IWAIS XIII, Andermatt, September 8 to 11, 2009

Survey and Analysis of Ice Accidents of Early 2008 in Southern China

Xingliang Jiang[1], Jie Zhao[2], Bing Luo[2], Jiwu Zhang[3] and Chunde Huang[3]
[1] The State Key Laboratory of Power Transmission Equipment & System Security and New Technology & College of Electrical Engineering of Chongqing University, Chongqing 400030, China
[2] Technology Research Center, China Southern Power Grid Co., LTD.
401# Huasui Rd. No.6,Zhujiangxincheng,Tianhe,Guangzhou,Guangdong 510623, P.R.China,
[3] Huaihua Electric Power Bureau
No. 46, Wushui Road, Huaihua City, Hunan Province, Huaihua 418000, China
xljiang@cqu.edu.cn

***Abstract*—In many cold regions of the world, the extremely cold winter, usually with serious ice and snow, is a great danger to power system, industry, communication, traffic, tour, et.al. During Jan. to Feb. 2008, an abrupt cold and rainy weather attacked most provinces in South China, which led to severe ice accidents on transmission lines and substitution stations, such as collapsing of poles and towers, galloping and rupturing of conductors, flashover of insulators, all of these resulted in a large-scale outage. The 2008's ice disaster caused a huge economic loss for Chinese. Taking the 2008 ice disaster and surveys of ice events in the past decades in China, this paper analyzes the reasons and characteristics of Chinese ice accidents and relative climate conditions. Considering micro-meteorology and micro-topography, the atmospheric icing distribution in China is concluded for the reference of insulation designing. The results show that long-duration and large-scale are related to the 2008's ice disaster; in addition, the effects of micro-meteorology and micro-topography are obvious. The conclusions indicate that two mainly reasons for the accidents, one is the severe cold rain that have not occurred for decades, which led the ice loads on power equipments exceed the design level; another is the lacking knowledge of icing, anti-icing and de-icing mechanism. In the end, based on the long-term observations and works, the suggestion of de-icing and anti-icing for power system are submitted.**

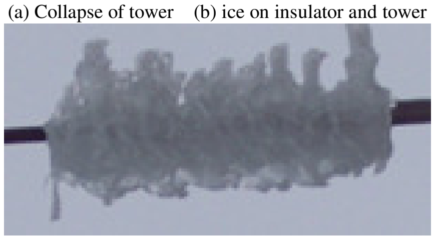
***Keywords*—power system; ice disaster; transmission line; icing; anti-icing; de-icing;**

I. Introduction

In many cold regions of the world, atmospheric ice and snow accretion on power system can lead to serious problems, such as collapse of poles and towers, galloping and rupture of conductors, flashover of insulators, and so on. These accidents effect the safe performance of power system; even take more effects as many relative departments as industry, communication, traffic, tour, et al. There were lots of reports about ice accidents international as article [1-5].

In China, there were more than one thousand ice accidents recorded since 1954. As the power networks expanded to more and more complex areas of atmospheric, pollution and high altitude, ice accidents were reported frequently in recent years. From December 2004 to February 2005, a large-scale ice event had occurred in power system of Hunan, Hubei and Chongqing, which caused 700 millions persons, suffered the disaster, and the economic loss reached 1 billions RMB, as reported in article [6]. From January to February 2008, an unusual cold weather with glaze ice made a surprise attack on most provinces in south China. The ice disaster influenced the safe performance of transmission lines and substitution stations, and caused a large-scale outage in 570 counties of 13 provinces as Guangdong, Guangxi, Yunnan, Guizhou, Sichuan, Chongqing, Jiangxi, Hunan, Hubei, Fujian, Jiangsu, Anhui and Zhejiang, which are noted in Chinese map as Fig 1. The 2008's ice disaster is the most serious ice accidents in China since 1937, and reports by Chinese State Department showed that the 2008's ice disaster attacked power networks of 19 provinces and economic loss reaches 53,7 billions RMB. Fig 2 shows the typical icing condition on 220kV lines.

(a) Collapse of tower (b) ice on insulator and tower



(c) ice on conductor

Fig.2 Ice on 220kV transmission lines

In China, the regions with icing, pollution and high altitude are abundant in energy sources and resources. Surveys showed that 79% of Chinese water and electricity resource is in south China with ice, contamination and high altitude so power system in these regions will undergo the effect of ice and snow. As the construction of HV, EHV and UHV transmission lines and substitution stations, the problems with ice and snow on power networks will be more and more severe.

According to the severe ice events happened in the past decades in China, especially the severe ice disaster in 2008, the paper investigates the reasons and characteristics for them, and then analyzes the ice distribution and related factors. In addition, as the experiences and productions, valuable anti-icing and de-icing measures and equipments are suggested in order to reduce or avoid the loss of severe ice events in the future.

Fig.1 Chinese map

II. Mechanism of Ice and Snow Accretion on Power System

A. Knowledge basic

According to past investigations, the mechanisms of ice accreting and shedding on structures and conductors were a focused problem international, and a lot of reports showed the investigations in many countries as Canada [7], Finland [8,9], Japan [10,11], China [5], etc. The main factors are related to ice accretion are as follows:

(1) There are enough super-cooled waters in air, which is related to meteorology.

(2) Super-cooled waters must be captured by the structure, which is related to hydrodynamics.

3) Super-cooled waters should freeze on the structure surface, which is related to thermodynamics.

(4) As the electrical equipments are working with applied voltage, ice accretion on electrical equipments is influenced by the electric field, which is related to electromagnetics.

(5) As the ice forming on towers, poles and conductors, the ice loads may press these equipments and led them to rotation and distortion, which is related to mechanics.

As the showed above, ice and snow accretion power equipments is a complicated problem which is related to meteorology, hydrodynamics, thermodynamics, electromagnetics, mechanics, and so on.

B. Mechanism of ice and snow

There are mainly 3 types of ice accretion on transmission lines and substitution stations, glaze ice, rime ice and snow. Meteorological variables which determine the type of icing event are air temperature, wind speed, the diameter of super-cooled water droplets in air, and the atmospheric water content.

Glaze ice often occurs when freezing rain falls through a layer of air temperature below 0℃ to the ground. Its aspect is usually transparent and rigid with high density near to 0.9g/cm^3. Rime ice usually occurs when drizzling rain and cold fog falls with air temperature is below -5℃. Rime ice usually contains two main forms, soft rime and hard rime. Soft rime is opaque and incompact with low density below 0.6 g/cm^3 so it is of little threaten to power system; hard rime forms with alternant process of ice melting and freezing, so its formation is opaque and rigid characteristics with density from 0.6 to 0.9g/cm^3. There are two types of snow, dry snow and wet snow. For power system, wet snow with density low than 0.3 g/cm^3 is also investigated because it is harmful to lines and stations during its melting process.

Furthermore, cold fog with drizzle and pollution usually caused insulator flashover so it should be studied as well as ice and snow mentioned above.

As the past investigations, glaze ice, hard rime and wet snow are always related to ice events and glaze ice is considered the most severe case, it is also showed that the main ice type in 2008's ice accidents is glaze ice.

C. Weather condition in China

Ice and snow accretion on transmission lines and substitution stations are always related to meteorology and topography, but the detail data were hard to acquire because there were various meteorology and topography in China. According to the past reports, ice accidents usually occurred in southeast, southwest and central China. Every year, the Siberia cold current and Pacific warm current join in these areas and form a short-term glaze ice or rime ice, although these temperature in these regions is above 0℃. Whereas, the temperature in other regions as east China is below 0℃ in winter, but there are short of water in the air, so the ice and snow are not accreted. In addition, lots of regions suffered icing weather as the micro-climate and micro-topography, so ice accidents often occurred in these areas.

For power system, a short-term glaze ice may cause severe damage so the rule of ice distribution and characteristic is important to study. According the past investigations, glaze days in a year are usual used to show the icing severity. Mean glaze days in a year can reflect the glaze characteristic and be useful to insulation design in a certain region. Based on the surveys during the past 50 years in China, results reveal the mean glaze days in 143 districts of 25 provinces in table.1, and the relative provinces are also displayed in Chinese map in figure.1. Combine table.1 and figure.1, the distribution of mean glaze days in China is displayed in figure 2.

TABLE I
SURVEYS OF MEAN GLAZE DAYS IN CHINA

district	days	district	days	district	days	district	days
Sichuan		Hunan		Jiangxi		Jiangsu	
Leibo	18.2	Bamian mountain	55.5	Ji'an	2.0	Ganyu	1.0
Zhaojue	9.7	Heng mountain	58.5	Lu mountain	39.6	Xuzhou	1.5
Meigu	24.0	Shimen	2.1	Jiujiang	2.0	Zhejiang	
Emei mountain	141.3	Sangzhi	3.3	Yichun	2.3	Wuhuankan	1.3
Xiyang	3.1	Yueyang	4.2	Nan city	2.2	Tianmu mountain	47.8
Chongqing		Nan county	2.2	Ninggang	2.5	Cangkuo mountain	38.0
Jinfu mountain	70.0	Changde	3.8	Guangchang	2.0	Pingyang	1.0
Yunnan		Ruan river	4.0	Nanchang	2.8	Fujian	
Zhaotong	9.9	Ping river	2.0	Suichuan	2.0	Qixian mountain	30.3
Huize	6.8	Ruanling	2.7	Ganzhou	2.3	Jiuxian mountain	13.3
Guyi	3.4	Anhua	3.4	Hubei		Pucheng	1.0
Guizhou		Jishou	2.3	Zhaoyang	2.1	Taining	1.7
Tongzhi	4.3	Changsha	3.7	Yingshan	2.8	Changding	1.2
Meitan	7.7	Huaihua	4.5	Zhongxiang	3.6	Anhui	
Zunyi	5.7	Xuefeng mountain	54.1	Wuhan	2.8	Huang mountain	36.1
Tongren	2.6	Shaoyang	4.8	Wufeng	2.7	Yang mountain	1.7
Bijie	18.8	Hengyang	4.1	Lvcongpo	61.5	Bo county	2.4
Qianxi	14.8	Yongzhou	5.0	Zhigui	3.4	Su county	1.4
Weining	51.6	Chenzhou	5.8	Badong	3.6	Fuyang	1.8
Kaili	9.0	Henna		Hebei		Shou county	1.2
Shandong		Anyang	1.2	Ba mountain	1.2	Liuan	1.0
Yangjiaogou	1.0	Sanmenxia	2.3	Changzhou	1.2	Liaoning	
Tai mountain	12.9	Kaifeng	1.3	Raoyang	1.2	Chaohekou	1.0
Dezhou	1.1	Zhengzhou	1.8	Shijiazhuang	1.5	Yingkou	1.0
Jiyang	1.3	Shangqiu	2.1	Nangong	1.2	Dalian	1.0
Weifang	1.3	Xuchang	2.6	Xingtai	1.4	New Jinpikou	1.8
Shen county	1.4	Nanyang	1.3	Dongshen	1.3	Moudangjiang	1.3
Tai county	1.1	Zhumadian	4.2	Jilin		Xingjiang	
Heze	2.3	Xinyang	3.9	Tianchi	18.5	Jimunai	1.3
Linxi	1.1	Gushi	3.1	Jiushao	1.1	Kelamayi	1.7
Shanxi		Luanzhou	3.5	Changchun	1.3	Wenquan	5.2
Hua mountain	19.8	Gansu		Ningxia		Jinghe	1.1
Wuqi	1.2	Wuqiaoling	3.4	Haiyuan	2.5	Qitai	1.0
Luochuan	2.9	Xifengzheng	7.9	Guyuan	3.9	Wulumuqi	4.9
Changwu	2.9	Huajialin	29.6	Xi	2.5	Boerala mountain	2.4
Tongchuan	1.5	Huan county	2.2	Baiyin	2.3	Beita mountain	2.8
Baoji	2.2	Huining	1.3	Qinghai		Heilongjiang	
Wugong	1.1	Pingliang	2.2	Riyue mountain	3.4	Hulin	1.5
Foping	2.5	Shanxi		Haibei	2.8	Shanzhi	1.0
Guangxi		Wutai mountain	5.0	Guangdong		Tianjin	1.0
Guilin	1.5	Yangquan	1.8	Shaoguang	3.4	Beijing	1.0

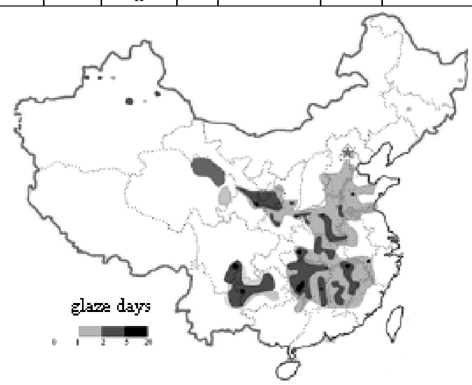


Fig.2 Mean glaze days in china

III. ICE ACCIDENTS ON POWER SYSTEM

The past studies show that ice can serious decrease mechanical and electrical strength of power system, and led to mechanical and electrical accidents. Based on the past investigations, the paper displays mainly five forms of ice accidents, as recorded by symbol A, B, C, D, and E.

A--Insulator flashover : Ice and snow accretion on insulators decline the arc distance and insulation strength, in addition, the high conductivity of water film on ice surface can severe reduce the insulation resistance. Insulator flashover also occurred in the ice-melting period.

B--Galloping of conductor : Under the driven of strong wind or asymmetrical icing shedding from conductor, icing conductor may surge and gallop, the result of which will cause the asymmetric tension and led to accidents as rupture of conductor, destroy of equipment, even result in tilting, distorting, and collapsing of towers and poles.

C-- Rupture and damage of conductor : Overload or asymmetrical ice may cause the conductor damage; retorting and distortion of conductor may also led the decline of mechanical strength; discharge in air gap may destroy conductors; asymmetric tension by retorting and distorting of pole, tower and other equipment may damage conductor.

D--shatter of insulators or hardware fittings: burned by flashover, falling off by overload ice.

E--Collapse of power and pole: collapse of power and pole are caused by overload ice, galloping of conductor, asymmetrical icing shedding, and other equipment injured.

IV. Survey of Ice Accident in China

A. *Statistics of the 2008's ice disaster*

According the surveys and studies, in the 2008's ice disaster, there were 570 counties of 13 provinces power systems affected. The reports by Chinese State Department showed, in these regions, for 500kV system, there were 7.54% substitution stations and 19.01% transmission lines were outage; for 200kV system, there were 5.97% stations and 9.38% lines. In addition, there were 0.742% 500kV towers and poles were collapsed or destroyed, and for 220kV, the percentage is 0.697%. Furthermore, the lower power networks were injured, as showed in the reports, for 35kV and 10kV systems, there are total 22433 lines were injured, the percentage is 20.5%. The ice disaster directly resulted in outage, and 13.3% users in these regions were influenced.

The detailed statistical data in these provinces are displayed in table.II.

TABLE II
Statistics of 2008's Ice Disaster

(a) Outage of substations

Province	500kV			220kV		
	Total number	Outage number	Percent (%)	Total number	Outage number	Percent (%)
Guangdong	25	0	0	224	1	0.446
Guangxi	19	0	0	65	7	10.77
Yunnan	15	0	0	70	2	2.86
Guizhou	12	5	41.67	51	27	52.94
Sichuan	18	2	11.11	98	0	0
Chongqing	9	0	0	4	0	0
Jiangxi	9	2	22.22	66	16	24.24
Hunan	14	6	42.86	96	32	33.33
Hubei	14	0	0	94	0	0
Fujian	9	0	0	92	0	0
Jiangsu	21	0	0	267	0	0
Anhui	11	0	0	97	0	0
zhejiang	23	0	0	177	1	0.56
Total	199	15	7.54	1441	86	5.97

(b) Outage of transmission lines

Province	500kV			220kV		
	Total number	Outage number	Percent (%)	Total number	Outage number	Percent (%)
Guangdong	67	0	0	516	12	2.33
Guangxi	53	5	9.43	135	19	14.07
Yunnan	27	4	14.81	164	24	14.63
Guizhou	45	29	64.44	147	94	63.95
Sichuan	36	9	25	251	3	1.20
Chongqing	25	3	12	126	1	0.79
Jiangxi	19	18	94.74	181	70	38.67
Hunan	35	22	62.86	249	96	38.55
Hubei	86	5	5.81	241	1	0.41
Fujian	20	0	0	227	2	0.88
Jiangsu	99	0	0	729	0	0
Anhui	35	1	2.86	229	0	0
zhejiang	79	23	29.11	463	21	4.54
Total	626	119	19.01	3658	343	9.38

(c) Collapse or destroy of towers and poles

province	500kV		220kV	
	Collapse numbers	Destroy numbers	Collapse numbers	Destroy numbers
Guangdong	0	0	303	176
Guangxi	26	25	90	38
Yunnan	0	2	72	78
Guizhou	169	134	147	86
Sichuan	1	2	2	3
Chongqing	0	7	0	0
Jiangxi	116	0	144	18
Hunan	182	82	630	167
Hubei	15	13	0	2
Fujian	0	0	1	2
Jiangsu	0	0	0	0
Anhui	2	2	0	0
zhejiang	167	28	43	16
Total	678	295	1432	586

As the surveys of the 2008's ice disaster and the tables above, some important statistical conclusions are acquired in the following:

1) The 2008's ice disaster was the most severe ice accident in the past years since records, the icing regions, during times and huge damages of which all exceed the past ice events in a single year, and both HV and EHV power system were serious injured in the disaster.

2) There were total 13 provinces were attacked in the ice disaster and 19 provinces were influenced, the most serious ice regions were Guizhou, Hunan and Jiangxi province. Large-scale outage happened in many counties in the 3 provinces.

3) There were mainly two reasons of the 2008's ice disaster.

One is the bad cold weather. The main climate of the disaster is the unusual weather with cold rain, which led sudden glaze ice accreting on transmission lines and substitution stations. As showed in the reports, the ice thickness of conductors exceeds 50mm in a lot of regions and a part of regions even reached to 90mm. The ice overload on lines and stations exceeded the design anti-icing standard and resulted in severe accidents.

Another reason is the correlative persons' knowledge of icing, anti-icing and de-icing mechanism is scarce. Many regions had not suffered severe ice accidents before the 2008's ice disaster and had not enough understanding and preparing of anti-icing and de-icing, so when the glaze attacked the power systems and ice accidents happened, they had a little measure to avoid its aggravating. In reverse, some severe ice regions were not serious hurt in the ice disaster because the relative departments made some valuable measures of anti-icing and de-icing for years, for example, the Liupanshui County in Guizhou province.

4) Statistics results showed that the main ice type was glaze ice, and sudden ice resulted in accidents. Furthermore, a part of regions also had hard rime, the alternating process of ice melting and freezing usually led to more severe results in power system.

5) Based on the surveys of the disaster, mechanical accidents are more than electrical accident, and the main types of accidents were collapse of powers and poles, destroyed of conductors, insulators and other equipments because of overload ice.

B. Ice accidents in the past decades

In the paper, the typical ice accidents in some typical regions and lines in the past decades in China are also revealed in order to compare and conclude the ice characteristics of power system in China. For every ice event, seven important parameters related are displayed in the following: region or line, voltage level, date, air temperature, wind speed, ice type, ice thickness, and destroyed condition. It is noted that not all the parameters are acquired in some cases because ice accident always happened randomly and suddenly so the relative condition is not record timely. Based on the analysis of part 3 in the paper, the destroy condition is distinguished as A, B, C, D, and E, as displayed in table.III.

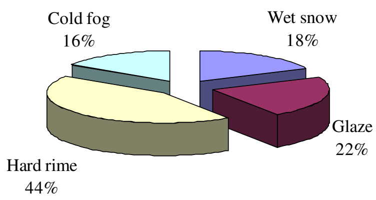
TABLE III
SURVEY OF TYPICAL ICE ACCIDENTS IN THE PAST YEARS

Province	Regions and lines	Voltage level/kV	Dates	*t*/℃	*V*/(m/s)	Ice type	*ε*/mm	Destroyed condition				
								A	B	C	D	E
Anhui	Long-zheng line	±500	2006.1	-3~0	／	G	40	√				
Beijing	Changping, Yanqing and Zhangjiakou area	110	2002.12	-5~0	／	C,W	／	√				
		500					／	√				
Chongqing	Xiu-qian line	220	2005.2.14~15	-4~-0	5~16	H	70~90		√	√		√
Fujian	Ji-long line	110	1975.12.13	／	／	H	20			√		
			1976.12.28	／	／	H	30			√		
			1977.1	／	／	H	20			√		
			1980.2.8	／	／	H	50			√		
Guangdong	Line Ping-Lang	220	2006.1.24	-4~-0	／	G	22	√				
Guizhou	Linpanshui City,	110	1966.2.3~25	-8~-3	10~15	H	＞50		√	√		
			1967.1.2~2.16	-8~-3	10~15	H	＞50		√	√		
			1971.1.2~10	-8~-3	10~15	H	＞50		√	√		
			1975.12.13~1976.2.16	-8~-3	10~15	H	＞50		√	√		
			1984.1~2	-8~-3	10~15	H	＞50	√	√	√	√	√
	Yu-yin line	110	2005.2	-3~0	／	C.W	／			√		
	Gui-fu line	110	2005.2	-3~0	／	C.W	／			√		
	Gao-zhao line	±500	2007.1	-3~1	／	G	30	√				
Hebei	Sha-chang line	500	1999.3	-5~5	0~5	C,G	20	√				
			2000.1	-5~0	0~6	H	30	√				
	Da-fang line	500	1999.3	-6~3	0~5	C,W	20	√				
			2000.1	-5~0	0~6	G	30	√				
	Nie-kang line	110	1999.3	-4~4	0~5	C,G	20	√				
	Handan and xingtai	500	2005.2	-2~2	0~5	G	30	√				
Hubei	Zhongshankou large span from Gezhouba Hydro Power Station to Wuhan	500	1987.2.19~21	-3~-1	4~18	G	15		√	√	√	
			1988.12.25~26	-4.5~-1	8~18	G	18	√	√	√		
			1990.1.29~31	-8~-1.5	2~18	G	15~23		√			
			1991.2.28	-5~-1.5	4~16	G	18~23		√			
			1991.12.24~27	-6~-1	3~15	G	15~25		√			
			1993.11.18~19	-3~-0	8~16	G	38~48		√			
	Ge-Shuang line	500	1993.11.9	-5~-0	3~15	G	36			√	√	
			1994.11.16	-1.5~-0	5~17	G	46			√	√	√
			2001.12.12	-4~-0	4~15	H	35~55	√				
	Southwest Hubei	220,500	2004.12	-5	／	G,C	60	√	√			
			2005.2	-2~2	／	G,C	50	√				√
Hunan	Changsha, Zhuzhou, Xiangtan system	6~35	1954.12~1955.1	／	／	H	90			√		√
			1957.1	／	／	H	120			√		√
	Tuo-xiang line,	110,220	1964.2	／	／	H	35~100		√	√		
			1969.2	／	／	H	40		√			
	Gang-yun line	500	1989.1.12~13	／	／	H	25		√			
			1990.1.30	／	／	H	25		√			
			1991.12.17	／	／	H	25		√			
	Luo-hong line	110	1997.2.12	／	／	W	80~100			√		
	Fu-sha line	500	2005.2	1.5	／	H,C	60	√				
	Jiangcheng line	±500	2006.1	-5~0	／	G	50	√				
			2007.1	-3~1	／	H	30	√				
Jiangsu	Qiu-hu line	110	1984.17~18	／	／	W	32			√		√
	Yang-Huai line	500	2003.2.21	／	／	G	30~50	√				
	Long-zheng	±500	2005.1.22~2.14 2006.1.23	-8~-0	／	G W	30	√				
Liaoning	Jingzhou system	500	1999.11.24	-4~1	6~17	W	8		√	√		
	Wang-nan line	500	2005.3.16	-7~0	5~15	H	25~30	√		√		

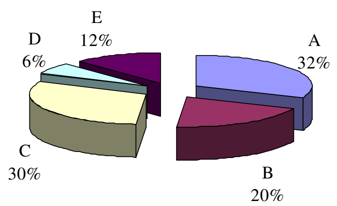
	Tong –Liao area	66,220	2004.10.30	-4~2	8	H	7~12		√			
Ningxia	Guyuan county	110	2004.11.2	-4~1	4~10	H	40~70	√	√	√		
			2006.4.18	-6~1	5~10	H	40~60	√	√			
			1991.1.28	-7~-5	⁄	H	50~150			√	√	
			2004.1.16	-8~-10	⁄	W	⁄	√				
Neimenggu	Hu-Wu lines	110	1989.1.6~8	-9~1	5~10	H	26	√		√		
	Huang-xiao line	110	1990.3	-3~0	⁄	W	⁄	√				
	Yun-dong line	110	1990.3	-3~0	⁄	W	⁄	√				
Qinghai	Hua-yan line	110	1990.3	-5~0	5~10	H,W	40	√				
			1992	-5~1	10~15	H,W	30	√		√		
	Longyangxia Hydro-Power Station	330	1992.10.3~4	⁄	⁄	H	40~60			√		√
	Long-huang	330	1992.10.3~4	-5~0	⁄	H	25			√	√	√
	Long-hua lines	330	1992.10.3~4	-5~0	⁄	H	25			√	√	√
	Hong-gong line	110	1993.5	-5~0	⁄	C	⁄					
	Bei-hao line	110	1992.10.3~4	-5~0	⁄	C,W	20	√				
Shanxi	Huo-xi line	110	1975.2	⁄	⁄	H	30			√		
			1990.3.27	-6~-1	3~8	H	22			√		
			2000.11.9	-7~1	2~9	H	14			√		
	Shen-yuan,	220	1986.11.23	-5~0	0~6	C,H	80	√				√
	Shen-xin line	220	1986.11.23	-5~0	0~6	C,H	80	√				√
	Yangchuan area	220	1998.12	-2	0~5	H	30	√				
Sichuan	Wu-xiu line	220	2005.2.14~15	-4~-0	5~16	H	70~90		√	√		√
Yunnan	Wu-zhen line	35	1973.12~1974.2	⁄	⁄	H	30	√				
			1974.2	⁄	⁄	H	30	√				
	Zhaotong area	110	2004.2	-3~0	⁄	G	40			√		
	Da-pan line	110	2005.2	-3~0	⁄	C.W						
	Xuan-zhe line	110	2005.2	-3~0	⁄	C.W						
	Qiaojia county	35	2007.1.9	-5~3	⁄	H	35					√

Annotate：① A-electrical accidents as insulator flashover, discharge of air gap, triple of transmission lines; B- galloping of conductors; C-rupture or shatter of conductor；D- shatter of insulators or hardware fittings；E- collapsing of poles and towers。② C-cold fog, H-hard rime, G-glaze, W-Wet snow, S-Soft rime, 。③ ε-Ice thickness, T-Air Temperature, V-Wind speed,

According the surveys of ice accidents in table.3, some statistical results as ice type and accidents type can be required and revealed in figure.3.



(a) ice type



(b) accidents type

Fig.3 Ice accidents type

V. ANALYSIS OF CHINESE ICE ACCIDENTS

Based on the reports of ice accidents during the past decades and the statistic in table.3 and figure.3, the characteristics of ice events in China are summarized in the following.

(1) China is one of the most severe icing countries in the world. Since records, there were more than a thousand ice accidents happened in the past years.

(2) Ice events are related to meteorology and topography. In China, ice accidents usually happened in high altitude regions in Central and South China. In these regions, the north cold air and the south warm air joins, and forms icing climate. In high altitude regions, the ice is severe, as shown of the records, the mean ice days are 40~60, many regions reaches 80~90.

Furthermore, different types of ice often happened in different regions with different weather and topography, for example, glaze often occurred in south China with low altitude as Hunan province, hard rime usually happened in high altitude regions as Guizhou province, while wet snow and cold fog were always reported in plain as Beijing.

(3) Micro-meteorology and micro-topography plays an important role in ice forming, glaze ice usually happened in plain, the typical region is Er-Zi transmission line; rime ice often occurs in high altitude mountain, the typical region is Liupan mountain; furthermore, wet snow and cold fog often forms in plain, the typical region is Tianjin, Beijing and Tangshan power systems.

(4) Recently, ice accidents happened more and more frequently and serious, for example, in the year 2005 and 2008, there were two large-scale ice disasters in South China.

(5) Both the mechanical accidents and electrical accidents usually occurred in a certain accident at the same time. Glaze ice and hard rime ice often led to mixture results while wet snow and cold fog usually caused electrical accidents as insulator flashover.

(6) For a certain region, ice accident were happened repeatly, for one example, there were six galloping events of ice-covered conductor reported during 1987-1993 in Zhongshankou large span, as showed in table 3, for another example, for power network of central China, there were three severe disasters in 2004, 2005 and 2008. have a period as observations, for example, the ice period of Three-Gorge Area is approximately 5 to 7 years.

VI. Suggestion of Anti-icing and De-icing

Considering the surveys of the past ice accidents, though the ice on transmission lines and substitution stations is severe, the loss may be minished and controlled if there are enough de-icing and anti-icing measures. As the experiential results, there are many valuable suggestions are displayed in the paper for the investigator, electrical engineering and designer in order to prevent the ice accidents in the future.

For the anti-icing and de-icing of power system, the relative work will be carried out as the following suggestions.

(1) Observe the ice characteristics of a certain icing region especially the micro-meteorology and micro-topography regions for long times, conclude the rule of ice distribution. And record the climate conditions for every icing event. The relative data will be used to design the transmission line.

(2) Study the icing and de-icing mechanism, investigate icing characteristics on power system lines, divide the ice distribution and protract the ice distribution map. Thereinto, the relative parameters as time, air temperature, altitude, wind speed, ice type, ice thickness on structures and conductors, the place of conductor should be record to explain the ice characteristics.

(3) For the insulation design in severe icing regions, there are mainly three factors should be considered. Firstly, the route of transmission lines should cross the icing, contaminated and high altitude regions as little as possible, and the route of partial line which usually suffered ice disaster should be changed to avoid icing; secondly, anti-icing design should be took into account with the transmission lines and substitution stations have to cross icing area, which contains choosing of tower, pole, insulator, conductor, and so on; thirdly, the assistant devices will be adopt to prevent the forming of ice.

(4) For the lines performance, the de-icing measures and devices should be chosen to melting the ice accreted on the power system, melting ice device should be used to transmission lines and substitution stations.

(5) The monitoring equipments should be studied and applied in power system. On the one hand, the ice characteristics and relative parameters can be records to investigate the icing mechanism; on the other hand, the ice monitoring may provide the alarm by using valuable programs for power system if the ice is threaten to lines.

VII. References

[1] T. Huecker and J.Gorablenkow, "UHF Partial Discharge Monitoring and Expert System Diagnosis", IEEE Trans. Power Delivery, Vol. 13, pp. 1162-1167, 1998.

[2] R. Baumgartner, B. Reuth, W. Lanz and K. petterson, "Partial Discharge- Part IX: PD in Gas-insulated Substations-Fundamental Considerations", IEEE Electr. Insul. Mag., Vol. 7, No. 6, pp. 5-13, 1997.

[3] Farzaneh M. Ice accretion on H.V. conductors and insulators and related phenomena. Invited article, Philosophical Transactions, The Royal Society, London, No.358, pp.1-35, 2000.

[4] Mulherin N D., Atmospheric icing and tower collapse in the Unite States. Proceedings of the 7th international workshop on atmospheric icing of structures, June 1996.

[5] M.Farzaneh and J.Kiernicki, "Flashover problems caused by ice build-up on insulators," IEEE Electrical Insulation Magazine., vol.11, no.2, pp5-17, Mar/Apr. 1995.

[6] T.Fujimura, K.Naito, Y.Hasegara, and T.Kawaguchi, "Performance of insulators covered with snow or ice," IEEE Trans. Power App. Syst., vol.PAS-98, pp.1621-1631, Oct. 1979

[7] X.Jiang, L.Shu. Chinese transmission lines' icing characteristics and analysis of severe ice accidents [J]. International Journal of Offshore and Polar Engineering. Vol.14, No.3, September 2004, ISSN1053-5381.

[8] X. Jiang and H. Yi, Ice Accretion on Transmission Lines and Protection. Beijing, China: China Power, 2002.

[9] D.Kuroiwa. Icing and Snow accretion on electric wires, U.S. Army Cold Regions Research and Engineering Laboratory, 1965, Research Report 123.pp.1-10

[10] I. Imai. Studies on Ice Accretion. Res. Snow Ice, 1953, Vol.1: 35~44.

[11] D. Kuroiwa. Icing and Snow Accretion. Monograph series of the Research Institute of Applied Electricity, 1958, 6. pp.1-30.

[12] G.F.Naterer. Coupled Liquid Film and Solidified Layer Growth with Impinging Supercooled Droplets and Joule Heating. International Journal of Heat and Fluid Flow 24, 2003, pp223-235.

[13] Jean Laflamme. Spatial Distribution of Ice Accretion within Ice Storms and Within Transmission Lines Routes. Proceedings of 5th IWAIS'90, Japan, 1990:A3-4.

[14] V.Jaiswal, M.Farzaneh. Flashover Performance of a Semi-Conducting Glazed Post Station Insulator Under Icing Conditions Based on Electric Field Distribution. 2005 Annual Report Conference on Electrical Insulation and Dielectric Phenomena. pp10-13.

[15] Li Qingfeng, Fan Zheng, Wu Qiong et.al , Investigation of Ice-Covered Transmission Lines and Analysis on Transmission Line Failures Caused by Ice-Coating in China. Power System Technology. Vol.32, pp33-36, 2008.