Research on the type of load of accessing to microgrid based on reliability

Longlong Zhang, Ming Sun

School of Electrical Engineering and Automation, Hefei University of Technology, Hefei, Anhui, China

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Abstract. The microgrid provides a new form of Distributed Generation accessed to distribution network .With the development and application of microgrid technologies, its ability to meet the power supply reliability needs of loads in microgrid has become a problem that should be solved. To this end, the paper divides the loads according to the power supply reliability, builds a microgrid model constituting of wind/photovoltaic power /independent storage power, and investigates the reliability evaluation method based on Monte Carlo simulation. By an example of IEEE-RBTS system, the paper compares the reliability level of loads in normal distribution network with those in the microgrid, finally draws the conclusion, the third-class load is the most suitable load accessed to microgrid.

Introduction

Distributed Generation(DG) is proposed in the late 1990s, which locates near the customers and can be used locally, consisted by renewable energy such as solar, gas, wind and etc. While the problems of accessing of DGs and contacting between power system and distribution network can't be solved efficiently, so the micro-grid is raised for the purpose. Micro-grid is composed by loads and micro generations, which can make DGs play an important role by achieving self-protection, self-control and self-management of the autonomous system. The loads in micro-grid can be divided into important loads and general loads, sensitive loads and non-sensitive loads, controllable loads and non-controllable loads, the loads also can be divided into the first level loads, the second level loads and the third level loads according to power supply reliability and the extend of loss or damage in politic and economic when power off. [LiangHuishi,2011][WuYabin,2012][Ge Xingkai,2013][LiZhiqi,2012]conclude that the reliability indexes have been improved when the micro-grid has drawn in system to some extend, it can certain that the accessed micro-grid not only saves energy but also improves the power supply reliability, so the correlation studies about micro-grid have been researched widely in recent years, which include micro-grid structure, protection, design and the optimal access location into micro-grid of DGs and so on. [MiaoYuancheng,2012] has showed that the reliability is different when the micro-grid accessed into different distribution network modes. But there is little research for micro grid accessing loads' types.

This paper analyzes the loads' type for micro-grid from the power supply reliability part, for this purpose, it constructs the wind/PV/ storage micro-grid model, uses Monte Carlo method evaluating loads in different conditions, finally analyzes and summarizes the results.

Loads in microgrid

Classification of loads in microgrid.

Different loads in microgrid will impact the configures, such as the accessed location of micro generations, the accessed capacity and the types of micro-generations.

There are many kinds of loads classification in power system, the loads will be classify to the first class loads, the second class loads and the third class loads from power supply reliability

[Xiongxinyin,2010]. The required reliability becomes lower and lower from the first loads to the third loads gradually, therefore the generation configuration and circuit topology requirements are different. The power sources configuration employs two independent power generation for the first class loads, while the double loop power supply is applied for the second class loads, and the radiating structure power supply is adopted for the third class loads.

Reliability index.

The traditional reliability index of distribution network can be divided into load point and system reliability indices[LiuChuanquan,2008].

Load point reliability indices include: average failure rate λ (times / a), the average outage duration r (hours / time), the average outage time U (h / year). System reliability indices mainly contains: system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), customer average interruption duration time (CAIDI), average supply availability indicators (ASAI), expected energy not supplied (EENS).

Wind/PV/storage microgrid model

Because the main new energy developing is wind power and solar energy, the model of DG in this paper including wind power, PV and storage.

Wind turbine model.

The relationship of wind turbine power output p_t and wind speed v is non-linear, and the exact expression is shown as below[GongWeijun,2011].

$$P_{WT}=\begin{cases} 0 & 0\le v_t\le v_{ci} \\ (A+B\times v_t+C\times v_t^2)*P_r & v_{ci}\le v_t\le v_r \\ P_r & v_r\le v_t\le v_{co} \\ 0 & v_{co}\le v_t \end{cases} \tag{1}$$

In the formula, P_{WT} , v_t represents real-time power of wind turbine and wind speed respectively, v_{ci} , v_r , v_∞ and P_r represent cut in wind speed, rated wind speed, cut out wind speed and rated power respectively. Constants A , B , C are the function of cut in wind speed and wind turbine rated wind speed.

There are several ways for simulation of wind speed, such as time series analysis and Webb parameter analysis method. The Webb parameter analysis can get the wind speed which is very close to the real wind speed. Its distribution function and probability density function expression as follow:

$$F(v)=P(V\le v)=1-\exp[-(v/c)^k] \tag{2}$$

$$f(v)=k/c*(v/c)^{k-1}*\exp[-(v/c)^k] \tag{3}$$

Where k , c represents shape and scale parameter of Weibull distribution respectively, and k which is ranging from 1.8-2.3 reflects the inclination of the Weibull distribution, c reflects the average wind speed when the precision is low[Zhou Shuangxi,2011].

PV model.

PV is the most potential renewable energy generation besides wind power generation, but it also has some intermittent and random, the output power of solar battery can be expressed[YangJinhuan,2013]:

$$P_{PV}=\begin{cases} \dfrac{\eta_C}{K_C}*S*I(t)^2, & 0<I(t)\le K_C \\ \eta_C*S*I(t), & I(t)>K_C \end{cases} \tag{4}$$

Where P_{PV} represents output power, η_C represents the conversion efficiency of solar panels, K_C is a constant which represents irradiance threshold, P_{PV} and $I(t)$ shows quadratic relationship when the irradiance threshold is below the K_C, P_{PV} and $I(t)$ shows linear relationship, where the constant is set as $200W/m^2$. S represents the area of solar panels, $I(t)$ represents the received solar radiation of PV panel, and $I(t)$ is directly affected by the clearness index k, k can be expressed [WangHaiying,2012].

$$k = \frac{1}{\lambda} W\left[\frac{(1+\lambda k_{th})(Y-1) - Ye^{\lambda k_{th}}}{e^{\lambda(\lambda k_{th}+1)}}\right] + k_{th} + \frac{1}{\lambda} \quad (5)$$

Where k_{th} is the maximum value of k; λ is a constant determined by the function of k_{th} and clearness index; $W()$ represents Lambert function W; Y is subjected to uniformly distributed random variable at (0,1).

The running model of distributed power and energy storage devices.

Micro-grid access distribution network, there are two basic operation modes: parallel operation and island operation. Distribution network and micro power supply to the load together in parallel operation mode, and only the micro power supply to the load of the network in island operation mode. During the micro-grid islanding operation, the load is powered by DGs and energy storage devices to meet the needs of the network load. The wind and light DGs are greatly influenced by the outside world, so the DGs' power supply can not meet the needs of the load when the weather/climate does not satisfy the conditions. At this moment, energy storage power supply need meet the demand of micro network internal power supply. When the external condition does satisfy the conditions, power supply is maybe greater than the network itself. At this time, energy storage device need to hoard excess capacity for future use.

Microgrid reliability index algorithm based on Monte Carlo simulation

After entering the micro-grid，multiple factors have join into the distribution network structure for which is original single, it is necessary to doing some fault analysis. In this paper, based on the component failure impact on the load, failure impact is divided into the following five kinds:① component failure has no effect on the loads and won't cause a blackout;②load power outage caused by component failure, and the outage time is the isolating switch operation time;③a power outage caused by component failure, and the outage time is the fault repair time.④ the fault causes the load area work in islanded operation state, and the islanding operation time is the isolating switch operation time.⑤ the fault causes the load area work in islanded operation state, and the islanding operation time is the fault repair time.

When micro-grid switches from grid connected mode to the islanding mode, there are certain probability of success. The successful transition probability sets 0.85 in this paper. In islanding operation, as the DGs affects greatly by external conditions and the stored energy is limited, the energy may not supplied and even lead to blackout.

Reliability assessment methodis mainly divided into analytical method and simulation method. This paper adopts the Monte Carlo simulation method, the particular steps are as follows:

①Enter the basic information of network, Including the failure rate of line, switch, transformer and other components. Then list the the matrix analysis of network fault consequences.

②Determine the simulation time and initialize the simulation time, in this time all the components are no fault. Random element by element in the shortest time to failure $T_{TTF\min}$, advances the simulation time to $T_{TTF\min}$.

③For the random components, generating a random number, and then get the repair time of the components .

④ According to the above analysis matrix failure consequences, we can get the component failure on the loads. If it is the former three cases, it can directly superimposed load point fault frequency and fault duration time; if the fault caused the load area operating in islanded mode, we needs to calculating the islanding operation time on the basis of every DG's operation situation and then determine the component failure time, finally we can get the load point fault frequency and fault duration time.

⑤ If the time reach the simulation time, stop. Otherwise, continue. At last, according to the corresponding formulas, we can get the failure frequency and the fault duration time, the reliability indexes can be obtained.

This paper uses the Monte Carlo simulation evaluating and comparing the reliability of loads in the normal distribution and the micro-grids modes, from the angle of power supply reliability determining the suitable loads type for the micro-grid.

Case studies

This paper uses the modified IEEE-RBTS BUS6 feeder F4[RoyBillinton,1996] as an example to study which kind of load is suitable for accessing in the micro-grid. Micro-grid system is constructed with load14 to load 17. The PCC switch is set on feeder 19. DGs and energy storing devices are set on the bus export which has the PCC switch. The success rate of switching from the grid to the island is 0.85. For the first-class load, the backup power is accessed on feeder 19. For the second-class load, it is accessed on the feeder which is extracted from feeder F4.

The micro-grid location is elected in 36.42^{o} north latitude and the distribution parameters of wind speed, k and c, are cited from the literature[WangHaiying,2012]: k is 2.12 and c is8.44. The average sky index is 0.495. The efficiency of solar panels takes 0.1. The maximum power output of small-scale wind farms and photovoltaic power generation both takes 1000KW. The energy storing device is 800KW.

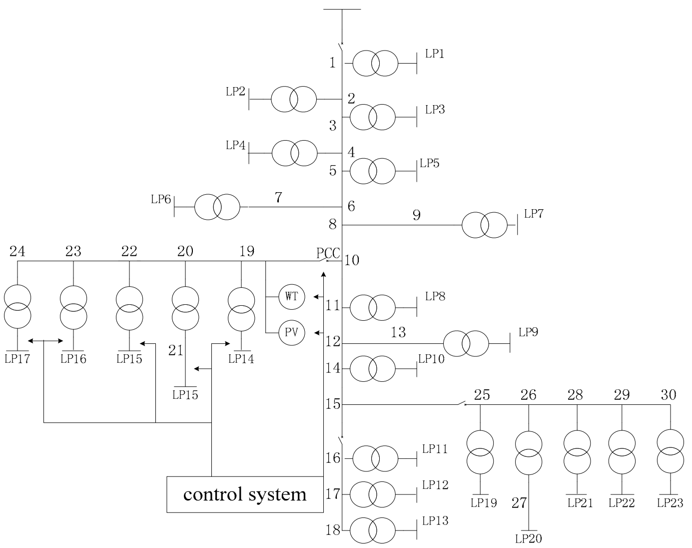

Figure 1 IEEE RBTS BUS6 F4 system

Tab1. The system reliability indices

	SAIFI	SAIDI	CAIDI	ASAI	ENS
first-class load	0.6776	1.7486	2.5805	0.9998	2.2944
second-class load	0.8440	2.1639	2.5637	0.9998	2.6921
third-class load	1.9693	4.9250	2.5009	0.9994	5.4878
microgrid	0.8564	2.1573	2.5190	0.9998	2.7107

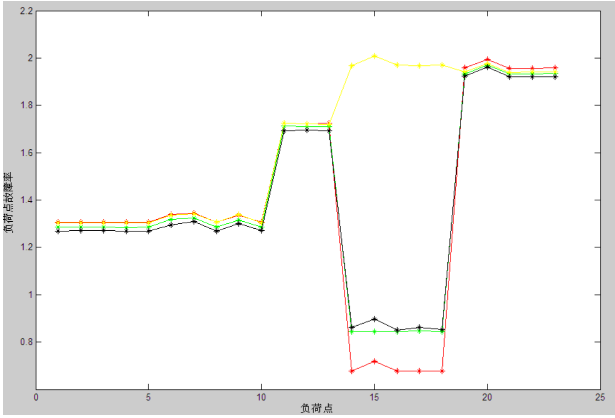

Figure 2 Comparison of load points' failure rate in different conditions

The Figure 2 shows the load failure rate under different conditions: yellow, black, green, red these four color represent the third-class load in the normal distribution system; the loads in the micro-grid; the third-class load in the normal distribution system; the second-class load in the normal distribution system; the first-class load in the normal distribution system.

From the results of calculation, conclusions can be obtained. First, the first-class loads can not be accessed in this micro-grid system because of the high reliability requirements of the first-class loads; secondly, when the second-class loads are accessed in this micro-grid system, the system reliability indices almost get the loads operation in the normal distribution system, but the load points' failure rate is higher than normal distribution system; Thirdly, when the third-class loads access in the micro-grid system, the increasing amplitude of reliability index is the largest. So, the third-class loads can access in the micro-grid system perfectly.

Conclusions

Whether the accessed microgrid can satisfy the power supply demand of load has been a key problem of microgrid accessing into distribution network. The paper divided the loads according to the power supply reliability, built a microgrid model constituting of wind/PV/independent storage power, and evaluated the reliability of loads which in normal distribution network or accessed to microgrid by reliability assessment method based on Monte Carlo simulation. As an example of IEEE-RBTS BUS6 system, the evaluation results show those: the system reliability index and probability of load fault when the first-class load accessed in normal distribution network are better than when accessed in microgrid; the reliability level when second-class load accessed in normal distribution is almost as when second-class load accessed in microgrid, the system reliability can almost satisfy, but probability of load fault has some improvement; the reliability level both system reliability index and probability of load fault has significantly increased when third-class load accessed in microgrid. Thus we can conclude that the third-class load is most suitable accessed in microgrid in contrast with first-class load.

References

[1] Liang Huishi et al. 2011. Monte Carlo Simulation Based Reliability Evaluation of Distribution System Containing Microgrids. *Journal of Power System Technology* 35(10):76-81.

[2] Wu Yabin et al. 2012. Reliability Evaluation of Distribution System with Microgrid Based on the Minimum-Cut Set. *Journal of Shaanxi Electric Power* 40(7):42-46.

[3] Ge Xingkai. 2013. Reliability Assessment of Distribution System With Micro-Grids. Shanghai Jiao Tong University.

[4] Li Zhiqi et al. 2012. Reliability of Distribution Netwok with Microgrid. *Journal of East China Electric Power* 40(5):803 -807.

[5] Miao Yuancheng et al. 2012. Evaluation of a Distribution Nework Connection Mode Considering Micro-grid. *Journal of Proceeding of the CSEE* 32(1):17-24.

[6] Xiong xinyin et al. 2010. *Introduction to Electrical Engineeing.*Beijing. China Electric Power Press.

[7] Liu Chuanquan. 2008. The Distribution Network Reliability Assessment Considering the Distribution Generation. Shanghai Jiao Tong University.

[8] Gong Weijun et al. 2011. The estimation algorithm on the probabilistic distribution parameters of wind speed based on Weibull distribution. *Journal of Renewable Energy Resources* 29(6):20-23.

[9] Zhou Shuangxi et al. 2011. *Wind power generation and power system.* Beijing. China Electric Power Press.

[10] Yang Jinhuan. 2013. *Solar photovoltaic application technology.* Beijing. Publishing House of Electronics Industry.

[11] Wang Haiying et al. 2012. Reliability assessment of grid-integrated solar photovoltaic system. *Journal of Power System Technology* 36(10):1-5.

[12] Roy Billinton et al. 1996. A Test System For Teaching Overall Power System Reliability Assessment. *Journal of IEEE Transactions on Power Systems* 11(4):1670-1674.