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Survey on Integrated Control and Protection System for Photovoltaic Microgrids

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Abstract
A micro grid is defined as a type of the grid consisting of prime energy movers, power electronics converters, distributed energy storage systems and local loads. Microgrid network enables an improved management of energy. The main goal of power management is to stabilize the system, in terms of frequency and voltage. This paper includes issues such as faults during grid connected mode and faults during islanded mode, voltage control, load sharing through P-f control and various types of protection schemes are discussed. Overall stability and reliability of microgrid depends on these factors.

Keywords- Control strategies, integrated protection, microgrid, operation modes.

I. INTRODUCTION

Electric power systems experience abnormal conditions like faults and disturbances which lead to power interruptions, loss of stability and blackouts. To prevent or at least minimize the fault consequences, a protection system is designed, installed and adjusted. Protection system consists of different types of relays that have different characteristics and functions. Relays are characterized according to their algorithms.

Some are operated by high current values like over current relay, some by under and over voltage or frequency, and others by impedance like distance relay. The requirement of redundancy is widespread in protection system. Hence, it is common to protect equipment using more than one kind of relays. For example in transmission lines the distance protection is the main and over current is the backup protection. Redundancy is applied to equipments in high and medium voltage networks but not to low voltage networks. Communication channels are normally combined with protection systems of the high and medium voltage networks. Power line carrier (PLC) and fiber optics communication systems activating more functions in relays in the network. For instance, the line differential relay uses communication channels (like fiber optics) to receive measurement information and send trip signals to the remote end. Deep understanding of basics and theories is very important to dealing with the distribution system protection problems. Protection system is a complex system since it is affected by most of changes and events in network, such as configuration changes, equipments outages, faults, loading, and power system stability issues.

As a result, protection engineers are following different protection philosophies for designing and setting protection system. The cost of the protection system depends on the network voltage levels: high, medium and low voltage levels. High voltage equipments are more expensive than lower voltage levels and therefore their protection system is more expensive. Nowadays, protective relays are using the digital techniques which enable to include many functions in one relay. For high and medium voltage level networks it is worthy, but for low voltage level networks it is expensive to use digital relays.

II. CONTROL OF MICROGRIDS

As explained in previous, adoption of the microgrid concept results in a cellular structure within distribution networks and, thus, it is no longer possible to control the network using the basic control strategies of conventional distribution systems. The control scheme of a microgrid should be designed in a way that the system can safely operate in both the grid-connected and the islanded modes. In the grid-connected mode of operation, DERs operate in a constant real- and reactive-power control mode meaning that they exchange a pre-specified power with the distribution network, e.g., to minimize the power import from the main grid [12].

In the islanded mode of operation, however, the control algorithm must control the local network voltage and frequency and provide the instantaneous real and reactive power of the loads. Thus, appropriate voltage and frequency regulation schemes are necessary to enhance the network reliability and to preserve the system stability. Otherwise, microgrids with a high penetration of DERs can experience reactive and/or real-power oscillations. Unlike a large power system, the impedances between DERs in a microgrid are not significant. Therefore, small errors in voltage setpoints of DERs may cause large circulating currents that exceed the DER ratings [13]. Control of microgrids can be broadly divided into (i) supervisory control and (ii) control of DERs.

1. Supervisory Control

Supervisory control schemes of microgrids, which are also know as network or overall control schemes, can be categorized into two groups: (1) centralized control schemes [14], [15] and (2) decentralized control schemes [12], [16], [17]. In the following subsections, the two aforementioned control schemes are:

- Centralized Control
- Decentralized Control

2. Control of DERs

Control strategy of a DER within a microgrid is selected based on the required functions and network operational scenarios. Control of the DER is also determined by the nature of its interactions with the system and other DERs. Two main functions of the control of a DER are (i) real- and reactive-power control in the grid-connected mode of operation and (ii) microgrid voltage and frequency regulation in the islanded mode of operation. Table 1.1 provides a general categorization of the major control strategies for a DER and classifies the strategies into the grid-connected-mode (grid-following) and islandedmode (grid-forming) controls [7]. Each category is further divided into no interactive and interactive techniques.

III. LITERATURE REVIEW

Pooja R.Anap ET AL. (2017) In microgrid, if fault occurs or any other contingency happens, then the problems would be created which are relatedto power flow, also there are various protection schemes are used for minimize or eliminate these problems. Voltage control is used for reactive power balance and P-f control is used for active power control. Various protection schemes such as, over current protection, differential protection scheme, zoning of network in adaptive protection scheme are used in microgrid system.

Jiefeng Hu et al. (2017) an REIF testbed with PVs and a micro-turbine is investigated. The behaviors of PVs and the gas micro-turbine are first studied under various grid voltage conditions. The experimental results demonstrate the stable operation of the REIF under various generation and load conditions. In grid-connection mode, the PVs and the grid supply power to the load with surplus energy fed back to the grid. In islanded mode, a micro-turbine is used to produce a high-quality voltage to sustain the normal operation of the load and to provide the external voltage source to which the PV inverters can synchronize. In addition, the responses of the REIF under the short circuit fault condition are studied, and the protection mechanisms are proposed, providing a technical guideline for the future grid where a significant amount of distributed generation systems are included.

Laijun Chen et al. (2015) an integrated protection and control system with a hierarchical structure is proposed and a 100 kWp photovoltaic micro grid is built to validate the effectiveness and feasibility of the proposed strategy. Test results show that stable and flexible transition between different operation modes of the PV microgrid is achieved and the viability of the micro-grid under severe fault is greatly improved.

P. Ebrahimi Fard Zanjan ET AL. (2014) The concept of micro grid is quickly taking root not only in the research community, but also on the agendas of utilities, power system component manufacturers, and policy makers. Micro grids, by definition, should be operational both in grid-connected and islanded mode. This paper tackles this issue from the point of view of protection. In this paper, a micro grid protection scheme based on optimally sizing of FCLs and optimally setting of OCRs is proposed. Inductive type FCLs are located at the main interconnection point of the micro grid to the main grid. Inserting the FCL as an optimal parameter in the protection coordination problem affects the system admittance matrix which allows for changes in the fault current levels. Thus, the results show that it is possible to have one optimal relay setting and enforcement station that satisfies both micro grid modes of operation of the grids. In addition, without the FCL, it was found that it is difficult to set the relays and enforcement station and operational modes implementations. The proposed approach was tested on a typical radial distribution system of IEEE 30 equipped with CSG and the results confirm the effectiveness of the proposed method.

Sarina Adhikari et al. (2014) summarized as follows:

1. This paper proposes and presents coordinated strategies of V-f control and P-Q control, respectively, for microgrids with PV generator and battery storage.
2. In the control strategies, the PV generator is operated at MPP, and the battery storage acts as a buffer in order to inject and absorb deficit or surplus power by using the charge/discharge cycle of the battery. The paper contributes in demonstrating the control strategies with effective coordination between inverter V-f (or P-Q) control, MPPT control, and energy storage control.
3. The proposed control strategy also provides a smooth transition of PV side PQ control in grid connected mode to V-f control in islanded mode. This is the most essential feature required in the modern microgrid controllers.
4. The proposed control algorithms are also capable of handling the battery SOC constraint. An effective seamless transformation of controls from V-f to constant active power and voltage control at the PV side and from constant active power control to frequency control at the diesel generator is validated with satisfactory results. This feature helps the controller to adapt to the changing irradiance levels while considering the battery availability.
5. The proposed V-f control method shows a very satisfactory performance in reviving highly reduced voltage and frequency back to the nominal values in a matter of only 2 seconds. It is much faster than the diesel generator control which takes around 10 seconds to settle down. Hence, PV and battery installations might be applied effectively in restoring the microgrid frequency and the voltage at PCC after disturbances.
6. Similarly, the proposed integrated and coordinated P-Q control algorithm can be effectively used in supplying some critical loads of a microgrid with solar PV and battery.

In the present methods, the control parameters are dependent upon the PV, battery, and external grid conditions and must be re-tuned with the changing conditions. This can be overcome by using an adaptive method to obtain these parameters dynamically based on the system conditions. The adaptive control methods could be a very useful and promising future direction of this work.

Chengshan Wang et al. (2013) An approach based on matrix perturbation for the coordinated optimization of droop coefficients in a micro-grid has been proposed in this paper. Parameter perturbation analysis is made on the droop coefficients to identify the manner and degree of parameters' influence on the statematrix. The increments of eigen solutions are then obtained based on the first-order perturbation items. In the optimization process, a comprehensive objective function is proposed to ensure the stability of the system, to enhance the damping characteristics, and to maintain a stability margin for a wide range of operating conditions. The computational flowchart is presented for the proposed optimization algorithm based on matrix perturbation. Numerical examples are performed using a benchmark low-voltage micro-grid. In the examples, the parameter-optimization process is analyzed in detail. And the time-domain simulations are carried out to illustrate the responses of the DG units during mode transitions and under disturbances. The robustness analysis of the optimized coefficients to the change of the exchanging power between the micro-grid and the main grid is presented as well. Theoretical analysis and evaluation results have confirmed the effectiveness of the optimization approach, the feasibility of the objective function, and the robustness of the optimized parameters.

WANG ChengShan et al. (2012) proposed a control strategy for the seamless operation mode transition for a master-slave controlled microgrid. The control strategy, focused on the master DG unit in the microgrid, consists of the control state and reference current compensation algorithm and separation switch control logic. Conclusions drawn from the validation are as follows.

1. When the microgrid switches from grid-connected operation to stand-alone operation, the proposed control strategy can effectively suppress the transient distortions of the microgrid voltage and master DG unit's output current, ensuring a smooth transient with minimum impact on the microgrid loads and DG units.
2. When the microgrid transfers from stand-alone operation to grid-connected operation, the proposed strategy can make the amplitude and phase angle of the microgrid voltage and the utility grid voltage the same. With appropriate compensation control, a seamless transition can be achieved.

Bo Zhao et al. (2012) An integrated microgrid laboratory system with multiple DGs and energy storage systems was developed and tested. The system structure was flexible as the microgrid system had several different topological structures according to different requirements. Control strategies for application during grid-connected mode, islanded mode, and mode transition were proposed. Many tests of the control strategy, protection, and power quality were carried out to obtain the optimal control method and operating conditions.

The tests demonstrated the flexibility of mode transition, stable behavior under different conditions, and high quality of power supply. All the results show that the microgrid system performs as expected and has a high level of robustness. As most components of the microgrid laboratory are real, it can also serve as a verification platform for engineering applications. Since microgrid projects are often constructed in remote areas, such as islands, it is difficult to validate the functions of equipments due to the adverse power situation. Thus, debugging and validation of equipment, such as converters, can be carried out with the aid of the microgrid laboratory.

Because of the flexibility and controllability of the microgrid laboratory, the control systems of the project can be debugged and validated more conveniently and easily by simulating different working conditions. We can adopt a verified method in the microgrid laboratory and then transfer it to projects. In this way, the microgrid laboratory has played an important role in our construction of an island microgrid project, Dongfu island wind-solar-diesel-battery-seawater desalination project. Thus, the microgrid laboratory also has a vital role to play in the construction of microgrid projects. Relevant information about the project will be presented in detail in the future. In the second phase of this integrated microgrid laboratory system, a monitoring system based on the IEC 61850 standard will be imported. The whole microgrid system will be connected to a distribution automation system. Additionally, more types of energy storage, such as compressed air, lithium batteries, sodium–sulphur batteries, super-capacitors, and electric vehicle devices will be employed. The integrated microgrid laboratory system will be further improved. Furthermore, continuing work will be carried out in the near future in order to conduct further research on key issues.

IV. CONCLUSION

In microgrid, if fault occurs or any other contingency happens, then the problems would be created which are related to power flow, also there are various protection schemes are used for minimize or eliminate these problems. Voltage control is used for reactive power balance and P-f control is used for active power control. Various protection schemes such as, over current protection, differential protection scheme, zoning of network in adaptive protection scheme are used in microgrid system

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