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Fast Service Restoration of Multi-Source Active Distribution Network with Microgrids and Electric Vehicles

Guangmin Fan[1, a], Lingxu Guo[1,b] ,Wei Liang*[1,c] and Hongtao Qie[1,d]

[1]State Grid Tianjin Electric Power Company, Tianjin, China

[a]guangmin.fan@tj.sgcc.com.cn, [b]lingxuguo@163.com, [c]losowei@163.com,[d]hongtaoqie@163.com

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Abstract. The increasingly serious energy crisis and environmental pollution problems promote the large-scale application of microgrids (MGs) and electric vehicles (EVs). As the main carrier of MGs and EVs, distribution network is gradually presenting multi-source and active characteristics. A fast service restoration method of multi-source active distribution network with MGs and EVs is proposed in this paper for service restoration of distribution network, which takes effectiveness, rapidity, economy and reliability into consideration. Then, different optimal power flow (OPF) models for the service restoration strategy are constructed separately to minimize the network loss after service restoration. In addition, a genetic algorithm was introduced to solve the OPF model. The analysis of the service restoration strategy is carried out on an IEEE distribution system with three-feeder and eighteen nodes containing MGs and EVs, and the feasibility and effectiveness are verified

Introduction

Since electricity cannot be stored in large-scale, once a fault happens, line outage or even large-scale blackouts of power system will result in huge economic losses to generation system, the transmission system and the consumers [1, 2]. In order to improve the power quality of demand side, reduce outage period and improve service reliability, the service restoration method must be devised in a very short period. With the continuous development technologies in microgrids (MGs) and the large-scale application of electric vehicles (EVs), distribution network is gradually presenting multi-source and active characteristics, which provides a new opportunity for multi-source active distribution network to choose service restoration strategy in an active way. MG is usually connected to distribution network through high speed and controllable electronic devices, which can supply flexible, reliable and economic power to power system or the local areas [3]. EV charging load is definitely a controllable load for demand response. Under the Vehicle-to-grid concept [4, 5], a number of batteries of EVs can act as an equivalent large-scale battery energy storage system if the charging and discharging process are properly controlled.

Few studies have been made to investigate service restoration of multi-source active distribution network containing MGs, EVs and other novel controllable loads. Service restoration of distribution network with distributed generations (DGs) is investigated in [6] and [7]. A multi-agent system for service restoration of distribution network containing DGs and MGs is built in [8] and [9]. In [10], the ant colony algorithm was utilized to solve the service restoration reconfiguration. The genetic algorithm was utilized to deal with the large area blackout in distribution network. In this paper, a fast and multi-level service restoration method of multi-source active distribution network with MGs and EVs is proposed based on exploring the advantages of MGs and EVs in distribution network service restoration, which not only can guarantee the customer comforts (takes the travel demand of EVs users into consideration), but also can improve the supply restoration capability and further enhance system reliability level. The multi-level service include the MG restoration scheme, the MG and EV cooperative control restoration scheme and the feeder restoration scheme.

Framework of the Fast Service Restoration Scheme

A. Effects of MGs Access on Distribution Network Restoration

MGs access on distribution network makes the service restoration present new characteristics as follows.

1) The connection of MG makes the uni-directional flow of the traditional distribution network become bi-directional flow, and the power flow may change at any time.

2) The MG control center (MGCC) can coordinate the operation of the DGs and controllable loads access on MG and communicate with distribution management system (DMS) in service restoration to respond to the control command given by DMS.

3) MG not only can meet the requirements of a particular power quality of local load, improve power supply reliability, but also can restore as much load as possible within the out-of-service area, and reduce the required number of switching operations in the restoration.

B. Framework of the Fast Service Restoration Scheme

The framework of the proposed fast service restoration scheme considering MGs and EVs is given in Fig.1. Firstly, the fault was be able to be isolated and the service restoration scheme could be selected in a short time under the cooperative control of DSM, MGCC and EVSCC. If the MG restoration scheme is selected, the DMS will adjust the power output from MGs in the outage area to restore as much load as possible; If the MG and EV cooperative control restoration scheme is selected, the DMS will adjust the power output from MGs and the load shedding from EVCS in the outage area through the cooperative control of the MGCC and EVSCC; If the feeder restoration scheme is selected, the DMS will dispatch the entire distribution network to adjust the power output from MGs and load shedding from EVCS all over the distribution network.

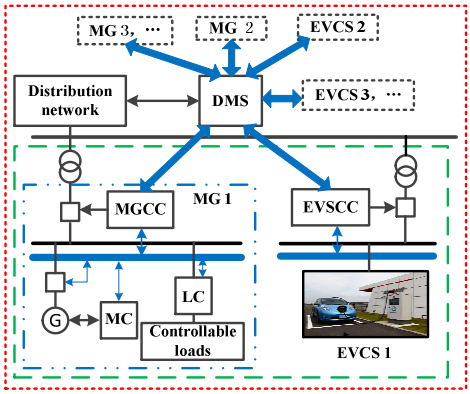

Fig.1 Hierarchy control of distribution system containing micro-grids and EVs for service restorsation

The Multi-level Service Restoration of Active Distribution Network with MGs and EVs

The load fluctuation of distribution network, the intermittent nature of DGs and the uncertainties of the EV charging load, EV charging locations and the time charging time starts make the capability of the MGs and the EVs response to the service restoration present multidimensional characteristic. Therefore, a multi-level service restoration is utilized to adjust to the changing external environment, which includes the MG restoration scheme, the MG and EV cooperative control restoration scheme and the feeder restoration scheme. When a fault happens, the MG restoration scheme should be selected first for sake of the customer comforts. Since the MG restoration scheme cannot satisfy the demand of loads and the corresponding operation indexes, the MG and EV cooperative control restoration scheme will be selected. And the feeder restoration scheme will be selected last. The Restoration flow chart is shown in Fig.2.

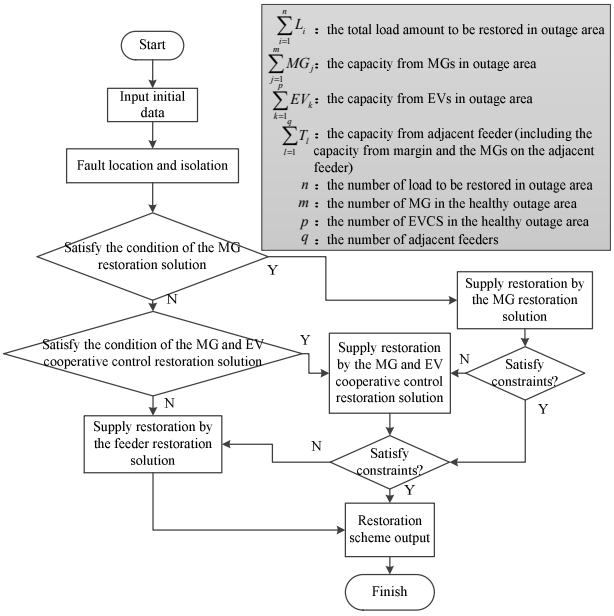

Fig.2 Restoration flow chart

Case Studies and Simulation Results

A. Case Study

A typical three feeder distribution network with MGs and EVs is shown in Fig.3. MG locates at bus 11 and two EVCSs locate at bus 8, 12 separately. To verify the effectively of the proposed strategy, branch 27, 28 and 29 are added to the initial case. When a fault occurs between bus 2 and 16, it was assumed that the fault was able to be located and isolated successfully. Consequently, the loads at bus 8, 9, 10, 11, 12 and 17 are de-energized. The initial data can be obtained in. Assuming all the EVs charge in EVCS with the corresponding power factor equals to 1.0. The maximum output power of MG is set to 14+j10MVA. The maximum available shedding charging load of EVCS1 and EVCS2 are set to 4.5MW and 5MW respectively in this case.

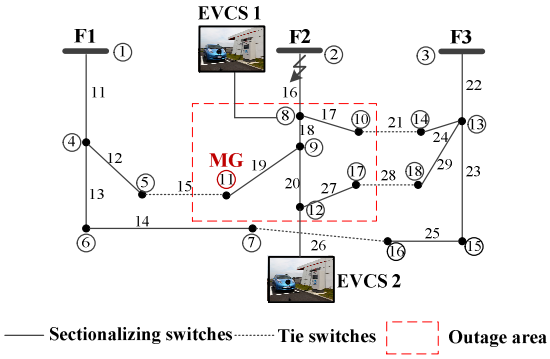

Fig.3 Model of the test system

B. Simulation Results for MG and EV Restoration Scheme

The simulation results suggest that the MG and EV cooperative control restoration scheme not only can restore all the load within the out-of-service area taking all the constraints into consideration, but also can guarantee a lower line loss rate after the restoration than the MG restoration, which verifies the advantages of EVs in the service restoration. The OPF calculation results based on genetic algorithm is shown in Fig.4.

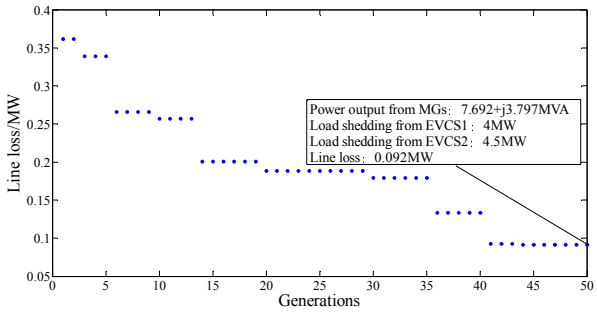

Fig. 4.The OPF results based on GA

Conclusions

In this paper, a fast service restoration method of multi-source active distribution network with MGs and EVs is proposed. The fast service restoration scheme include the MG restoration scheme, the MG and EV cooperative control restoration scheme and the feeder restoration scheme, and different OPF models for multi-level restoration strategy are developed separately. Then OPF based on genetic algorithm was utilized to determine the optimal scheme for service restoration. The feasibility and effectiveness are verified by simulation on the IEEE three-feeder and eighteen nodes test system with MGs and EVs.

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