International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
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IJIEMR Transactions, online available on 29th May 2021. Link :http://www.ijiemr.org/downloads.php?vol=Volume-10/ISSUE-05

DOI: 10.48047/IJIEMR/V10/I05/53

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Volume 10, Issue 05, Pages: 232-238

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TRANSIENT STABILITY ANALYSIS OF DISTRIBUTED POWER GENERATED SYSTEMS USING EMERGENCY CONTROL STRATEGY

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ABSTRACT: In recent years, while fossil fuel prices have increased, these fuels have reduced to access. More importantly, it has reached an irreversible point in climate change. This situation has led to increasing importance of renewable energy resources, notably wind and solar energy. The active and reactive power generated by distributed generation changes greatly in case of grid failure, and it is lack of coordination with the existing emergency control measures, which threatens the safe and stable operation of the grid. Stability is the most important change in the power, which plays a vital role in system planning and operation. These sources have tended to leave the grid in the event of a failure. Also, variable generation features always pose a risk for system stability. So, transient stability analysis of distributed power generated systems using emergency control strategy is proposed in this paper. The emergency control strategy, the process of the distributed power participating in the transient emergency control is divided into three stages: the active regulation of the distributed power, the correction of the emergency control strategy and the additional strategy in turns. This method gives full play to the fast support ability of the distributed generation to the power grid after the power grid fault, and improves the economy of the emergency control measures on the premise of ensuring the safe and stable operation of the system.

KEYWORDS: transient stability, distributed generation, emergency control.

I. INTRODUCTION

Operation of a Power System is very complex and poses a great challenge to security due to high voltage of electricity being produced [1]. Power grids face disturbances caused by changes in the load, switching operations, faults and loss excitation. Historically, blackouts [2] have also been observed due to such disturbances. Thus, it is imperative to bring the system back to a stable state after the disturbances. Hence Power Stability studies are required to analyze the behavior of system under different conditions which can obviate the instances of Blackouts, Loss of Synchronization etc. While it is not possible to perform such studies on field, simulation software provisions the ability to perform such studies on different test systems. Power System Stability is defined as Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact [3]

With the rapid development of power electronics technology [4], Distributed Generated (DG) devices such as distributed photovoltaic, distributed wind power, fuel cell power generation and biomass power generation are more and more widely used [5]. These DG devices are based on power electronic devices. The response time constant can be as small as several milliseconds, and the response speed is much faster than that of conventional

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emergency control. The regulated response of these DG devices has an important impact on the static and transient stability, voltage level and frequency characteristics of key transmission sections, and greatly improves the transmission capacity of the power grid and explore the potential of equipment transmission [6].

Power Stability can be broadly classified into three categories viz. steady-state stability [7], dynamic stability and transient stability [8]. Steady state stability is the ability of system to regain its original state after its operation, whereas dynamic state stability is the ability of system to regain its original state on exposure to small disturbances. Thus, steady state stability and dynamic state stability are the abilities of power system to regain the synchronism after encountering slow and small disturbances. Both the phenomena have fewer applications and are applied where one or a few machines are undergoing slow or gradual changes in operating conditions. The difference between both the studies is too minimal as the stability problems are the same in nature, they differ only in the degree of detail used to model the machines.

"Three lines of defense" is an important means to ensure the safe and stable operation of the power grid. After serious faults occur in power grid, traditional emergency control measures such as generator-tripping and load-shedding need to be implemented through security control system to maintain stable operation of power grid. Due to the access of DG devices in power grid, serious faults will trigger simultaneous operation of multiple DG devices and control systems. It is necessary to pay attention to the coordination between DG devices and traditional emergency control methods.

II. DISTRIBUTED POWER GENERATED SYSTEMS WITH TRANSIENT STABILITY

The ability of the power system to maintain synchronism after an impact of a severe disturbance such as short circuit on transmission line is called transient stability. Transient stability analysis is the corresponding study of transient stability of system under such transient faults. Transient stability has been used to improve energy storage systems [9]. Such studies are widely carried out when problems involve large disturbances that do not allow the linearization process to be used and nonlinear differential and algebraic equations must be solved by direct methods or by iterative step-by-step procedures. Transient fault involves major disturbances like loss of generator, line switching and short circuits etc. While such disturbances are rare, but they have the ability to bring entire system along with transmission lines to halt. Thus it is required to calibrate a power system against such faults.

Conventional systems consist of synchronous generators. These generators produce the inertia constant and damping torque that plays a vital role in making system stability. When the system encounters a fault, speed and voltage regulators step in for frequency and terminal voltage values of synchronous generators. These values bring by regulators either to the stable operation point previous the error or to a new stable operating point. Thus, the stability of both synchronous generators and power system protects. However, due to the existing controllers and the power of the synchronous generators, the operation limits of synchronous generators are confined. The

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power systems further limit by the continuous increase in the energy demand in the world, as well as the economic, environmental, technical and legal restrictions. This situation causes to operate at its maximum stability point which is dangerous for the reliability of the system. Even though distributed generation is encouraging in the face of potential limitations and reliability, it must be careful when integrating into the grid due to their structures and technologies.

In recent years, the coordinated design and control of DG has become a hot issue in the field. Scholars have proposed various coordinated control technologies and achieved some results. However, at present, most of the research on the participation of DG in power grid emergency control are the aspects of coordination design and control of DG [10], which does not involve the research on enhancing the stability of the system by using the fast response and control performance of DG device to realize the cooperative control between DG device and traditional emergency control. In view of the above shortcomings, according to the different characteristics of DG control and traditional emergency control methods and time scales, this paper puts forward the idea of DG participating in transient stability emergency control and elaborates the implementation method in detail, compares the advantages and disadvantages of DG before and after participating in transient stability emergency control.

III. PROPOSED SYSTEM

The primary objective is to observe the changes that will occur in the power system stability. First of all, fault scenarios have implemented only for the base case in which central generations include (G1, G2 and G3). Generally, only one value of distributed generation is used in other studies. In contrast, 24-hour average generation profiles are used in this study. Fig. 1 shows our proposed modified systems. Three-phase fault is applied at level of the bus 4 and the fault has been cleared at 0.3s by removal of line 4- 5. Rotor angle differences variation time base on method is preferred to perform a more efficient analysis in multimachine systems.

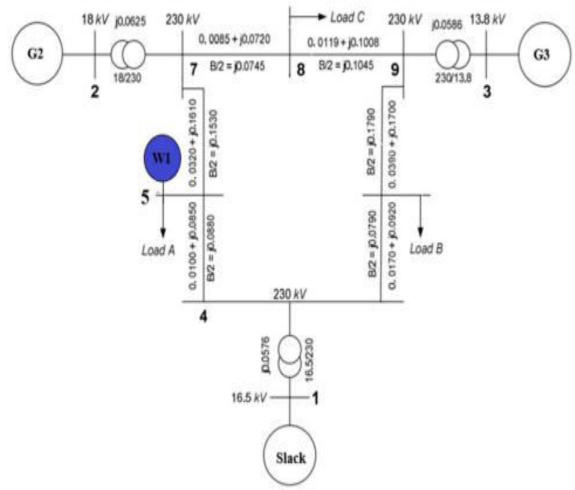

Fig. 1: MODIFIED BUS POWER SYSTEM

Consideration of DG Participating in Transient Stability Emergency Control:

A transient safety and stability emergency control method is proposed, which can effectively evaluate the comprehensive support capability of various DG devices and integrate with traditional generator-tripping and load-shedding emergency control. The participation of DG in power grid transient emergency stability control is divided into three stages: stage of DG devices actively adjustment and stage of revising emergency control quantity and stage of additional control by rounds. The combination of DG control and traditional control means ensures the security of the

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system and improves the economy of control measures.

Realization of DG Participating in Emergency Control Method of Transient Stability:

Off-line simulation of fault f is carried out under the condition without DG devices, and the key transmission section limit $P_{\lim\_ori}$ is calculated when the fault occurs; then putting all DG devices into operation, the key transmission section limit $P_{\lim\_new}$ is calculated. It is considered that the regulating capacity ΔC_{i_off} released by i th DG device is the maximum adjustable capacity Ci_max(i=1'2'…'n). The control sensitivity of each DG device is as follows:

$$\lambda_i = \frac{P_{\lim\_new} - P_{\lim\_ori}}{\Delta C_{i\_off}}$$

In the formula: For the faults f, λi represents the control sensitivity of the i th DG device when n DG devices are put into operation at the same time. The sensitivity matrix is placed in the off-line strategy files of the emergency control station of the safety and stability control system. It needs to be explained that there is a one-to-one correspondence between the sensitivity matrix calculated by off-line simulation and the specific anticipated fault, and different anticipated faults correspond to different sensitivity matrices.

All DG devices upload the dynamic adjustable capacity of the current time to the emergency control station in real time. If a fault f is detected, the emergency control station looks up the off-line control strategy files to determine the off-line control quantity for the fault; otherwise, if the fault f does not occur, the dynamic adjustable capacity of DG devices at the current time will continue to upload to the emergency control station in real time. The emergency control station calculates the comprehensive control effect ΔP_{em} of adjustment of DG devices according to the difference of dynamic adjustable capacity of the DG devices received before and after the power grid fault.

$$\Delta P_{em} = \frac{1}{n} g[\lambda_i, \lambda_i, \dots \dots, \lambda_i] \begin{bmatrix} \Delta C_1 \\ \Delta C_2 \dots \\ \Delta C_n \end{bmatrix}$$

Where, the vectors [ΔC1,ΔC2,…,ΔCn] T is the difference of dynamic adjustable capacity of i th DG device before and after power grid fault.

Advantages of DG in Transient Stability Emergency Control:

Compared with DG and traditional emergency control, the proposed emergency control method for transient security and stability has the following advantages.

1) The functions of the existing safety and stability control system are extended. The emergency control station not only receives the information of fault detection, power transmission section flow and switch status from the sub-station or the execution station, but also receives the dynamic adjustable capacity information from each DG device at the current moment in real time, thus realizing the coordination between the traditional emergency control system and the DG devices.

2) The connotation of off-line strategy is enriched. On the basis of existing off-line strategy, the emergency control sensitivity information of DG devices for specific anticipated faults is added.

3) According to the difference of response speed, the emergency control of transient safety and stability after the operation of DG devices is divided into three stages according to the priority of execution: stage of DG devices actively adjustment and stage

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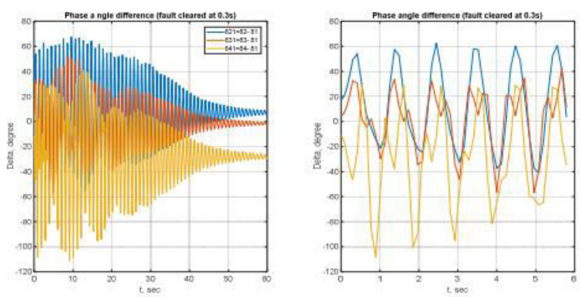
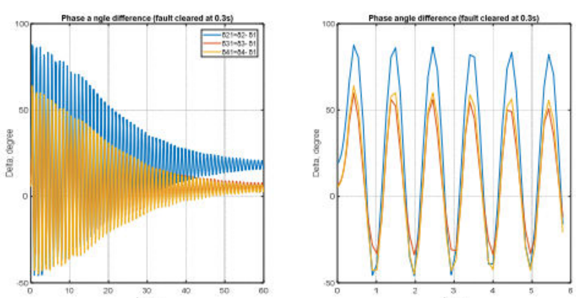
of revising emergency control quantity and stage of additional control by rounds, which can not only effectively take into account the impact of DG devices on transient safety and stability, but also avoid potential risk of out-of-control or over-control.

IV. SIMULATION RESULTS

In this paper, IEEE 9 bus power system is used to examine the effect of distributed generation based on renewable energy sources above power system stability. A three-phase fault defines in bus 4 for both systems at the fourth hour when the wind generation is highest (Fig. 1). The simulation is made by considering this fault cleaned at 0.3s by removal of line 4-5. Fig. 2 indicates the variations of rotor angle differences according to the slack machine obtained as a result of the simulation.



a) W1 case



b) W2 case

Fig. 2: GENERATOR ROTOR ANGLE DIFFERENCES VARIATION

As shown in Fig. 2, while W1 case has unstable and lower oscillations during 6 seconds, W2 case has stable and higher oscillations. In contrast with W1 case, W2 case has more stability. Nevertheless, both cases are continued stability as rotor angle differences tend to decrease over time.

The same fault is repeated at the thirteenth hour when wind generation is least. Table 1 indicates result which obtains in the simulation. Table 1 has shown that as increase clearing time at 4th and 13th hour, W2 case is some more stability in contrast with W1 case. In the case of low generation (for W2 case), the inverse ratio between cleaning time and power generation has seen to be prominent. In the formation of this inverse ratio has been efficient the integration of distributed generation at the low voltage level.

Table 1: STABILITY STATE

	4^{th} hour	13^{th} hour	Stability
W1 case	0.3/0.35/0.4s	0.1/0.15/0.2s	Stable
	0.45s and subsequent values	0.25s and subsequent values	Unstable
W2 case	0.3/0.35/0.4/0.45s	0.3/0.35/……/0.7/0.75s	Stable
	0.5s and subsequent values	0.8s and subsequent values	Unstable

Considering the interaction of DG and their coordination with traditional emergency control, the proposed emergency control strategy for transient safety and stability considering DG has less emergency control quantity than that in the safety control strategy without considering the operation of DG under the premise of guaranteeing the stability of the system. The correctness of the proposed control strategy is verified by a simulation example.

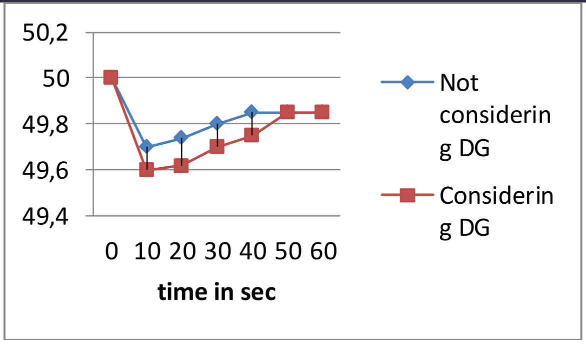


Fig. 3: COMPARISON OF POWER GRID HD FREQUENCY CURVES BEFORE AND AFTER CONSIDERING 'DG'

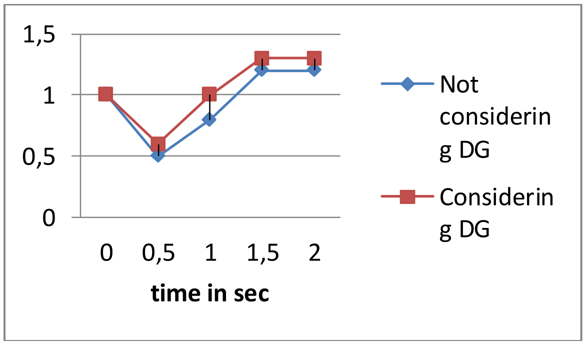


Fig. 4: COMPARISON OF POWER GRID HD VOLTAGE CURVES BEFORE AND AFTER CONSIDERING 'DG'

V. CONCLUSION

In this paper, Transient stability analysis of distributed power generated systems using emergency control strategy is proposed. The participation of DG in power system transient stability control is divided into three stages: stage of DG devices actively adjustment and stage of revising emergency control quantity and stage of additional control by rounds. This strategy not only takes advantage of the fast action of DG devices, but also makes use of the accuracy and conservativeness of traditional security control system. The high integration of distributed generation brings about the improvement in stability if there is no loss to entire system's inertia. it has observed that turning from traditional generation to distributed generation causes considerable loss of overall system inertia. So, loss of system inertia has revealed to causing loss of stability of the system and it has also understood that the system stability depends on the location of distributed generation. As a result, the base purpose is to accelerate the transition to the smart grid and to increase system reliability. In the future, further research will be carried out in these areas.

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