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Dynamic Control Strategy and Fault Protection for Microgrids with High Renewable Energy

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ABSTRACT

Microgrid is a group of interconnected loads and distributed energy resources (including microturbines, diesel generators, energy storage, renewable resources, and all other kinds of distributed energy resources) at distribution level with defined electrical boundaries that has black start capacity and can operate in island mode and/or grid-connected mode. Because of the uncertainty, intermittent, and discontinuity of the renewable resources, transient disturbance and dynamic disturbance exist in the microgrid. For the fault current is small in the system and the microgrid has very little inertia, the disturbance control and fault protection of microgrids are more difficult than the ones of traditional grids.

The most challenging part of protection and dynamic control of microgrids is figuring out whether a fault or disturbance is occurring in the system. In the microgrid, there may appear transient characteristics similar to the transient and dynamic disturbance at the initial faults. If there is a fault, the transient disturbance control should be used to prevent the system from collapsing and make sure the right breakers should be tripped.

But if there are transient and dynamic disturbances, even the initial characteristics of the transient and dynamic are very similar to the fault ones, the breakers should not be tripped. So that Mr. Zheng has been leading his team to propose and develop the dynamic disturbance control, transient disturbance control and fault protection technologies, and they all have been well applied in practical projects.

The main innovations are as follows:

(1) Relying on the dynamic disturbance control technology of the energy storage system, it can achieve safe and stable operation under the condition of high permeability of renewable energy, and can support 100% consumption of renewable energy generation in microgrid system.
(2) Through real-time load and power generation monitoring, analysis and control technology, relying on power and energy storage energy to effectively suppress transient disturbances and dynamic disturbances, respectively, to achieve unplanned seamless switching from grid connected mode to island mode or vice versa (time less than 10 milliseconds), Improve the safe and stable operation level of the system.
(3) Based on the Park transformation and the fault identification technology of branch current and voltage harmonic rapid changing rate, the precise positioning and fast isolation of the fault components of the microgrid are realized.
(4) Based on the power and load side comprehensive treatment technology, the total harmonic distortion rate (THD) of voltage and current is less than 3% when operating on an island.

The microgrid dynamic disturbance control technology, transient disturbance control technology and fault protection technology have been evaluated by domestic and foreign experts as reaching the international leading level.

Keywords: Digital frequency relay, Load frequency control (LFC), Microgrid, Renewable energy sources (RESs), Dynamic

INTRODUCTION

In past, several cascaded blackouts happened in electrical power systems due to frequency instability in case of the imbalance between the electrical load and power supply or N-1 contingency [1]. Nowadays, this problem increased after the growing of renewable energy sources (RESs), which have several impacts on the dynamic security of the islanded microgrids (MG). The dynamic security of MG is the ability of electric grid to maintain the system synchronism when subjected to various transient disturbances [2]. Figure 1 shows the dynamic security issues of MG. One of these issues is the lack of system inertia due to the high integration of RESs. Consequently, increase the voltage and frequency fluctuations, loss of generation source, forced load shedding, and short circuit faults [3]. Furthermore, RESs exchange electrical power to MGs through power electronic inverters, which cause higher power fluctuations than the traditional synchronous generators. Hence, if the RESs penetration becomes larger, the islanded MGs might become insecure as the stabilizing in system frequency and voltage is difficult in that situation [4, 5]. Moreover, there will be unbalanced between the generation and load due to the variable nature of RESs. These changes lead to the appearance of challenges for the MG dynamic security such as, nature transient variations in MG. These variations are highly affected by the operation mode of MG whether grid-connected or stand-alone [6, 7]. Moreover, the selection and coordination of conventional protective relays became more complex due to the frequent bidirectional power flow in connection feeders of MGs to utility grids [8, 9]. Regarding to the previous challenges, the stability and protection coordination issues have become interested and must be highlighted. Therefore, this work proposes a coordination of LFC and digital OUFR for maintaining the dynamic security of an islanded MG.

PROBLEM FORMULATION

The dynamic security issue is one of the most critical issues, which face the power system designers. Dynamic security refers to the ability of the electrical power system to maintain the synchronism when subjected to a sever trainset disturbance [2]. Therefore, the dynamic security deals with disturbances that impose momentous changes into the system variables. Among these are short-circuit faults, loss of a dominant generation source, and loss of a large load. The system response to these disturbances includes large deviations in the system variables such as voltage magnitudes and angles, generator speed, and system frequency. Hence, the balance between the input mechanical power and the output electrical power is disturbed. And then, the mismatch makes the synchronous generators (SGs) either accelerate or decelerate.

On the other hand, preserving dynamic security is different between the bulk power systems and MGs. In the case of the bulk power systems, the conventional synchronous generators are considered the source of the dynamics. Likewise, in MGs, the RESs are the host of dynamics. Moreover, most of the available methods for preserving the dynamic security of the bulk power systems are considered inefficient for MGs due to these methods are devised based on the features of the bulk power system, which are significant inertia constant and rather slow dynamics. Therefore, this research studies the dynamic security issue in the microgrids. In the MGs, the RESs exchange power to the MGs through inverters/converters. The power electronic interface-based RESs are static devices without any rotating mass so that the associated inertia constant is roughly zero. On the other hand, synchronous generators-based RESs are small-scale generators with noticeably low inertia constants.

Such a low inertia constant renders the MGs more vulnerable to the transients than the bulk power systems. Furthermore, the power generation from RESs are unpredictable and variable, results in more fluctuations in power flow and frequency in the MG, which significantly affects the power system operation.Also, the randomly changes in load power demand caused a bad response to the PCC voltage, active, and reactive powers transfer. To solve the dynamic stability problems, it must be determined the effective factors, which steer the MGs toward the insecurity.

These factors include a low inertia constant, frequent fault occurrence, and inadequacy of existing protection schemes. Moreover, the performance of the protection system is one the most significant factors which imperils the dynamic security of the µGs. Therefore, the stability and protection coordination issues have become a center of interest especially for power system researchers. Hence, this research proposes an efficient coordination of secondary frequency control (i.e., LFC) and the digital OUFR for an islanded MG security considering high penetration of RESs.

CONCLUSION

This paper proposed a coordination strategy of Load Frequency Control (LFC) and digital Over/Under Frequency Relay (OUFR) protection for an islanded microgrid system security considering high penetration of RESs. This coordination strategy is proposed for supporting the frequency stability and protecting the islanded MG against high-frequency deviations, which increased recently due to high penetration of (RESs), random load variations, and system uncertainty. These changes threaten the MG dynamic security and can cause under/over frequency relaying and disconnect some loads and generations, which may lead to cascading failure and system collapse. The simulations results proved that the proposed coordination has been achieved an effective performance for maintaining the MG dynamic security. Whereas, the LFC has been succeeded to readjust the frequency deviations to its allowable limits under different conditions of transients, load disturbances, and RESs penetration levels. However, in some cases of large disturbances and high RESs penetration, the LFC cannot maintain the frequency stability as the frequency fluctuates beyond the normal limits. In that case, the digital frequency relay trips the generation units. Furthermore, the results confirmed that the digital OUFR has superiority in terms of accuracy, sensitivity and wide range controlling.

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