Occurrence and countermeasures of urban power grid accident

WangWei¹, ZhangTao²

¹ School of Electrical Engineering and Automation, Anhui University, Hefei, China
² School of Electrical Engineering and Automation, Anhui University, Hefei, China

Email address: 790956038@qq.com (authorname1)

Abstract: With the advance of technology, the development of network communication and the extensive use of power grids, people can get to know power grid accidents around the world through the network timely. Power grid accidents occur frequently. Large-scale power system blackout and casualty accidents caused by electric shock are also fairly commonplace. All of those accidents have seriously endangered the property and personal safety of the country and people, and the development of society and economy is severely affected by power grid accidents. Through the researches on several typical cases of power grid accidents at home and abroad in recent years and taking these accident cases as the research object, this paper will analyze the three major factors that cause power grid accidents at present. At the same time, combining with various factors and impacts caused by power grid accidents, the paper will put forward corresponding solutions and suggestions to prevent the occurrence of the accident and lower the impact of the accident.

1. Introduction

Due to the continuous development of the society, the improvement of people's living standards and the gradual increase of electric load, the demand for electricity is increasing. As a result, the frequency of grid accidents is also increasing [1]. In recent years, there are many large-scale power grid blackouts and countless casualty accidents caused by electric shock, which are big blows both for the country and for the individual. And these accidents also have seriously affected the stabilization of social order and economic development. In 2015, due to the massive "3.31" power outage in Turkey, power supply in the 80 provinces was completely disrupted, which affected more than 70 million people and caused an economic loss of $700 million (Source: Surging News); During Christmas in 2015, Ukraine was hacked, which led to a massive power outage, resulting in the destruction of information security of the power system[2]; On 28th, September, 2016, a large-scale power blackout occurred in Australia, which caused the entire power grid in South Australia collapsed[3];On the 11th, January, 2017, a power plant boiler in Uttar Pradesh, India exploded, which killed 26 people and injured more than 100 people. The generator set causing explosion has been stopped (Source: Xinhuanet.com); In 2012, "5.17" serious personal casualty accident of Hebei Electric Power Corporation was caused by equipment defects, which caused 11 burns, 7 deaths, and 4 minor injuries (Source: National Energy Agency); On 15th, August, 2017, there was the largest power blackout in the history of Taiwan Province. Power outages occurred in Taipei, New Taipei, Hsinchu and Taoyuan, affecting 17 counties and cities. It is estimated that the accident affected about 6.68 million households (Source: Southern Power Grid Technical Information Center).

The continuous occurrence of large-scale power outage and casualty accidents caused by electric...
shock should attract people's focus and attention. The widespread blackouts affect the normal life of the residents and the normal development of society; the frequent electric shock deaths have also seriously affected the normal life of a family. Ensuring the safety of power supply is the most desirable result of every country, society and people. A large number of researchers analyze and summarize the causes of power grid accidents from different fields and propose corresponding solutions. Based on the accident case, this paper analyzes the cause of the accident and puts forward the corresponding prevention methods and measures referring to the previous research findings, in order to achieve a stable and safe power supply.

2. The cause and case analysis of urban power grid accidents
As we can see from the city power grid accidents over the years, there are mainly three factors causing the accident, including Internal factors of power grid, external man-made destruction and natural disaster factors. If any one of them happened, it is likely to lead to power grid accidents. Detailed analyses are as follows.

2.1. Internal factors of power grid
The internal factors of the power grid mainly include the lack of strict implementation of the safety rules and regulations of the power grid company, the false operation of employees, the damage of the power grid equipment and the defects of the old and the grid structure. It is every grid employee’s responsibility and obligation to Learn and seriously implement the company safety rules and regulations. In reality, some Front-line operators have weak safety consciousness. They always work in their subjective consciousness deciding that there would be no danger, lacking self-protection ability and safety knowledge of frontline staff. In some countries and regions, due to the lack of safety management and weak supervision awareness, pre-job training is only a form, which can easily lead to mis-operation and mis-decision in the work of employees. After long-term use of grid equipment both at home and abroad, because its equipment structure complicate maintenance is not complete, grid equipment often cannot keep permanent stable work, during which a problem appeared, the overall equipment may not work, causing power grid accident[4]. The weak grid structure and unreasonable planning in the power grid have always existed in the transmission grid line, which also needs to be paid enough attention. And the internal factors of these power systems are likely to cause widespread blackouts and electric shock casualties. Table 1 lists the power grid accidents caused by internal factors of the power grid in the last five years. In this paper, the example of the accident of power transmission tower in Jiangxi and a massive power failure in India are given to further illustrate the serious consequences of power grid internal factors.

| Number | Time       | Cause of the accident                      | Accident consequences                                                                 |
|--------|------------|---------------------------------------------|---------------------------------------------------------------------------------------|
| 1      | 2017.3.23  | Substation line failure                     | Changdu central substation and Sichuan dam, Yunnan dam substation power failure        |
| 2      | 2017.5.7   | The tower anchor bolts are not fastened     | Jiangxi power transmission and substation company construction of the iron tower collapsed, 4 people died and 1 were injured |
| 3      | 2017.6.7   | Maintenance personnel operation is not standard. | Operator of power supply company in Anxi county was electrocuted                      |
| 4      | 2016.6.18  | Cable trench ignition                       | Shaanxi 330 kv nanjião substation total shutdown, loss load 280,000 kw.              |
| 5      | 2016.4.1   | Insufficient safety awareness of operating personnel | Induced electric shock occurred during maintenance of Tangshan electric power company, resulting in death |
| 6      | 2015.3.18  | Operator misoperation                      | Xuancheng power supply company staff malfunction repair misoperation, cause the right foot of the right hand was burned by arc |
| 7      | 2015.3.31  | Chain fault caused by heavy                | Turkey’s power has been almost interrupted, causing                                  |
load trip of line | a large-scale blackout.
---|---
8 | 2012.10 Fault of electrical short circuit and power system protection device | Three power outages occurred in Brazil, involving 417 cities
9 | 2012.9.9 Transmission line failure | A massive power outage in Cuba has cost more than 1.3 m kw
10 | 2012.7.30 Power grid load capacity is insufficient and grid structure is too weak | A large area of power outages in India, more than 600 million of the population was affected

2.1.1. The accident of power transmission tower in Jiangxi. In 2017.5.7, the 500kv Luofang-Fuzhou transmission line project built by Jiangxi province power transmission and substation company, the anchor bolt of the 181# tower is not fastened, and the left and right side phase conductors are respectively provided with reverse temporary pull line, which is about 55 degrees from the ground angle, the result was the collapse of 181# tower, the fall of five workers, four deaths and one injury. The accident reflects the problems of imperfect safety liability system, violation of safety regulations and inadequate supervision and management. After the tower was built, the construction and supervision units were not strictly checked, the safety awareness of field operators is weak, and the ability of self-protection is weak.

2.1.2. Massive power failure in India. In 2012.7.30, India has suffered the biggest outage in all history, and more than 600 million people are affected by power failure[5].The cause of the accident is that the infrastructure of the India power grid is backward, the equipment is old, the grid structure is weak and the planning is unreasonable. The power companies have not been able to control the load in time, which leads to the insufficient power load capacity of the power grid, resulting in two continuous large-scale outages.

2.2. External man-made destruction factors
External man-made destruction factors, first of all, are connected with each country's security and social stability, national quality. The domestic frequent man-made destruction factors mostly are stealing cable wire, doing sth without authorization to steal leakage, damaging electric power facilities. And for foreign countries, they also include the destruction of war, terrorist attack and hacking besides what we have mentioned before. Table 2 lists the power grid accidents caused by human factors in recent years. This paper takes the accident of large-scale power failure caused by the hacking of Ukraine to analyze.

| Number | Time    | Cause of the accident            | Accident consequences                           |
|--------|---------|---------------------------------|------------------------------------------------|
| 1      | 2016-2017.3 | Violation of planting trees, vehicle accident touch broken pole, et | 27 tripping events in Kunming power grid        |
| 2      | 2015.12 | Hacker implants malware         | Large scale power outages in several regions of Ukraine |
| 3      | 2013.12 | Artificially planned destruction | A massive power outage in Venezuela             |
| 4      | 2013.6  | Gas pipeline is damaged         | Nigeria power grid is frequently paralyzed       |
| 5      | 2012.3.6 | People cut the iron tower cable | Two base collapses                                |
| 6      | 2006.8  | The crane damaged the high voltage cable | Massive power outages and traffic crashes in downtown Tokyo |
| 7      | 2005.10 | The militants blew up power facilities | Power outages in most areas of Baghdad, Iraq    |

2.2.1. Massive power failure in Ukraine. In 2015.12, Ukraine power grid suffered a malicious hacker implanted virus software, resulting in extensive domestic large-scale blackout area on Christmas Eve. The large-scale power cut accidents caused by the network information attack are the first known
deliberate use of malicious software attacks caused by power failure case[6]. The investigation shows that the failure of the information network is the key cause of the accident, the specific attack process of the power system structure is shown in Figure 1 below. The power accident was affected by at least three areas in Ukraine and more than 1.4m people. On the other hand, as early as 2007, BlackEnergy was found to be a hacker tool, but still successfully invaded by phishing mail. It shows that Ukraine power grid's security management capability is weak, and staff safety awareness are not enough, the overall defense system of the power grid needs to be improved.

Figure 1. Diagram of the power system being attacked

2.3. Natural disaster factors

Natural disasters are the abnormal phenomena that occur in the nature on which human beings live. And once the natural disaster happens, the damage to human beings is very shocking. Among natural disasters, Meteorological, floods and geological disasters are the most important factors in the power grid accident. The frequency and uncertainty of natural disaster lead to frequent accidents at home and abroad, especially when power system infrastructure is exposed to the external environment and severely damaged. Affected by the bad environment, it is difficult and risky for power companies to repair, and then the system's recovery was slow, and without electricity for a longer time, the probability of casualties increases. In table 3, the domestic and foreign cases of power accidents that are caused by natural disasters occurred in the past 10 years are listed. This paper expounds the serious consequences of natural disasters from the typical case of power failure in Australia and the case of power failure in the United States.

Table 3 Accidents caused by natural disasters

| Number | Time  | Cause of the accident          | Accident consequences                                                                 |
|--------|-------|-------------------------------|--------------------------------------------------------------------------------------|
| 1      | 2017.2| The effect of blizzard        | An employee of Shanxi local electric power company died when he took up poles.       |
| 2      | 2016.9| The effect of windstorm       | Large-scale power failure in southern Australia                                       |
| 3      | 2016.8| The effect of landslide       | During the construction of the white crane beach hydropower station, the top arch collapsed and 1 people died. |
| 4      | 2012.6| Flood disaster                | The power facilities were badly damaged in Guangdong, Guangxi and Yunnan             |
| 5      | 2012.9| The impact of the storm       | Large-scale power failure in Washington, D.C.                                        |
| 6      | 2012.10| Hurricane Sandy              | In the United States, 8 million 100 thousand households and businesses are blackout   |
| 7      | 2012.10| The influence of strong wind  | More than 200 thousand people cut off power in Japan                                  |
| 8      | 2012.8| The influence of sea anemone  | In Zhejiang Province, 1.13 million home power outages                                 |
The impact of the Earthquake
Power facilities in Sichuan and other places are badly damaged

10 2008.1 Ice disaster The power facilities are badly damaged in the whole country

2.3.1. Power failure in Australia. In 2016.9, in central and southern Australia, due to the impact of bad weather storms, lead to a large area power grid paralyzed, facilities severely damaged, resulting in energy prices also rose[3]. The South Australia grid suffered five system failures in 88 seconds due to the storm, only two minutes after the transmission line failure occurred, the system frequency collapsed and the south Australia power grid collapsed. It has brought negative effects to people's life, social order and regional economic development in the central and southern regions.

2.3.2. Power failure in America. In 2012.10.29,"hurricane" sandy log in the United States, more than 8.1 million homes and businesses blackouts in 17 states in the east, while schools students, hospital ICU patients were tested, electrical wiring poses a personal threat, residents living environment seriously damaged, have tens of billions of economic loss is huge.

3. Measures to prevent the occurrence of grid accidents

3.1 Domestic grid accident statistics
Since the enforcement of The 13th Five-year Grid Planning, situations of domestic grid production safety is prone to be stable. Nevertheless, there is still occasional recurrence of regional power outages and casualties due to grid production accidents. Taking domestic grid safety accidents statistics for instance. In table 4, the importance of grid accidences prevention can be further illustrated.

| Time  | Blackout | Liability | Natural disaster | Deaths | More than 1 Million losses |
|-------|----------|-----------|-------------------|--------|---------------------------|
| 2016.10 | 0        | 10        | 0                 | 14     | 0                         |
| 2016.11 | 0        | 3         | 0                 | 75     | 0                         |
| 2016.12 | 0        | 3         | 0                 | 3      | 0                         |
| 2017.1  | 0        | 4         | 0                 | 4      | 0                         |
| 2017.2  | 1        | 3         | 1                 | 4      | 0                         |
| 2017.3  | 3        | 5         | 0                 | 5      | 0                         |
| 2017.5  | 0        | 7         | 0                 | 13     | 1                         |
| 2017.6  | 1        | 8         | 0                 | 12     | 0                         |
| 2017.8  | 0        | 2         | 1                 | 3      | 0                         |
| 2017.9  | 0        | 5         | 0                 | 5      | 0                         |
| 2017.10 | 0        | 10        | 0                 | 14     | 0                         |

3.2 Recapitulation of grid questions
(1) The staff safety education should be further strengthened in the development of power grid construction [7]. The company should organize its staff to carry out "the safety" training, because safety consciousness of some staffs is still weak as well as their safety study understanding is not thorough, and they cannot strictly enforce the safety stipulation.

(2) On-site work safety requires improving. Staff quality is deficient. Operating irregularities still exists in on-site work, such as unauthorized equipment charge, illegal risk-taking operations, and the neglect of on-site security measures.

(3) Lax enforcement of working regulations still exists. As an example, violated operation accident illustrate unqualified acceptance check and reception of engining equipment, formality of overall
supervision, and frivolous enforcement of rules and regulations.

(4) The capacity of disaster prevention still intermingles. In recent years Southern Power Grid vigorously promoted reinforcement and reconstruction projects of transmission line in some coastal areas, not only did it install wind monitoring points to collect meteorological data to form a large database, but also continuously improved the power grid disaster resilience [8]. By comparison, some inland city grid companies are still weak in power network structure and these companies still need to be further improved.

3.3 The countermeasure study of three factors

3.3.1 Study on the countermeasures of internal factors

- The company should ensure individual duties of job security, firmly establishing the concept of safety first, and remember that prevention awareness is the first condition of safety work. It should also adhere to the principle of "safety responsibilities should be taken by the head of job", while fully implement each level of security responsibility.
- The company should guarantee the safety of power grid operation and equipment management. For one thing, it should further strengthen the monitoring of power grid operation, entirely inspecting the risk of power grid operation, and release timely safety warning as well as implement control measures seriously. For another thing, the company should organize single-line power supply substation to check hidden troubles, continuously improving the grid structure, with marking the dangerous switching operation points in advance, and strengthen the prevention and remediation of the mistake atresia for the sake of strict prevention of misoperation accidents.
- The company should ensure the establishment of job shift system. Grid companies can send supervision groups to evaluate agency units comprehensively at all levels from the implementation of responsibility.

3.3.2 Study on the countermeasures of external man-made destruction factors

- The establishment of joint law enforcement network which includes power grid companies, public security departments and urban management departments. The maintenance of power facilities should not only rely on the regular inspections and repairs of the staff of power grid, but also should get the support of the government and law enforcement agencies. Therefore, it is necessary to establish the joint law enforcement network. On the one hand, media publicity can promote the awareness of the general public to serious consequences of destroying electrical facilities and stealing cable wires in early time. On the other hand, the serious trial of the cases that have taken place can make the criminals get the punishment they deserved.
- In the event of power outage in Ukraine, the criminals did man-made destructions to the power grid by using the internet. So, first of all, the staff who work in the grid company should enhance the awareness of information security and confidentiality, and develop good security habits of using network; Secondly, it is necessary to upgrade the security of internal servers and other equipment in the power grid, to enhance the closed-loop management of information security work, and to strengthen the password configuration from time to time.
- Learn some effective measures from Kunming Transmission and Distribution Management Station: introducing the video surveillance terminal actively, which is with the function of video channel visualization, alarms of foreign body intrusion, message alarms of giving a warning, acoustic control alarms of reporting an emergency on the scene and checking the power grids through WeChat, page or APP at any time and other functions. It also solved the problem that the fixed construction site is invisible.

3.3.3 Study on the countermeasures of natural disaster factors

- The establishment of experts group including the experts who work in the grid companies, the meteorology departments and the hydrology departments can help people to get the information of
disaster at the earliest time, and it can also help people to study the law of the coming of the disaster and to know how to give a warning to the grid within the shortest time.

- It is necessary to continue to strengthen the construction of a strong power grid, optimize the response mechanism to the disasters and improve planning system of the power. The government should establish a set of mature disaster prevention and emergency response systems with reference to the experiences and lessons learned after the natural disasters such as snowstorms and earthquakes. So when the disaster is approaching, it can minimize the risk of power accidents if all deployment and personnel transfer is conducted in an orderly manner through the platform information system of emergency command.

- The government should comprehensively promote anti-wind reinforcement and renovation projects for power transmission and distribution lines in the coastal areas, install wind monitoring points in the coastal areas and form large databases by collecting meteorological data. So the stability of lines and equipment can be improved continuously by combining the wind distribution models of meteorological departments and rationally arranging the distance between the equipment and the coastline.

4. Conclusion

This paper summarizes and analyzes the causes of the accident in the power grid from the case of enumerating the accident and the detailed description of the typical events. Firstly it describes the possible factors that cause the accidents of city power grid: internal factors and man-made damage factors and natural disasters, followed by a variety of accident statistics summarized the problems existed in city power grid. On the basis of the above factors and problems, the countermeasures to reduce the power grid accidents and the safe operation of the power grid are studied. To reduce grid losses and improve the safe operation coefficient of power system, in the final analysis, we need to strengthen personal safety awareness, optimize the power grid structure, accelerate the research of power supply emergency construction, and increase the investment in science and technology for disaster prevention and relief in power system. Combined with the above suggestions and measures, we must have a deep understanding of the prominent problems in the current power grid safety work, and take effective measures to resolutely curb the development trend of electric accidents and enhance the ability of safety protection, so as to maintain social stability and ensure people's safety and happiness.

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