STABILITY IMPROVEMENT OF MULTI-MACHINE POWER SYSTEM BY THE FUZZY CONTROLLER

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***Abstract*— The goal of achieving decarbonized operation of power systems in response to climate change has led to an increase in the number of sources connected to electrical grids through inverters, of which photovoltaic systems are an example. The operating characteristics of these systems in steady-state or transient operation are different from those of synchronous machines, giving rise to issues related to power system stability. The vast majority of grid codes stipulate that fault ride-through operating requirements should be enabled during severe contingencies in the transmission network, prioritizing the delivery of reactive power to the power system to support voltage stability. However, this control action may contribute to the rapid collapse of the system voltage under adverse operating conditions, such as when the critical voltage in the power vs. voltage curve is near the reliable voltage operating bound. Supporting power system stability under these circumstances represents a new challenge for inverter control schemes. This project adapts a recently published fault ride-through control scheme for PV inverters for use in a multimachine power system and shows that the scheme can successfully maintain transient and voltage stability even under adverse voltage operating conditions. Fuzzy logic-based controllers have been designed for controlling a STATCOM in a multimachine power system. Such controllers do not need any prior knowledge of the plant to be controlled and can efficiently control a STATCOM during different disturbances in the network. Two different approaches for the controller are mainly used: one is a conventional controller using PI design and the other one is a fuzzy logic design based on membership functions. The review is based on simulation results, along a comparison of the conventional PI controller performance with that of the fuzzy logic controller will be presented. Thus the several advantages of FLC-based intelligence-controlled STATCOM serve as the most reliable system for our future power transmission.**

***Keywords*— electrical grids, synchronous machines, critical voltage, fuzzy logic, STATCOM.**

1. INTRODUCTION

The negative environmental impact of burning fossil fuels for energy conversion, a process which releases enormous amounts of carbon dioxide and other greenhouse gases into the atmosphere [1], [2], has focused attention on the use of renewable energy sources (RES) to generate electricity. In general, conventional fossil fuels are non-renewable, posing a potential threat of resource depletion. The most advanced RES that has been widely integrated with electrical grids and represents a trend in modern energy systems is photovoltaic solar energy [3], considered one of the most vital and promising RES [4].The present study aims to assess the performance of the control scheme proposed in [34] when used in a meshed power system. The results are compared with those obtained when the requirements of the German GC are met [14]. Both strategies are used to control the inverters of a PV system in a modified Western System Coordinating Council (WSCC) 9-bus power system [35] during a major disturbance in the transmission network. The paper focuses on making the necessary adjustments to the control scheme proposed in [34] and shows that the scheme can be adapted to be applied in a meshed power system under the stresses of a severe fault and helps to significantly improve the transient and voltage stability of the power system. To improve the performance of ac power systems, we need to manage this reactive power in an efficient way and this is known as reactive power compensation. There are two aspects to the problem of reactive power compensation: load compensation and voltage support. Load compensation consists of improvement in power factor, balancing of real power drawn from the supply, better voltage regulation, etc. of large fluctuating loads. Voltage support consists of reduction of voltage fluctuation at a given terminal of the transmission line. Two types of compensation can be used: series and shunt compensation. These modify the parameters of the system to give enhanced VAR compensation. In recent years, static VAR compensators like the STATCOM have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission Systems (FACTS). This allows an increase in transfer of apparent power through a transmission line, and much better stability by the adjustment of parameters that govern the power system i.e. current, voltage, phase angle, frequency and impedance. Controlling of STATCOM can be done by using fuzzy logic. Fuzzy logic is used instead of conventional method because it can be operated under uncertain condition. Today’s changing electric power system creates a growing need for reliability, flexibility, fast response and accuracy. FACTS are new devices emerging from recent innovative technologies that are capable of altering voltage phase angle and/or impedance at particular points in power system. Objective of the project is to control the reactive power of multi machine system using fuzzy logic base STATCOM. Fuzzy logic control is used to remove the problem of uncertainty and non-linearity in power system. Fuzzy logic based controller’s output is compared with the conventional PI controller’s output in MATLAB. The main focus of the research in fuzzy logic is on the development of intelligent controllers for reactive power and voltage regulation. Currently, research is done in progress on fuzzy logic and genetic algorithm techniques to improve load balancing within a distributed system.

2. PROPOSED FRT CONTROL SCHEME FOR PV INVERTERS IN A MULTIMACHINE POWER SYSTEM

The fault ride-through (FRT) control scheme proposed in [34] for a single SM and single PV system connected to a power system was modified in this project to allow the control scheme to work in a meshed electrical system operating with several SMs, loads and transmission lines. In [34], for a radial power system, the control scheme calculates the active power that needs to be absorbed to keep the active power of the SM close to its pre-fault value based on the difference between the power passing to the infinite bus through the transmission network during the disturbance and the active power of the SM during pre-fault conditions. The flow chart in Fig. 2 depicts the control scheme. The control scheme adapted to operate in a system configuration having multiple transmission lines coming into the PV system’s point of common coupling (PCC). The proposed FRT scheme now compensates for the power flows in all the transmission lines coming into the PV system’s PCC, the only power flow that is not compensated for is the flow through the transmission line on which there is a fault (k 6= TL-f). The faulted line is identified by a distance relay installed on each transmission line. The meshed configuration adapted power references computation block, depicts how power flow from each transmission line coming into the PCC is compensated for by calculating the inverter power reference needed to keep the power flow in each transmission line at its pre-fault value by absorption of active power into the dc-link capacitors in the PV system. The capacity to absorb is, also, limited by the inverter’s maximum dc bus voltage.

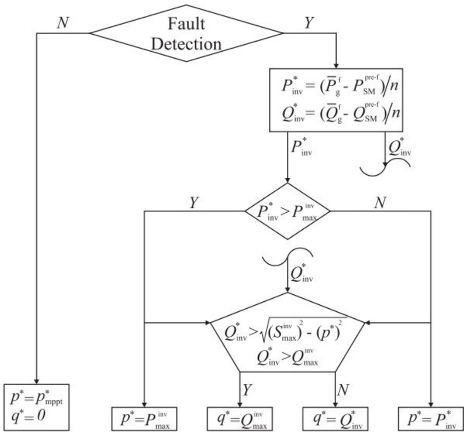

Figure1. Computation of inverter power references based on the control scheme described.

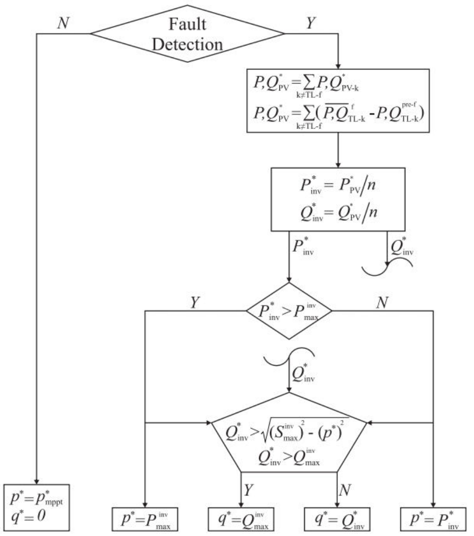

Figure2. Computation of inverter power references adapted for use in a multimachine power system.

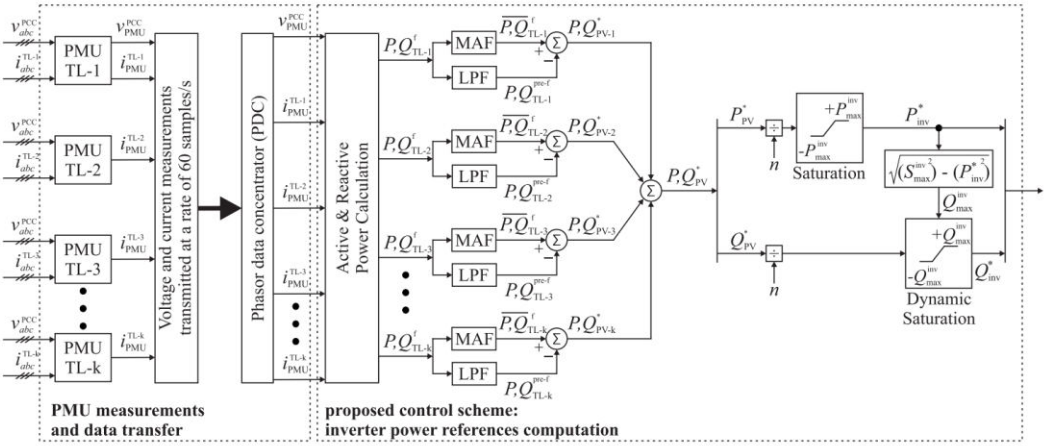

Figure3.

A major advantage of a meshed power system is that all the information required for the inverter power reference calculation can be collected at the PCC using measurements from each transmission line's PMU unit installed at the PCC bus, which is also where the PV system's substation is located, resulting in no delay in the transmission of information to the PV system's phasor data concentrator (PDC). This was a setback in [34] because the information regarding the operational status of the SM and grid during the disturbance had to be collected by the PMU unit and transmitted to the PDC located at the PV system substation, causing a delay that could affect the performance of the FRT scheme.

Adjustments made to the FRT control scheme phasor measurement unit (PMU) measurements and data transfer block and FRT inverter power references computation block.

3. STABILITY OF THE WSCC 9-BUS TEST SYSTEM

In the modified WSCC 9-bus test system shown in Fig. 5, a PV system is connected to bus-8, which is considered the PCC. The PV system consisting of twenty-five 2 MW PV units amounts to a total of 50 MVA nominal apparent power. This amount of power, according to the requirements of most GCs, should be available to be delivered as reactive power during a fault in the transmission system. Power system strength at the PCC is assessed with a contingency. The reason for choosing this line is that this scenario yields a critical power vs. voltage curve for the PCC bus. The nose curve that the critical voltage is close to the normal operating range (approximately 0.9 p.u.), which could indicate a potential voltage collapse. From this analysis, any FRT control scheme applied to the inverters of a

PV system should be assessed in terms of how well it helps to ensure power system stability

4. REACTIVE POWER COMPENSATION AND STATCOM

Reactive power is the power that supplies the stored energy in reactive elements. Power, as we know, consists of two components, active and reactive power. The total sum of active and reactive power is called as apparent power. In AC circuits, energy is stored temporarily in inductive and capacitive elements, which results in the periodic reversal of the direction of flow of energy between the source and the load. The average power after the completion of one whole cycle of the AC waveform is the real power, and this is the usable energy of the system and is used to do work, whereas the portion of power flow which is temporarily stored in the form of magnetic or electric fields and flows back and forth in the transmission line due to inductive and capacitive network elements is known as reactive power. This is the unused power which the system has to incur in order to transmit power. Inductors (reactors) are said to store or absorb reactive power, because they store energy in the form of a magnetic field. Therefore, when a voltage is initially applied across a coil, a magnetic field builds up, and the current reaches the full value after a certain period of time. This in turn causes the current to lag the voltage in phase. The zero average does not necessarily mean that no energy is flowing, but the actual amount that is flowing for half a cycle in one direction, is coming back in the next half cycle. The source V1, a power line and an inductive load. The system without any type of compensation. The phasor diagram of these is also shown above. The active current Ip is in phase with the load voltage V2. Here, the load is inductive and hence it requires reactive power for its proper operation and this has to be supplied by the source, thus increasing the current from the generator and through the power lines. Instead of the lines carrying this, if the reactive power can be supplied near the load, the line current can be minimized, reducing the power losses and improving the voltage regulation at the load terminals.

This can be done in three ways:

1) A voltage source.

2) A current source.

3) A capacitor. In this case, a current source device is used to compensate Iq, which is the reactive component of the load current.

In turn the voltage regulation of the system is improved and the reactive current component from the source is reduced or almost eliminated. This is in case of lagging compensation. For leading compensation, we require an inductor. Therefore we can see that, a current source or a voltage source can be used for both leading and lagging shunt compensation, the main advantages being the reactive power generated is independent of the voltage at the point of connection.

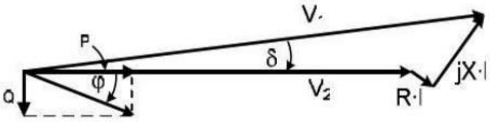

Figure4. Circuit diagram and phasor diagram of system without any compensation

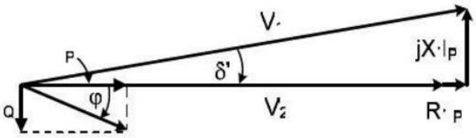

Figure5. Circuit diagram and phasor diagram with shunt compensation

5. FUZZY LOGIC CONTROLLER

Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans.

Block Diagram of Fuzzy Logic Controller

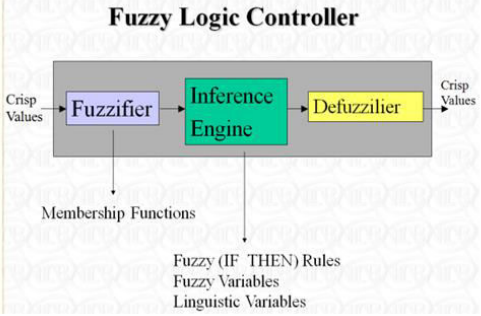

Figure6.

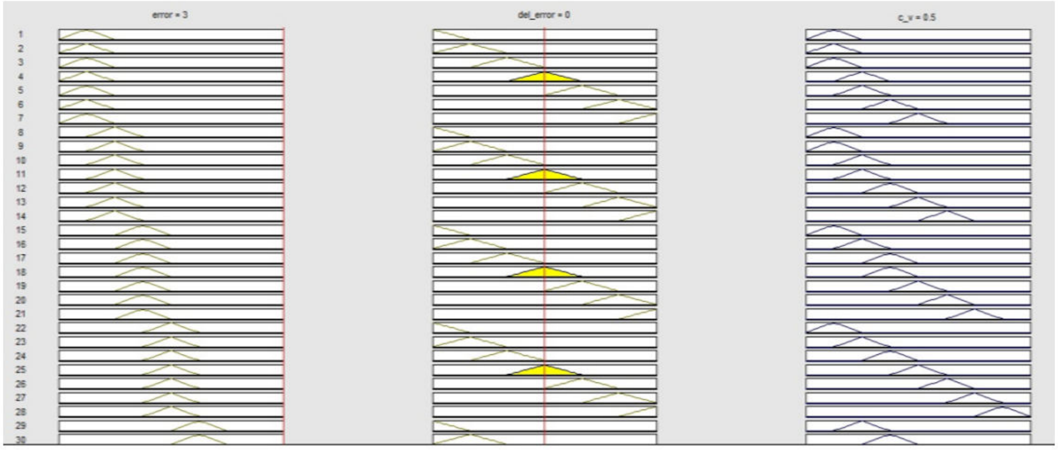

Figure7. Rule viewer of fuzzy

6. Simulation Results

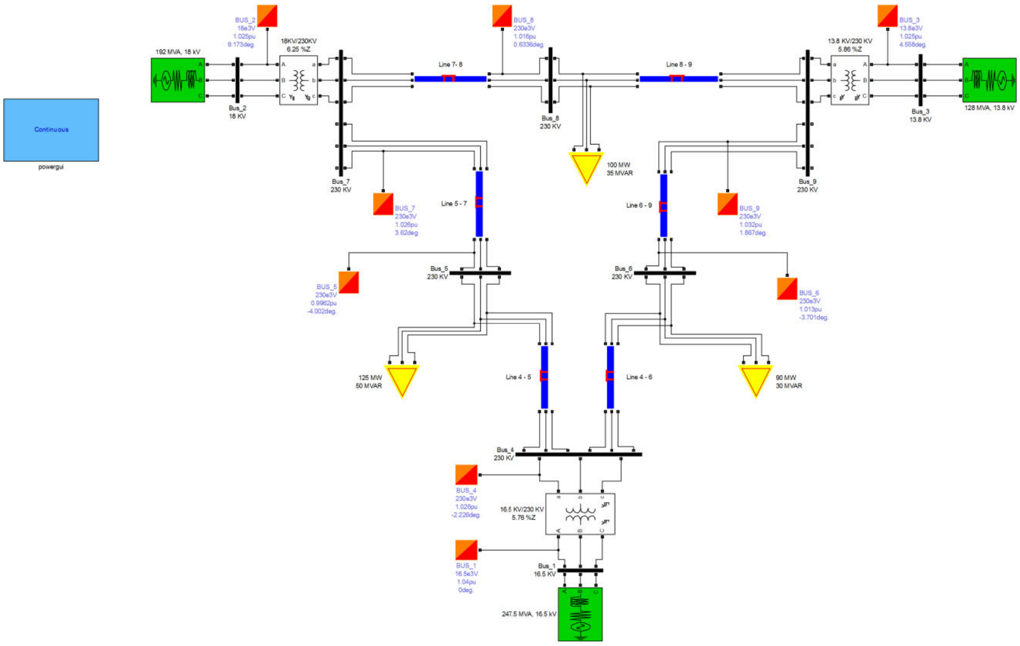

Figure8. Simulation Diagram of the Existing System

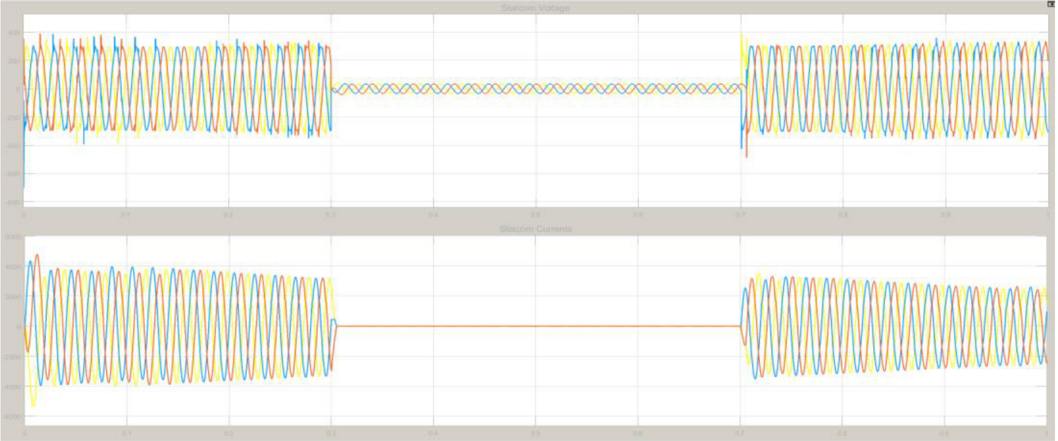

Figure9. Fault case at 0.3 to 0.7

After the fault, the load is shown in the above figure there the fault occurrence time period is t=0.3sec to 0.7 sec. by this the active power will drop to zero.

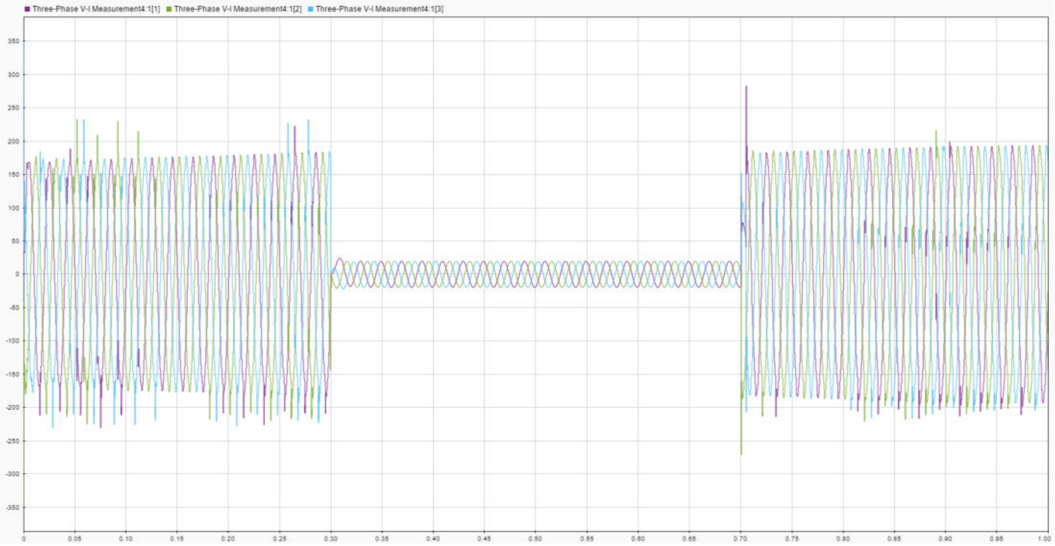

Figure10. Grid 1 Voltages

Analysis of Grid 1 have almost the same performance in supporting power system transient and voltage stability. It would seem that no major improvement has been observed with the proposed control strategy. However, this case does not involve a scenario in which the fault location could potentially lead the power system to voltage collapse.

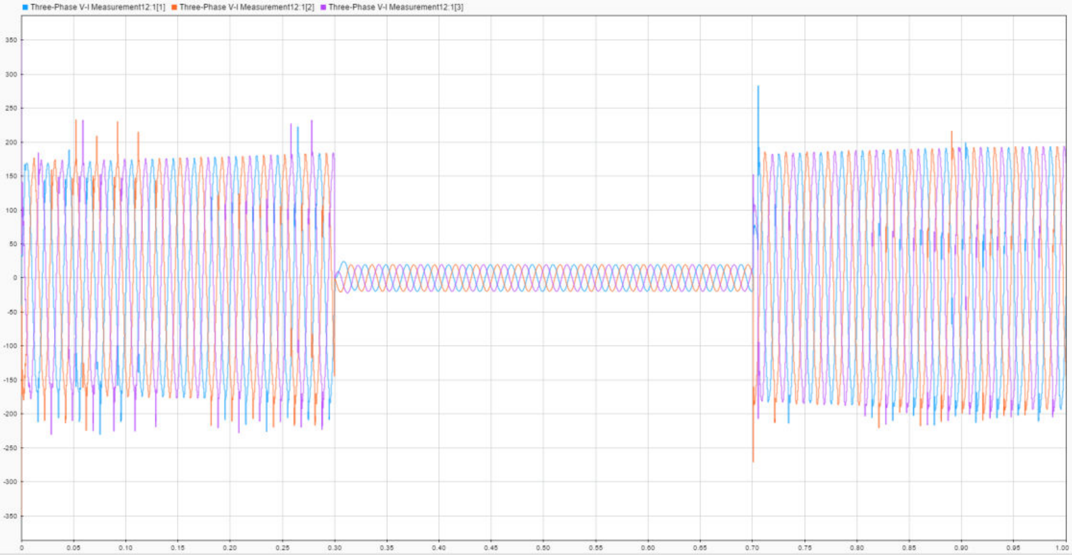

Figure11. Grid 2 Voltages

The active power in this region is negative with the proposed control scheme, indicating that energy is being absorbed, making the slight increase in the Voltage in the transmission lines coming into the PCC possible. After the fault, both control strategies start to decrease the output Voltage.

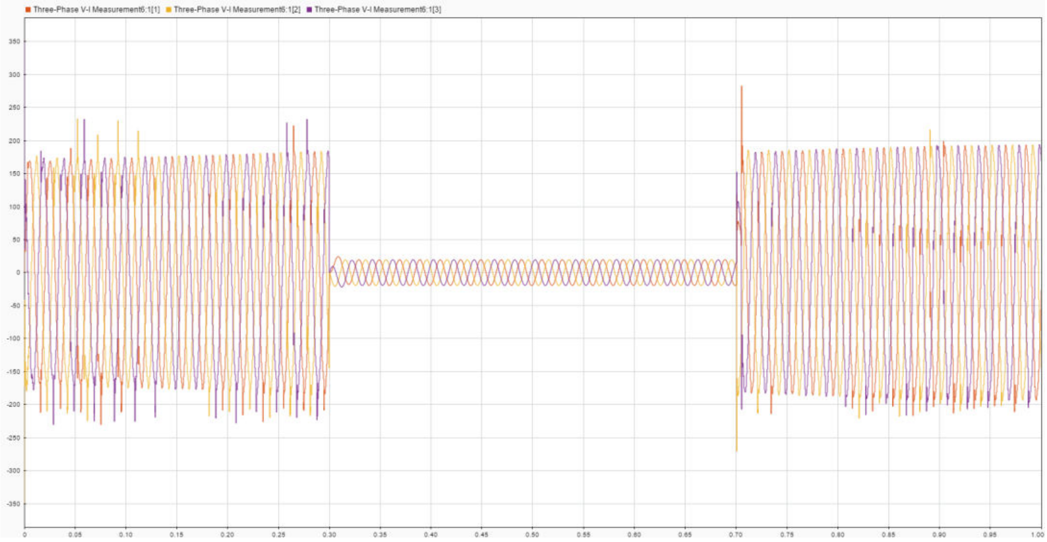

Figure12. Grid 3 Voltages

The results for the PCC voltage show that even with the reactive power support provided by the control strategy, the voltage is very similar to that obtained using the proposed control scheme.

In this case, voltage stability has been maintained with both strategies and there is little difference in performance between them. Analysis of the voltage shows that during the fault the voltage is kept at almost the same value but with small transients when the control strategy

Figure13. Load Active Reactive Power

During the fault period shows negative active power with the proposed control scheme, indicating that energy is being absorbed and making an increase in the power in the transmission line coming into the PCC possible (Fig. 16). After the fault, both control strategies start to increase the active power output. However, with control, the system is unable to reach the pre-fault power output because the voltage at the PCC has already collapsed. The control action to makes the inverters deliver reactive power when a voltage drop below 0.9 p.u. is detected. However, because the voltage drops to a very low value during the fault (0.15 p.u.), the reactive power output shown in Fig. 19 is very low even though the inverters are injecting reactive current close to their nominal value. Because the voltage is still below 0.9 p.u. after the fault, the inverters continue to inject reactive power, which is not an efficient control action to maintain voltage stability. The voltage at the PCC finally collapses after the transmission line is reconnected. The proposed control scheme calculates that no reactive power support is needed. The results for the PCC voltage show that only the proposed control scheme is able to maintain voltage stability, ensuring that the system returns to an operating point close to pre-fault conditions.

CONCLUSION

In this work, the control scheme for PV inverters presented in [34] has been adapted for use during severe disturbances in the transmission network of a meshed power system with multiple SMs. The control scheme priority of improving transient stability rather than voltage stability resulted in better performance than the control action required by the German GC and with other GCs in power systems with a voltage condition that could lead to voltage collapse. In such a case, reactive power support may even accelerate voltage collapse. The simulation results with the proposed control scheme show that the rotor angles of the SMs return to their pre-fault operating values and, even without reactive power, the voltages on all the buses in the power system are restored to their pre-fault values as well. We have studied 9 different cases and compared the effects of STATCOM with PI controller and STATCOM with Fuzzy logic controller on bus voltage, reactive power and active power. The above cases we can easily understand that when we do not use any compensation device voltage profile at the load terminal is very poor, but after applying STATCOM it is improved to an operating value. Our study clearly shows that Fuzzy logic controller based STATCOM is much better that the PI controller based STATCOM controller. The analysis presented here has shown that the proposed control scheme can be implemented in the inverters of a PV system to improve the transient and voltage stability of a multi-machine power system.

FUTURE SCOPE

With the advent of batteries with increased capacity and the portability, as seen by the various lithium-based battery technologies, standalone systems are being heavily considered in the application of mini-grids. These systems, essentially large scale standalone systems that operate like a grid, can serve the purpose of providing energy from multiple sources for a community separate from the grid. This is likely to be widely implemented as increasing awareness of the effects of fossil fuels on the environment and increasing costs of electricity puts standalone PV forward as a cheaper alternative.

The concept of mini grids is of great significance, since it means that entire communities can be powered autonomously. What is more noteworthy, however, is the possibility of having entire neighborhoods or suburbs that are currently connected to the traditional grid becoming separate and running independently through PV, wind, geothermal, or hydro where possible, with a grid connection as a backup supply, increasing the reliability of the system.

In this present article the reviews of some important developments in the different types of FACTS devices. It may help the new researchers and young scientists to study the recent developments in the transmission and distribution systems in power system and to propose some better new invention of FACTS devices. The future, the aim will be to improve the time taken for each iteration. It is expected that fractional controller performance can be achieved by the proper tuning of controller parameters. In this regard, work can be planned on the application of evolutionary optimization techniques for the optimal configuration of fractional controllers.

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