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Problems, Investigation Methods, and Solution of Using String Suspension Insulators

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Abstract: - This paper presents the problems, investigation methods, and solution of using suspension string insulators in Thailand. Corona loss, punctured insulator and easy flashover for contaminated insulators are the problems that have existed after using these insulators for a period of time, usually after a few years. These problems incur the reliability degradation of electrical power system. The investigation methods includes; first examination of corona phenomena of the string insulators helps in separating any punctured insulators out of the tested string insulators by observing the corona spots. Second, distributed voltage of the string insulators was checked by using the simple small sphere gaps. Finally, the string insulator characteristics under high humidity were under investigation. We propose the alternating shed long rod insulator prototypes designed and constructed according to IEC to handle the aforementioned problems. The test results are reported in this paper.

Key-Words: - contaminated insulators, corona, flashover, humidity, puncture, sphere gap

1 Introduction

Porcelain suspension insulator has been used in the transmission and distribution line system because it is cheaper and more flexible compared with other insulators. However, the electricity utilities have encountered the problems of using the string insulators in some areas of Thailand especially in the areas with polluted environment. Those problem in easy to flash over and puncture are considered in this paper.

1.1 Corona phenomena

Corona is a practical problem which frequently takes place in high voltage systems. It always occurs at points, sharp edges, and the rough surfaces of high voltage electrodes. Corona is an important problem of the transmission and distribution line system because it causes power loss. The corona phenomena may develop to complete breakdown leading to failure in the power system. So detecting corona phenomena is needed in the power system. There are two factors in favor of corona occurred in the string insulators. The first factor is installing string insulators in the contaminated environment with high relative humidity. The second factor is the unequally distributed voltage of each insulator of a string insulator caused by its capacitor and an avoidable stray capacitor. The effect of the humidity on suspension string insulators is also reported in this paper including a simple way to detect the distributed voltage of the string insulator. Many measuring devices are used to detect corona phenomena such as a corona camera detector, an ultra probe, and a partial discharge detector. Although, the corona phenomena are not unsatisfied, it can help electrical engineers to investigate the punctured suspension insulators from the installing string insulators.

1.2 The punctured insulator and contaminated insulator problems

Two problems countered after installing the suspension insulators in the transmission line or distribution line system are the punctured insulators and the contaminated insulators. According to IEC 383 [1] insulators can be classified into two types, type A and type B, which depend on the shortest flashover in air outside the insulator and the shortest puncture part through the solid insulation of the insulator. The examples of the type A insulator are line post insulators, pin post insulators or post insulators whereas the suspension insulators or the pin insulators are the kind of type B insulator. The reference paper [2] reported that there are more than 50 units of the suspension insulator punctured per year in the transmission lines of EGAT(Electricity Generating Authority of Thailand). The punctured insulators absolutely occur with the type B insulator. It was also proved that the steep front lightning

voltage with steepness of 2500 kV/μS or higher may cause suspension insulator to be punctured [3-4].

It is easy to flashover when the polluted porcelain suspension insulators are installed in the environment of highly relative humidity especially before light raining or in the early morning. It is known that the conduction film leads to the higher leakage current which causes the dry band. The dry band may develop finally to flashover. Many suggestions to solve the contaminated insulator problem were introduced such as replacing the porcelain suspension insulator with the silicone or composite insulators, or the semi conducting glazed porcelain insulators and so on [5-7].

2. Experiment

2.1 Punctured insulator detection by examining the corona phenomena of each suspension insulator of the string insulator.

The corona of the proper, improper (punctured), mix proper- improper string insulators were examined using the test circuit shown in figure 1. The punctured voltages of three improper insulators were approximately 13, 14, and 16 kV respectively[8].

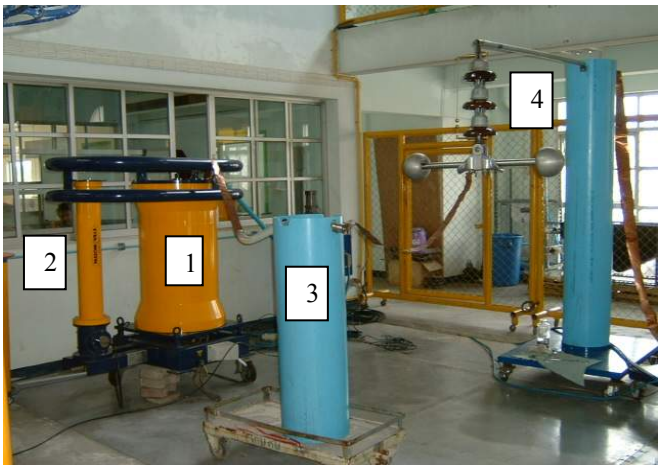


Fig.1. circuit connection arrangements for the experiments

Where 1 = Test Transformer 125 kV, 15 kVA
2 = Capacitor voltage divider 125 kV
3 = Damp resistor 300 kΩ
4 = String insulator (class 52 – 1)

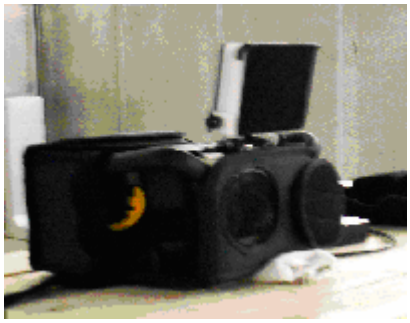


Fig.2. corona camera detector [9]

In the test, ac voltage was applied to the tested string insulators with the increment of 5 kV per step. The corona phenomena of tested insulators and applied voltages were recorded. The detail of the tested string insulator is shown in table 1

Table 1. string insulator patterns

Case	Tested string insulators
1-3	1, 2, or 3 proper insulators units
4-6	1, 2, or 3 improper insulators units
7-8	1 proper and 1 improper insulators units
9- 11	1 proper and 2 improper insulators units
12-14	2 proper and 1 improper insulators units

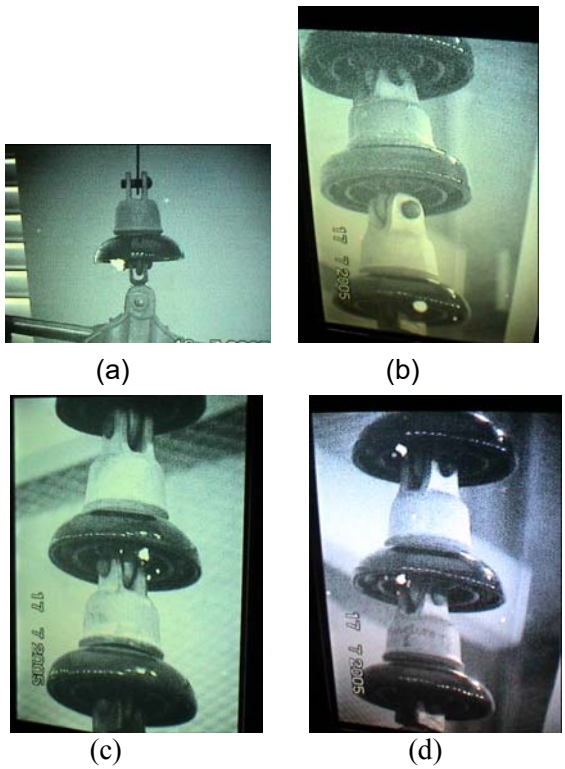
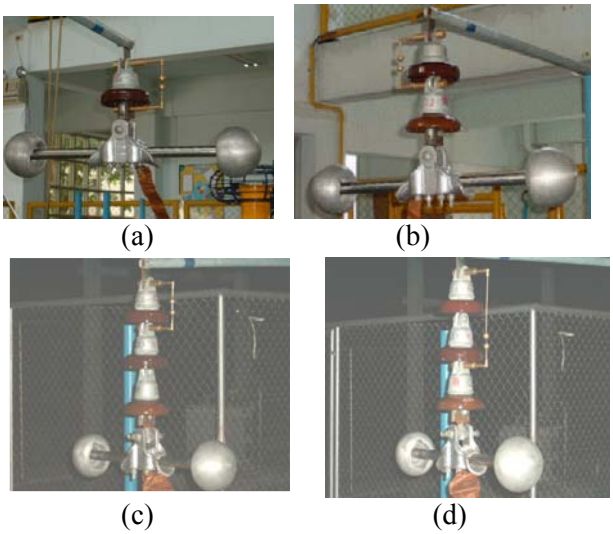


Fig.3. corona phenomena, white spots, of the tested string insulators (a) one proper insulator at 21kV (b) two earth-end punctured insulators and one line-end proper insulator at 19 kV (c) line and earth – end punctured insulators and one middle proper insulator at 19 kV (d) two earth-end proper insulators and one line- end punctured insulator at 45 kV

The test results show that corona camera detected the corona phenomena of the energized proper insulators at the inception and the higher voltage. In case of the energized improper insulators, the corona phenomena were detected also at the inception voltage but it were not be detected if the voltage of the improper insulator reached its punctured voltage. In the cases of mix proper- improper string insulator, the corona spots of the proper insulators can be detected but the corona spots of the punctured insulators cannot be detected. Using this knowledge, we can separate punctured insulators out of proper insulators in a string insulator.

2.2 The simple way for measuring the distributed voltages of a string insulator [10]

The voltage distribution of the strings of two and three suspension insulators was measured using the small sphere gap of 2 centimeter diameter with varied gap spacings(s) of 0.5, 0.7, and 1 centimeter respectively. The sphere-sphere electrode system was connected across any particular insulators as shown in the figure 4. Then, the voltage applied to the string insulator was raised until the spark over of the sphere gap occurred. The voltage was kept constant at that value about 5 seconds. The distributed voltages of the string insulators were measured in percentage as shown in table 2 – 3 respectively.



(a) (b) (c) (d)

Fig.4. the distributed voltage measurement of the string insulators

Table 2. distributed voltages of two insulators of the string insulators when the insulator number one (#1) is the earth-end insulator and number two (#2) is the line-end insulator.

String number	Distributed Voltage (%)					
	S = 5 mm.		S = 7 mm.		S =10 mm.	
	#1	#2	#1	#2	#1	#2
1	45.2	54.8	42.3	57.7	47.6	52.4
2	44.8	55.2	42.6	57.4	47.3	52.7
3	45.7	54.3	42.8	57.2	47.1	52.9

Table 3. distributed voltages of three insulators of the string insulators when the insulator number one ($\#_1$) is the earth-end insulator, number two ($\#_2$) and three ($\#_3$) are the remainders of the insulators towards the line end of the string insulators.

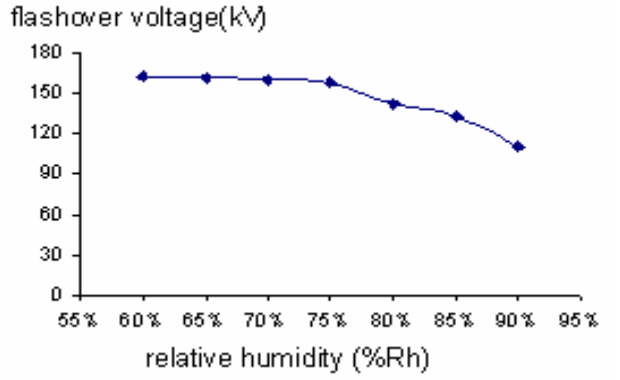
String number	Distributed Voltage (%)								
	S = 5 mm.			S = 7 mm.			S =10 mm.		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
1	28.8	21.9	49.3	29.1	22.8	48.1	33.5	27.4	39.1
2	31.1	23.2	45.0	29.1	25.4	45.5	31.9	26.8	41.3
3	31.7	20.2	48.1	28.6	21.9	49.5	29.7	25.9	44.4

We conclude that for two suspension insulators of string insulators, the voltage across the line-end insulator was about 52% – 58% of the line voltage. The voltage shared on the earth – end insulator was approximately 42% – 48%. For three suspension insulators of the string insulators, the voltage across the line – end insulator was about 39% – 49% of the line voltage. The voltages across each of the remainders of the insulators towards the earth end of the strings insulator were 20% – 27% and 28% – 33% respectively.

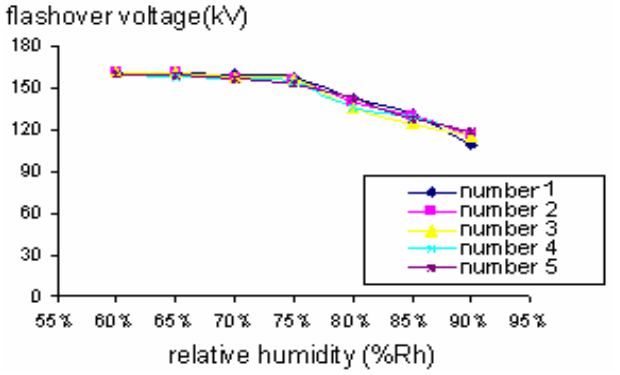
2.3 The effect of humidity on the suspension string insulator

The Humidity effect on electrical breakdown of suspension string insulator was examined using the modified test circuit shown in figure 2 in which the string insulator was installed in the test chamber. The fog generator with a controllable steam input

rate into the chamber was constructed according to IEC 507[11]. Before testing, the distributed humidity in the testing chamber was checked by 8 humidity sensors. Then the ac voltage of 19 kV was applied to the string insulator about 15 minutes. Next, the steam was fed into the chamber with 50-200 g/hr/m^3 until reaching the specified relative humidity. After that, the applied voltage was increased until the flashover occurred. The test results are shown in figure 5.



(a)



(b)

Figure.5. ac power frequency flash over voltage of the string insulator at varied relative humidity levels. (a) string insulator number 1 (b) string insulators number 1-5

From the test results, We conclude that the flash over voltage at power frequency was relatively constant at 60-70 % relative humidity and reduced to 75% at 90 % relative humidity compared with of the initial flashover voltage at 60% relative humidity

3. Problem Solution

To solve the problems of using suspension insulator, the 2 types of long rod insulator practically unpuncturable were designed and constructed complying with IEC 815[12]. The designed alternating shed long rod insulators, ordinary porcelain and semi conducting glaze insulators, were tested according to IEC 507[11]. The arcing distance and leakage distance of the designed long rod insulators are 525 mm and 1370 mm respectively. The experiments were carried out in two parts, flash over voltage test of clean insulator and flash over voltage test of natural polluted insulator after hanging the specimens collecting the pollution at Bang Pu substation 4,8,and 12 month respectively. Bang Pu substation is close to the industrial zone and away from the sea coast about 3 km.

(a) (b)

Figure.6. alternating shed long rod insulators
(a) ordinary porcelain insulator (b) semi conducting glaze alternating shed porcelain insulator

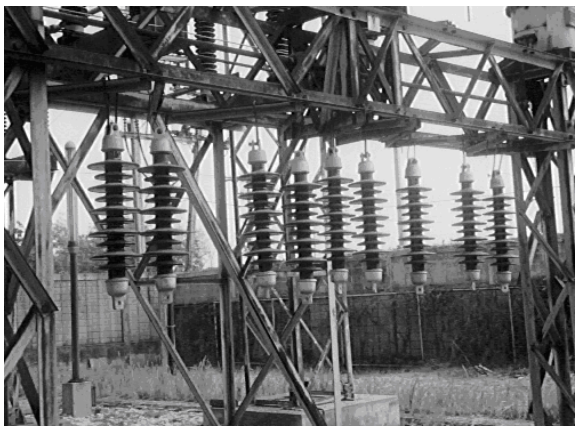


Figure 7 sample insulators hang for collection the contamination

The test experiment was carried out according to IEC 507. The ac phase voltage of 19 kV was applied to the sting insulator installed in the test chamber about 15 minutes. Then, the steam was fed into the chamber with 50-200 g/hr/m^3 for about another 15 minutes. The applied voltage was increased in the rated of 50 kV/ min until the flashover occurred. The flashover voltage and leakage current were recorded. The test results are shown in figure 8-9 which the dry clean flash over voltage of the specimen insulators in dry condition is approximately the same as that of in clean wet condition [13].

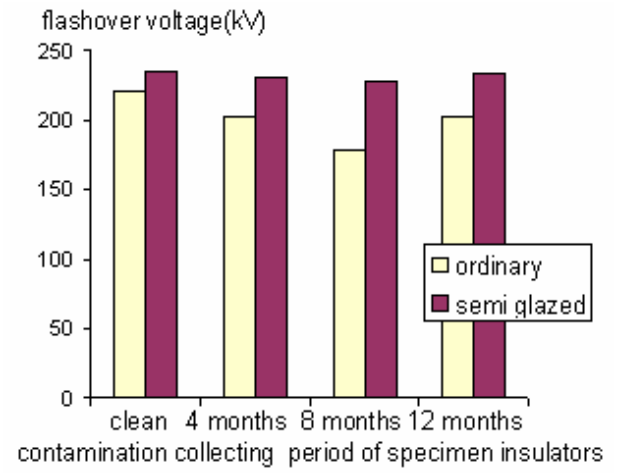


Figure.8. flashover voltages of clean and polluted long rod insulators

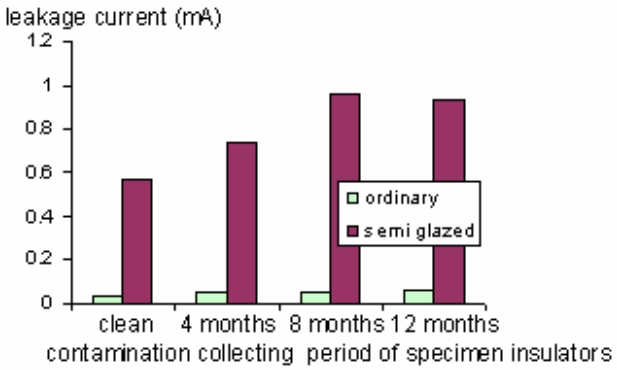


Figure 9 leakage current of clean and polluted long rod insulators at 30 kV applied voltage

From this experiment we conclude that the semi conducting glaze alternating shed insulator is an alternative choice to solve the problem of punctured in insulators, especially using in contaminated areas because of its benefits in no dry band occurring and being type A insulator.

4. Conclusion

The problems of using string suspension insulators in contamination areas and puncturing can be solved with using the semi conducting glazed long rod insulators which have higher flashover voltage level and practically unpuncturable. However, the prototype long rod insulators can be improved in weight and relatively big size.

5. Acknowledgement

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