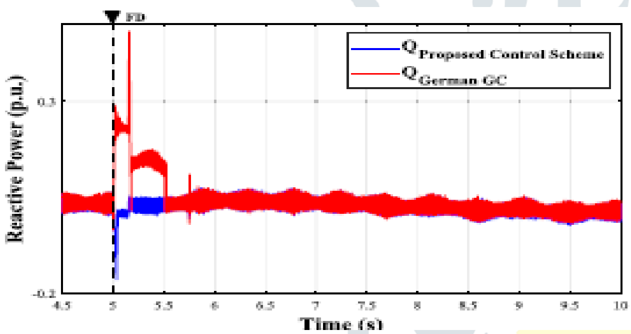


Fig 6: PV power plant in case 1 of the test system's reactive power output

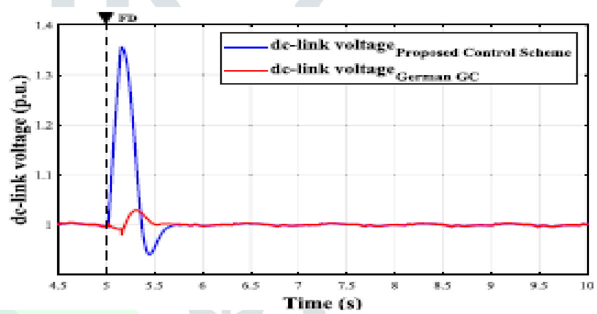


Fig 7: Case 1: Inverter DC-Link Voltage in P.U.

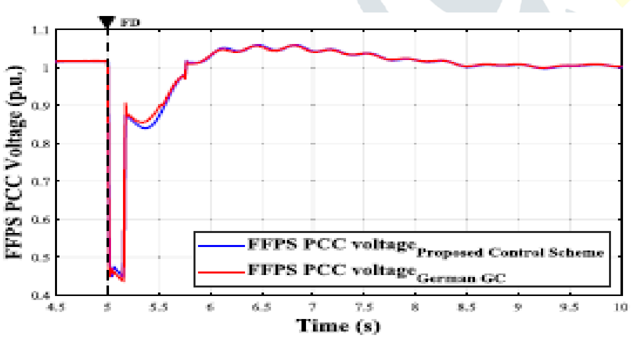


Fig 8: Power supply voltage at the power control circuit in instance 1.

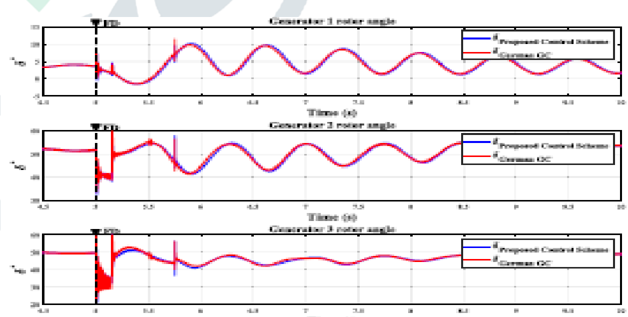


Fig 9: Case 1: SM rotor angle.

When the control strategy based on the German GC is applied, the voltage is maintained during the fault at almost the same value with brief transients, according to analysis of the dc-link voltage Graphs.In contrast, when the suggested control approach is used during the fault, the dc-link voltage increases. The maximum inverter dc input voltage of 1500 V limits this rise, which suggests energy is being stored in the dc-link capacitors of the inverter.

The analysis of case 1 shows that the performance of both control schemes in providing voltage stability and power system transients is nearly equal. It would appear that the suggested control technique has not produced any discernible improvements. Nevertheless, there isn't a situation in this case where the fault site can possibly cause a voltage collapse in the power system.

CASE 2 SIMULATION RESULTS

As demonstrated in subsection III-A, the German GC's required control response, which transfers reactive power from the PV system to the transmission network, can hasten the loss of power system stability. This indicates that the requirements set by most GCs are not always appropriate for all scenarios.

The active power flow in the transmission line between buses 8 and 9, based on the simulation findings. (The

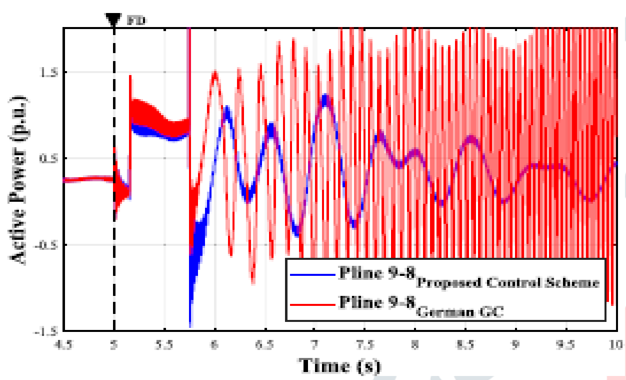


Fig 10: In PU - the situation 2, there is active power flow in the transmission line connecting buses 8 and 9**.**

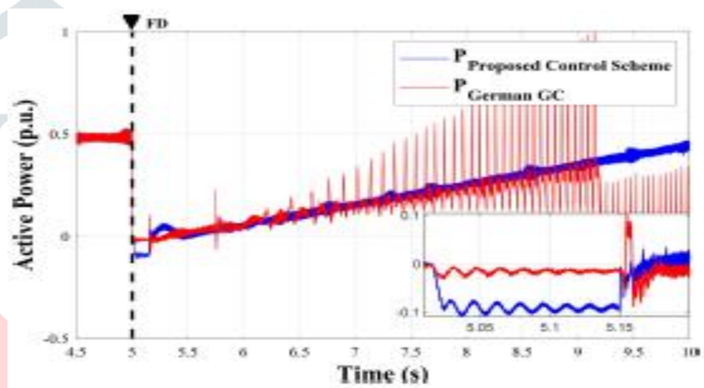


Fig 11:PV power plant test system's active power output in p.u. - case 2.

transmission line connecting busses 7 and 8 is not displayed since the suggested control method is unable to make up for the malfunctioning line.) After the transmission line is linked again, there is a total loss of stability when the PV inverters function as required by the German GC. On the other hand, the power system stays stable when the suggested control strategy is applied, reaching the pre-fault operating position the control action mandated by the German GC causes the inverters to produce reactive power when a voltage drop below 0.9 p.u. is detected. Even though the inverters are injecting reactive current that is almost exactly equal to their nominal value, the reactive power output indicated in Fig. 19 is very low since the voltage drops to a very low value (0.15 p.u.) during the fault. due to the voltage's continued below-0.9 p.u.

The control method based on the German GC keeps the voltage at the nominal value of 1100 V, according to the results for the dc-link voltage. Since energy is being stored in the dc-link capacitors of the inverters, an increase in dc-link voltage during the fault with the suggested control technique is anticipated, much like in instance 1. But this rise stays below the maximum 1500 V (1.36 p.u.) dc input voltage of the inverter.

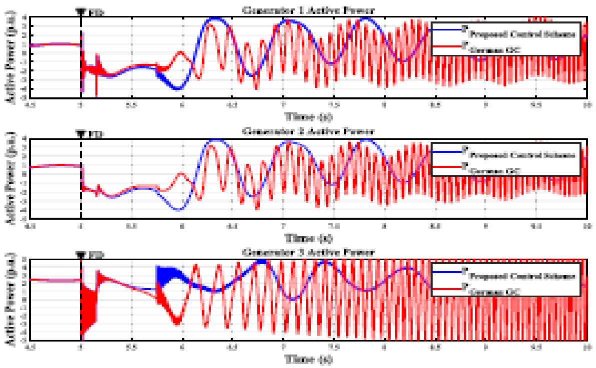


Fig 12: The test system generators' active power output in PSU-case 2**.**

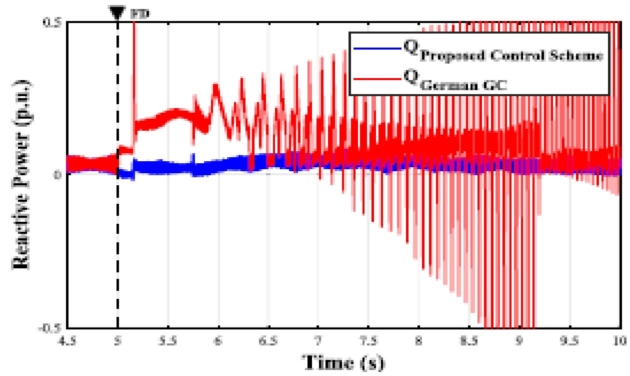


Fig 13: PV power plant test system's reactive power production in example 2.

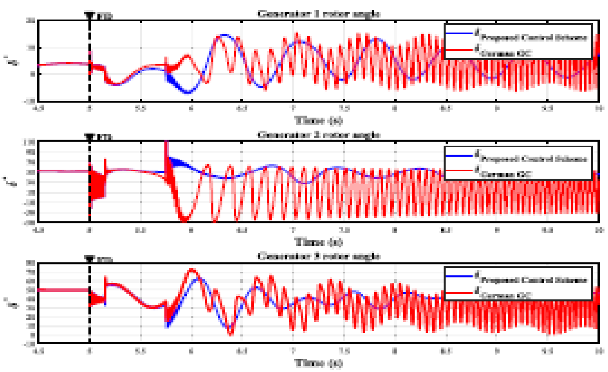


Fig 14: Case 2: SM rotor angle.

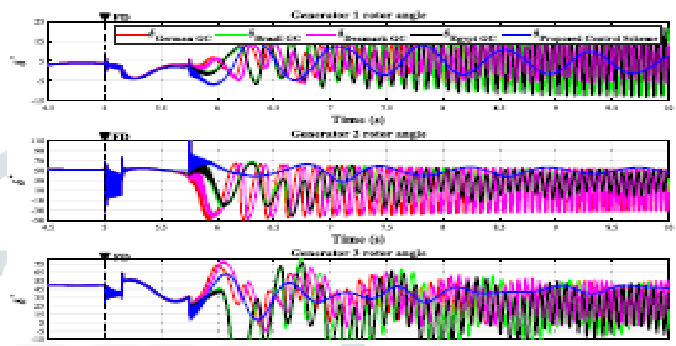


Fig 15:SM rotor angle responses in example 2 when utilizing the suggested control strategy in comparison to different GCs.

The control method based on the German GC keeps the voltage at the nominal value of 1100 V, according to the results for the dc-link voltage. Since energy is being stored in the dc-link capacitors of the inverters, an increase in dc-link voltage during the fault with the suggested control technique is anticipated, much like in instance 1. But this rise stays below the maximum 1500 V (1.36 p.u.) dc input voltage of the inverter.Transient and voltage stability in power systems with PV resources connected to the grid through inverters for any contingency scenario are two major stability problems that the proposed control scheme has been shown to be able to solve. This is because it prioritizes absorption of active power over the reactive power support that most GCs require.

V. CONCLUSION

The control strategy for PV inverters described in has been modified in this work to be used in the event of severe transmission network disruptions in a meshed power system with several SMs. In power systems with a voltage condition that could lead to voltage collapse, the control scheme priority of enhancing transient stability rather than voltage stability produced higher performance than the control action needed by the German GC and with other GCs. Reactive power support in this situation can potentially hasten the voltage decline. Based on the study presented here, a multi machine power system's transient and voltage stability can be enhanced by using the suggested control strategy in the PV system's inverters.

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