

Measurement of Site Pollution Severity under DC Voltage by Means of A Portable Test Station

Zhiyi Su¹, Weimin Ma², Dong Wu^{3*}, Urban Åström³, and Greger Karlsson³
¹China Electric Power Research Institute (CEPRI), Beijing 100085, P. R. China
²BDCC of State Grid Corporation of China (SGC), Beijing 1000xx, P. R. China
³ABB Power Technologies, SE-771 80 Ludvika, Sweden
*E-mail: dong.wu@se.abb.com

Abstract: The first step towards a reliable design of outdoor insulation for a HVDC system is to have a good evaluation of the site pollution severity. Long-term on-site measurements on insulators of the same type and energised at the same voltage provide the best accuracy for this purpose. However, for practical and economical reasons, such a measurement is seldom being performed. To meet the need of on-site pollution measurement under DC voltage a portable test station has been designed by STRI on the request of ABB. In a joint research activity between BDCC of SGC, CEPRI and ABB, this portable test station has been utilized in site pollution measurements for Three Gorges-Shanghai projects. In this paper the design of this portable test station is described. The measurements performed on Huangdo and Guojiagang sites are also presented.

Key Words: HVDC. Outdoor insulation. Site pollution severity Pollution measurement. Natural pollution test station.

INTRODUCTION

The advantage of HVDC system in large-block and long-distance power transmission has long been recognised. Evidently, more and more such transmission system has been built in recent years, especially in China. At the same time, the knowledge on the outdoor insulation design to prevent flashovers caused by pollution has been improved significantly due to the enormous efforts world widely [1]. The first step towards a reliable insulation design is to have a good evaluation of the site pollution severity. Long-term on-site measurements on insulators of the same type energised at the same voltage provide the best accuracy for this purpose. However, for practical and economical reasons, such a measurement is seldom being performed. A simpler way is to measure on insulator in the AC systems at the nearby site. In this case, one would need a correction factor for the difference on pollution accumulated under AC and DC voltages [2] involving approximations. To meet the need of on-site pollution measurement under DC voltage a portable test station has been designed by STRI on the request of ABB. In a joint research activity between BDCC of SGC, CEPRI and ABB, this portable test station has been utilized in site pollution measurements for Three Gorges-Shanghai projects.

In this paper the design of this portable test station is described. The measurements performed on Huangdo and Guojiagang sites for one year and one and a half year respectively are also presented.

THE PORTABLE TEST STATION

Requirements

To reach an economically and technically balanced design, following requirements were adopted from a longer wish list for the test station:

1. Portable. The station should be easy to transport from one site to another site at ordinary road conditions. It should be possible to be packed up and reinstalled in relatively short time.
2. Reliable. The equipments in the station should be able to withstand long-term continuous operation in polluted environment. A forced outage for longer time than a few days may downgrade the quality of the measurements.
3. Personal safety. Proper grounding system for high-voltage parts is necessary. Fence or wall is required for the yard with high-voltage.
4. DC voltage level of 90 kV. A higher voltage level would be desirable but will result in a increased total size of the station.
5. Relative strong DC power supply. This supply should be strong enough to energise several insulators in parallel with wetted pollutions without significant voltage drop.
6. Protection and control. The equipments in the station should be protected and the voltage supply tripped when earth fault has occurred due to various reasons.
7. Leakage current measuring system.
8. Weather station.
9. Data acquisition system.
10. Layout drawings and instruction documents. A layout drawing that take into consideration the arrangement of insulators and the measuring equipments should be provided even though changes will be needed for specific site conditions. Instruction document for engineers to operate the station will also be necessary.

Equipments

The test station includes the following parts:

1. A standard container in which the DC generator and the control room are located.
2. A DC yard with insulators of different types and measuring sensors for leakage current. A Directional Dust Deposit Gauge is also located in this DC yard.
3. A weather station.

The DC generator consists of an AC-regulator transformer, an AC transformer, a rectifier bridge and a filter circuit, as shown Fig. 1 (AC-regulator transformer is not in the figure). The DC generator has a rating of 600 mA as maximum current at 90 kV. The level of ripples at a continuous 200 mA current is 5.8%.



Figure 1. DC generator inside the container

Other equipments installed together with the DC generator are:

- A wall bushing
- A disconnector
- Surge arresters
- An earthing switch



Figure 2. The container after installation at Huangdo

As shown in Fig.2 is the container after installation with a wall bushing, a disconnector and arresters on the top.

An air-condition equipment is also installed. A separate area with data acquisition system is also placed inside the same container as the control room. The auxiliary supply required for the test station is three phase 380 V, 125 A.

The DC voltage is connected from the wall bushing to the DC yard. The leakage current signal, with total 9 sensors, is connected from the test objects back to the container with cables of 25 meter in length. In the DC yard, selected test objects, in this case station-post insulators and line insulators, were installed as shown in Fig. 3.



Figure 3. Line insulators (higher view) and station-post insulators (lower view) used in the test at Guojiagang

The weather station is a commercially available product. It measures the rain intensity, air temperature, relative humidity, wind speed, wind direction, and the solar radiation. It is driven by a solar panel.

With the help of lifting equipments, all the equipments except the DC yard can be installed within two weeks by three engineers or disassembled and packed within one week by two engineers. For the DC yard, the amount of work included is dictated by the site conditions. For the

two measurements performed at Huangdo and Guojiagang, the test station was, in both cases, installed inside existing AC substations. The work is therefore largely reduced with regards for the gantry, pedestals, grounding and safety measures.

MEASUREMENTS

The measurements performed were leakage current and weather conditions during the whole measuring period. The pollution levels on various insulators were measured in the end of the test period.

At Huangdo Site

The Huangdo 500 kV substation is located 25 km north of Shanghai. The substation is surrounded by farmland with a highway toward Shanghai nearby. The pollution test station was installed in an open area between the 220 kV and 500 kV switchyards, about 150 m from the highway. Fig. 4 is the overview of the test station inside the Huangdo substation.



Figure 4. Overview of the test station at Huangdo

Five porcelain station-posts insulators with three different shed profiles were used as test objects. The wall bushing of silicone rubber housing installed on the top of the container is also considered as a test object. The parameters of these insulators are given in table 1.

The profiles of the line insulators tested are given in table 2. Five different line insulators of cap-and-pin type, type A – E in table 2, one long-rod porcelain insulator, type G, and two long-rod silicone rubber insulators, type H and I, were used as test objects in this site.

The test period at this station was from December 8 of 2000 to November 22 of 2001. Pollution measurements were performed once in August 2001, on insulator F only, and once at the end of the test period on all the insulators. For comparison, pollution measurements were also performed at the same time on one post insulator under AC voltage in the 220 kV switchyard. Operational experience from AC systems in this region has shown that the occurrence of pollution related flashovers is

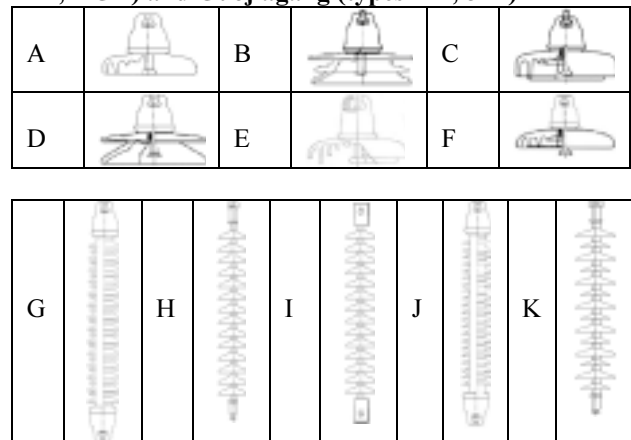
concentrated in the period from December one year to January next year. Therefore, the best time for pollution measurement would be inside this period but before the first rain in the spring. The measurement could have been done a few weeks later at this site if not because of the tight schedule.

Table 1 Parameter of the tested station insulators

All parameters are in mm

	Station post 1	Station post 2	Station post 3	Wall bushing
Profile	Alternating	Alternating	Deep under-rib	Alternating
Spacing	95	79	95	60
Overhang	95/55	73/51	95	60/33
Core diameter	227	227	224	150
Insulation height	1695	1695	1695	1067
Creepage	6950	7200	6850	3913
Creepage under test	3292	3443	3244	3910

Table 2 Line insulators tested at Huangdo (types A-E, G-I) and Guojiagang (types A-F, J-K)



Leakage currents of 9 test objects were measured continuously during the test period. The current sensors were connected to all 5 station-posts, the wall bushing, and 3 line insulator strings.

At Guojiagang Site

The Guojiagang 220 kV substation is located on the hilly country south of the Yangtze River. The surroundings are small forest, pond, residents and roads. 500 meters southeast of the substation there is a cement manufacturer. The test station is located in the open place beside the 110 kV switchyard, as shown in Fig. 3.

The same station-post insulators used in Huangdo station were used also here but with only one insulator of each

profile. The line insulators of cap-and-pin type used were types A – F in table 2. A long-rod porcelain insulator of type J and a long-rod silicone rubber insulator of type k were also used as shown in table 2. There were also non-energized insulators installed in this test site.

The test period at this station was from October 15, 2002 to March 12, 2004. Since the main pollution accumulation period had already started at the time of commission of the test station, the test period was extended to March 2004. Operational experience from AC systems in this region has shown that the occurrence of pollution related flashovers is mostly in the period from February to March. The measurement that took place at the end of the test period is therefore considered to be representative for the yearly maximum pollution level.



Figure 5. Pollution sampling at Guojiagang test station

At the same time, pollution measurements were also performed on two post insulators in the 110 kV switchyard and one post insulator in the 220 kV switchyard. Leakage currents were measured, continuously during the test period, on 3 station-posts, 3 line insulator strings, and the wall bushing.

RESULTS

Test Station

The portable pollution test station, after operation at two sites, has been proved to be an effective tool for study the site pollution severity. The main equipments of the test station have been proven to be reliable even though leakage current of a few hundreds mA had been recorded and one trip were reported during the second test period. The performance of the weather station was not satisfactory. Fortunately the weather data is available from the nearby airport. A new weather station will be needed. The test station has recently been moved to a new site. The commissioning work is in progress when this paper is written.

Site Pollution Severity

Large amount of data were obtained from the two test stations. These are the ESDD/NSDD values from

insulator of various types, at different positions of each insulator, under DC or AC voltage or non-energized conditions. Only some of the results are presented in this paper.

For Huangdo site, the pollution levels, in the term of average ESDD, obtained on the 5 DC post insulators of different shed profiles were between 0.024 and 0.038 mg/cm². The average NSDD levels were between 0.093 and 0.156 mg/cm². Taking into account of the effect of the earlier measurement at this station, correction was introduced to the measured data. The values for yearly-accumulated ESDD were then obtained to be in the levels of 0.04-0.055 mg/cm² for the corresponding shed profiles.

For porcelain line insulators at Huangdo site, the average levels of ESDD are in the range of 0.049 - 0.062 mg/cm². The levels of NSDD are in the range of 0.18 to 0.283 mg/cm². These values do not differ significantly from the values on station-post insulator.

For the Guojiagang site, the pollution levels obtained on the three DC post insulators of different shed profiles, in the term of average ESDD, were between 0.156 and 0.181 mg/cm². The average NSDD levels were between 0.450 and 0.592 mg/cm². The measurements on line insulators in this case gave the average levels of ESDD in the range of 0.101 - 0.173 mg/cm². The levels of NSDD were in the range of 0.230 to 0.567 mg/cm². It can be observed that the line insulators at this site collected less pollution than the station-post insulators. This may partly be caused by the larger particle size obtained in this site than that at Huangdo.

For both Huangdo and Guojiagang sites, the ratio between pollution accumulated under DC voltage and the pollution accumulated under AC voltage was about 2. This results support the recommendation given in [2].

Chemical analysis was also made on the pollution samples collected from both stations. The amount of Calcium ion is high, 80% for Huangdo and 90% for Guojiagang. In artificial pollution test, it has been proved that different pollution type give different flashover voltage, [1]. The effects of Calcium ion, which give higher flashover voltage in the laboratory, have been studied and reported [3].

Leakage current

Fig. 5 is an example of the leakage current pulses measured on three station-post insulators tested at Goujiagang site during a period of three days. The maximum values of the current pulses were compared among insulators of different type and profiles. As expected, during the measurement at both sites, the wall bushing and the line insulators with silicone rubber sheds have had very low current, in comparison to all other insulators. The current on silicone rubber insulators were

always less than 1 mA. The current on the wall bushing was most of the times less than 1 mA, except in two occasions when current pulses of magnitude of 5 mA were observed. The current curve obtained need to be further studied together with the weather conditions.

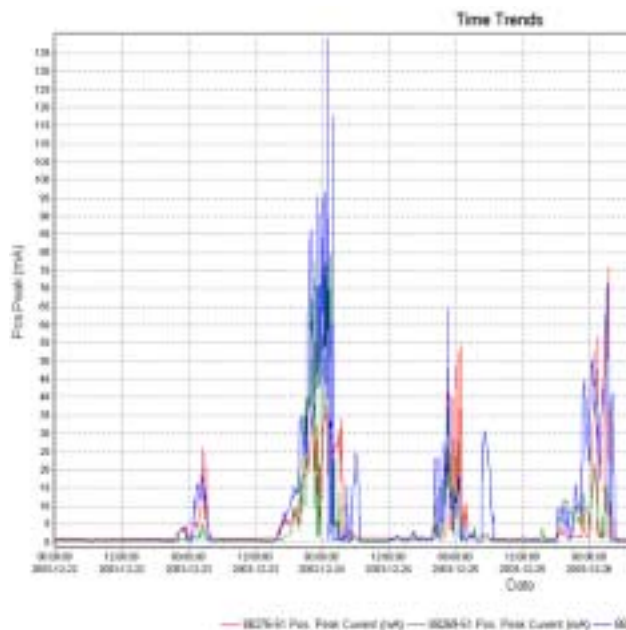


Figure 5. Examples of leakage current pulses recorded from three porcelain station-post insulators under test (the figure is a section of a plot)

CONCLUSIONS

The portable pollution test station, after operation at two sites, has been proved to be an effective tool for study the site pollution severity. Measurements performed at these two sites, Huangdo and Guojiangang, have provided reliable results and recommendations for the design of Three Gorges-Shanghai projects with regard to the pollution performance.

ACKNOWLEDGEMENT

The authors wish to acknowledge the contribution of STRI for design and manufacturing some of the test equipments and the support when commissioning the test station. The authors also wish to express their gratitude to engineers from Shanghai EHV Power Transmission Company, East China EPTRI, Yichang Department of Hubei EHV Bureau, and Hubei EPTRI, for their support in the operation of the test station and pollution measurements.

REFERENCES

- [1] Cigré brusher 158: "Polluted insulators: a review of current knowledge"
- [2] D. Wu, Z. Su, "The correction factor between DC and AC pollution levels: review and proposal", 10th ISH, August 25-29, 1997, Montreal, Canada.
- [3] Z. Su, X. Liang, Y. Yu, "Important correction factors in HVDC line insulation selection, Paper submitted to 14th ISH, August 25-29, 2005, Beijing, China