On Disaster Mitigation of Power Distribution Network

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The paper introduces the disaster (or say as network fault) happened in the city of Xiamen, China at October 1999 which caused the power cut off in the whole island due to a raid of strong typhoon and the problems exposed by this disaster. Summarization the experiences about construction and retrofit of the Xiamen distribution network, the problems of the distribution network against the disaster was discussed to improving the abilities to preventing the widely power off in a city.

1 Introduction

The demand for the electric power was increased due to the advancement of modern society and human civilization. If a large power system faults cannot be controlled and disposed in time and effectively will influence the system stability and collapse the power network leading to loss of electricity in a large area and bringing catastrophic results for society. The examples can see from the power cut across U.S. and Canada on August 14th 2003 and that through the whole Italy on September 28th 2003 etc. So it is quite important to study the measures to prevent the power cut of the large power network as well as the urban distribution network which may influences the power supply to numerous houses and families in a district or the whole city and brings catastrophic outcome as well. Some natural disasters such as typhoon, thunderstorm and earthquake are not avoidable or even some faults caused by a wrong operation of the personals may be happened and induced a serious system faults. It is important for the utilities to prearrange a practical scheme for the restoration of the system during such serious faults.

In the following paper, the relevant measures to improve the abilities of distribution network are introduced to meet the emergency needs during the catastrophic fault through analyzing the fault made by a strong typhoon raid on Xiamen in October 1999, which caused the whole island losing electrical power.

2. The overview of the system faults in October 1999

Xiamen is a city of coastal island in the southeast of China and has an area of 123 km². It is one of the four major special economic zones in China. At that period, the system of Xiamen contains one 500kV substation, six 220kV substations and thirteen 110kV substations, supplying nearly 4 billion kWh per year. There are three 220kV substations supplied by the lines from the nearby city’s power sources, one of them is through a submarine cable, called as the first passage, and the another two are through two overhead lines on a same tower across sea, called as the second passage. The three 220kV substations are linking together by the 220kV lines. The urban distribution network inside the island contains 248 distribution substations and switching stations, and has 124 10kV feeders, in which 336 kilometers are 10kV overhead lines and 458 kilometers are 10kV underground cables. There are about 60MW of fuel emergency supply sources within the island. The normal load of the whole island is nearly 500MW.

On October 9th, 1999, a strong typhoon made a frontal attack on Xiamen; the strongest wind-force reached more than 14 Class with the maximum wind speed 47 meters per second. The center of the typhoon stayed in the area of Xiamen for up to 8 hours, the rainfall exceeded 200 mm. during that period caused a large area power cutoff and influence the water supply, suspend the air and shipping services, suspend classes and shutdown of the factories, thus brought the great economic losses and bad social influence to Xiamen. The seriously
damaged of the transmission and distribution facilities caused the loss of electrical supply in the whole island of Xiamen for 3 hours. The major problems exposed by the calamity were:

(1) Social ability to resist the emergency was weak. The power cutoff caused the cut off of the water supply; the paralysis of important social communal facilities and only the broadcasting station keep in operation of all the news media.

(2) The uninterrupted power supply (UPS) of SCADA for dispatch automation system could support less then 2 hours only and then become invalidation and caused the dispatching center lose its "eyes". The linkage between the substations are so week and difficult to transfer the loads according the demands of the system at that time. The Dispatcher is difficult and shrieved to dispatching the power networks facing such large-scale distribution faults arose by the natural disaster.

(3) The urban power network was seriously damaged due to the typhoon

1) The 220kV overhead line was tripped because of the intermittence fault caused by the jumper on the angle tower swung to the tower angle by the wind and flash to the tower. The loosen of the leads for voltage transformer, coupling capacitor and line trap coil (the reason was that the equipment connection clamps were designed to have only a single bolt and was easily loosen when ceaselessly swung in strong wind) caused the outage of the other two cable lines. These trip resulted in the totally interruption of the three 220kV lines supplying to the whole island one after another.

2) There are 14 lines with voltage over 110kV was tripped due to the loosen or even twisting into broken of the leads for voltage transformer, coupling capacitor and line trap coil and causing permanently fault trip. Two 110kV towers were topple over during typhoon.

3) The loosen of the leads concerned above caused the all the five 220kV substations in the city lost voltage wholly. The rain leakage into the control room and switchgear room of two 220kV substations from the doors or windows caused the forced out of operation of the primary and secondary equipments.

4) The medium and low voltage distribution networks were damaged seriously. 115 feeders were tripped which have overhead lines. 434 poles of the MV and LV overhead lines were topple over, 46 distribution transformers was damaged, the overhead lines broken and fall down for more than 605 places and the number of the faults reported from the customer are more than 3000. All of these failures were caused by the turn over or fallen of trees, advertisement boards and scaffold used for building construction etc.

5) The antenna of the microwave communication was blown to be departure the normal direction and so caused the interrupted of the communication.

(4) The emergency power supply inside the island failed to start at the crucial moment due to the lack of maintenance and operating experience as well as the lack of the schemes for black starting of the system.

3 Retrofitting of the Xiamen urban power networks against disaster and its effects

The Xiamen power network was retrofitting and construction to improve the abilities for combating the disasters may meet according to the exposed problems in above-mentioned disaster in recent years. A large amount of construction and retrofit were carried out and had got a lot of obvious effects.

(1) In the year 2001 the third 220kV power source entering into the island greatly improved the power supply reliability of the system in Xiamen.

(2) The use of the insulated conductor for overhead lines raised to 77.31% and use of the underground cables in the urban distribution networks raised to 61.67%, vigorously improved the abilities to against the disasters.

(3) The planning and design of the distribution network and equipments used fully considering the meteorological condition and natural disasters may meet in the district. such as wind, thunder, flood etc. The "micro topography" meteorological condition were investigated in the different areas such as the air opening places, places easily to suffering thunders and floods etc were defined and special treatments were fully considered in the distribution network planning and design.

(4) Retrofit of the distribution facilities.

1) Retrofit of jumper on angle tower of 110kV and higher rank lines fully considered the shift of the wires due to the fastest instantaneous wind speed under the fitful wind state, and improved the suspending mode of the jumper string from single suspending point into multiple suspending points.

2) Change the connection clamps to have double bolts for the down leads of the voltage transformer, line trap coil, coupling capacitor etc. to increase their fastening and prevent to twist when ceaselessly swung in strong wind. The results proven it are good enough to prevent the damage, which may cause before improvement.

3) Retrofit the doors, windows and the drains of the
substation and other places where used the same designed to prevent the leakage of rain or water into the room. In addition, the operation, maintenance and management of power networks have been strengthened and the accident prediction scheme of power network for combating the disaster was constituted, drills were carried out regularly, ability of operator dealing with the combat of the disasters had been issued and improved. At the same time, the power supply scheme and outfit of emergency supply for the very important department or customers were treated with the same measures. The results are proven to be obviously effective and ensuring the reliability of the power supply after retrofitted in Xiamen power networks under numerous attack of typhoon and thunder in recently years.

4 Relevant questions in the urban disaster management and the measures to improving the ability of power networks to combating disasters

The urban disaster is defined as a kind of natural incident and social incident caused by the factors that can't be controlled or not to be controlled which seriously influence the people's lives and properties as well as the social wealth in the urban areas. There are lots of factors, which may cause the urban disaster, for example, the natural disaster such as strong wind, storm, earthquake, plague etc. and the man-made or technical factors caused the hidden dangers such as traffic accidents, chemical accidents, large areas power interruption etc. Relevant research shown since the middle of 20th century with the fast increasing of the processing of urbanization, losses caused by the disaster suffered in large and medium cities are greater and greater. The management of urban disasters had already become the most important matters of the country in resisting the disasters. The disaster management of the electric power networks seems to be most important as the electricity is the sources served for many fundamental facilities for personal lives and factories production. So the scheme to combating the outage of electric power is a most important part in the urban disaster management and also the perfect of the scheme for cities to combating the disaster may strengthen the efforts for the power utilities to combating the disaster of the power systems. The relevant measures to improving the ability of power networks to combating disasters related to the planning, construction and management of power networks and closely related to urban disaster management as well. The relevant measures of improving the ability of urban power networks to combating disaster was gained from the working experience from the construction and retrofit of Xiamen distribution network after suffering from the disaster met before. The measures summarized are as following:

4.1 Constitute the combating plan against the disaster. The plan against disaster must regard as the important component of the developing plan of the distribution network. The measures and projects of the plan that implement in different year should be scheduled clearly, disaster risk had to assessed every year and additional measures must be taken to meet the requirements for disaster management improvement and the raise of the funds required must be prepared in advance of the planned date.

4.2 Constitute the faults combating scheme against disaster beforehand. Urban distribution network is the infrastructure related to the public safety and public interests. The safety of the power network must paid great attention to the angle of safety and steady of the city. So, in one hand, the urban distribution network must constitute accident prediction scheme against great disaster with the prediction scheme linked with the government and the administrative department of important social facilities and at the same time the scheme should be rolling to perfect every year as well as the simulated drilling to improve the disaster treatment ability of operators frequently. On the other hand, the utilities must submitted to the government to contain the power system accident prediction scheme against disaster into the emergency processing prediction scheme of the urban crisis. At the same time the emergency education for the publics should be strengthened to enhance their consciousness of saving oneself and guarantee to run well in urgent cases thus can reduce the losses to a maximum extent.

4.3 Set up the basic security power network in the city. This is generally composed of putting urban emergency supply into the underground cable networks. It can ensure the power supply to the social vital parts or the important organization for war preparedness in urgent cases. The set up of the special basic security network for the city is uneconomically. It must starting from planning firstly in normal cases, the basic security network of the city is a component of the urban distribution networks and have a normal load flow in the normal time. But as the disasters happened, the basic security network of the city can be dispatching to supply the demand of social vital organization
according to the prediction scheme. The basic security networks of the city are mainly bases on the underground cable networks. If a feeder with overhead line and cable in series need to dispatching to supplying security loads, it must to be retrofitted to be a pure cable feeder for security.

4.4 Allocate the emergency security supplies. The urban key departments and units, for instance, the water supply, news media, financial management, government department etc. should allocate an emergency security supply by themselves and guarantee to run well in urgent cases. There are many ways to offering emergency security supply for the key departments. One of them is the units along the basic security network of the city can be offered by the basic security network. The second way is to allocate the generator set by unit themselves and keeps a good regular maintenance to avoid the failing of operation in urgent cases. The third way is to adopt mobile generator set by the relative department of the city. It’s more flexible to move to the place where the generating sets are needed in any time. But this measure is rather expensive due to the effectiveness for a given period of time is rather low and the capacities are limited.

As for a city (or a district) also needs to allocate a certain capacity emergency supply. The urban emergency supply can be formed by single or multiple medium or small power plant in the city. Plant used for emergency supply should own the characteristics of quick starting, to meet the requirements.

4.5 Choose and design the lines or substations with a suitable meteorological condition according to local to the local weather recorded.

Planning and design of distribution network must fully consider the disaster factors. For instance, the insulated conductors or underground cables should be firstly selected to use in coastal typhoon areas. The largest wind speed value recorded should be considered as the serious meteorological condition for design standard. The same consideration is for the design of the floor level of the substation; it should consider the maximum height design of overhead lines for security operation during worse of the floods might happen in that area historically.

5.6 Must carried on a good assessment for the ability of distribution network against disasters. An expert’s team should carry on the assessment scientifically. Appraisal contents the urban disaster management and crisis emergency prediction scheme, urban disaster trend, the emergency processing mechanism of distribution network against disaster, the actual distribution annual operation index achievement (such as reliability, fault restoration times etc), outfit condition of emergency security supply for the urban disaster, power supply furnished for important areas and customers in the city etc. After assessment, the risk still existing and the main weak points can be found and a plan had to be issued for improving the ability of the distribution network against disaster in next term.

6 Conclusion

The ability of urban distribution network to combat the disaster directly related to the safety and stability of a city, the security of people’s lives and properties. The improvement and perfection of the ability of urban distribution network combating disaster is a systematical project. It not only relates to the planning, construction and management of distribution networks, but also the city management and society's emergency ability etc. The measures summarizing from the experiences gained from the accident happened in Xiaman due to the disturbance of typhoon at 1999 help us to improving the ability of urban distribution network to combating disasters. But the measures still should be constantly explored and perfected through practice.