765kV 2회선 송전선의 코로나 방전에 의한 환경영향 연구

速報論文
45~3~1

Environmental Effects by Corona Discharge from a 765kV Double Circuit Transmission Line

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Abstract - This paper specified the measurement results conducted by the Korea Electric Power Research Institute(KEPRI) 765kV double circuit transmission test line that measured the audible noise, hum noise, radio interference, electric field and aeolian measurement. This test line consists of 6-480㎟ conductors per phase. The analysis of the test results shows that this 6-Rail conductor bundle satisfies the audible noise criterion under the stable rainy weather condition and the radio interference level under the fair weather. And the other items are also agreed with the design level criterion.

Key Words : Corona, Audible Noise, Environmental Impact, Test Line

1. Introduction

Environmental effects produced by corona has become an important consideration in the design of high voltage transmission lines. Although it does not appear that transmission lines are major contributors to the community-noise problem and other environmental problems, electric utilities have to consider this environmental impact in the design of transmission lines.

The environmental effect items of transmission lines are divided as follows:

* Electrical Effects
  - Random Noise
  - Hum Noise
  - Radio Interference
  - TV Interference
  - Ozone
  - Electric Induction
  - Magnetic Induction
* Mechanical Effects
  - Aeolian Noise
  - TV Ghost
  - Visual Impact

From the above items, KEPRI studied all items except ozone, magnetic induction and TV ghost. Because the effect of ozone is so little that we did not measured it and the other items will be done later.

After the audible noise measurement of 8 kinds of conductor bundle in the corona cage from 1984 to 1989, KEPRI has found that a bundle of 6-Rail conductors is the minimum one to meet the audible noise criterion of 50 dB(A) and any large 4-conductor bundle can not meet the criterion of 50 dB(A). The Rail conductor's cross section and diameter are 480 ㎟ and 29.61㎜. In 1989, before the decision of the upgrading the system voltage, KEPRI decided to build a full scale test line with a bundle of 6-Rail conductors to compare with the result of the corona cage test and to evaluate the environmental impact of corona in the vicinity of a 765kV transmission line and electrical & mechanical performance of the localized equipments prior to the start of the design of the commercial line. The test line is located in Kochang, the southwest coast in Korea peninsula and has been operated since April, 1993.

The corona characteristics data measured at test line on a long term basis are audible noise (AN), radio interference (RI), TV interference(TVI), aeolian noise; wind noise (WN) and electric field intensity (EF) at 1m above the ground level. These data have been automatically recorded under the various weather conditions since August 1993. Comparisons between the measured value and the predicted level by computer calculation of corona performance have been made.

2. Test Facility

Kochang 765kV test line was designed as a full scale double circuit transmission line in the electrical and mechanical strength. The tower geometry and the number

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接受日字 : 1995年 11月 8日
最終完了 : 1996年 2月 6日

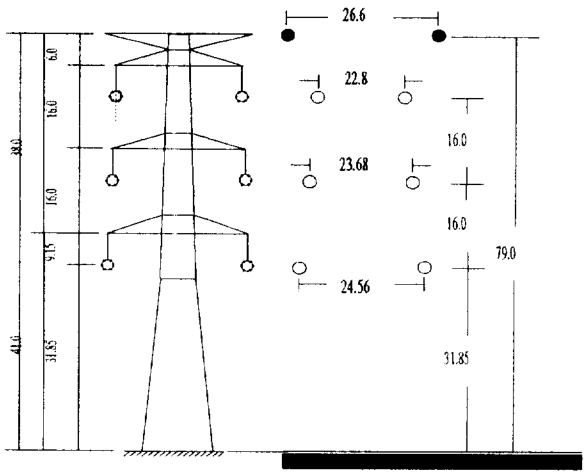

Fig. 1 Configuration of conductor & suspension tower

of the insulator discs were designed to demonstrate a 765kV double circuit line in general area. But the test line is located near the seaside, the frequent cleaning of the insulator string is prerequisite. Fig.1 shows the configuration of the conductor and the suspension tower in the test line. The spacing of the subconductors is 40 cm which gives the minimum surface gradient on the conductors. The test line consists of two dead end towers, two suspension towers and three spans. The span lengths are 200, 300 and 200 m respectively. Three 3MVA 23/765kV auto- transformers feed power to the test line by overhead 8-Rail conductor bus in the low reactance phase arrangement using a dead-end and transposition tower and 5 overhead bus-supporting towers. The voltage of the test line is controlled by a 1500kVA on-load tap changing transformer. Six line traps are installed in the series connection to cut off the noise of the transformers and hardwares of the insulator string in the overhead bus. Most of the measurement sensors are installed in the middle of midspan of 300m in the relatively flat terrain[2].

3. The instrumentation system

The acquisition data from the sensors located in the midspan, meteorological towers, rain gauge and capacitor voltage transformers have been recorded on line by DEC workstation. The scanning interval is 3 minutes. The weather data include wind speed and direction, relative humidity, air temperature, barometric pressure, rain rate, cloud height, solar radiation, lighting.

All kinds of sensors for AN, HN, RI, TVI and aeolian noise are installed along the lateral direction in the middle of the midspan and connected to the measuring instruments in the measuring room by long coaxial cables. To measure AN, 1/2 inch weatherproof microphone units made by Bruel and Kjaer type 4184 are located at 0(A-1:reference point), 15(A-3:evaluation point), 60(A-4) and 178m(A-6:back ground noise) respectively from the ground level point directly under the right outmost phase conductors along the lateral direction in the middle of the midspan. The noise level analyzers, B&K type 4435 with 120Hz narrow band pass filter have been used to measure the corona hum noise (HN). The microphones of those analyzers are installed at -32, 8, 18, and 28m respectively from the reference point. The height of AN and HN microphones is 0.34m instead of 1.5m in IEEE standard to get rid of the ground reflection effects of noise waves and winds generated noise [3]. To measure WN, the same measuring system as AN has been used with C-weighting filter due to the impulsive noise characteristics. Two microphones of the wind noise are installed directly under the outmost phase conductors and in front of No. 2 tower to measure conductor noise (CN) and tower noise (TN) respectively. The electric field strength at 1m above ground was measured with a 60Hz free body type meter(model HI-3604).

RI data have been collected with the test receivers, Rohde & Schwarz (R/S) type ESHS 30 using Quasi Peak (QP) detectors. Active loop antennas, R/S type HFH2-Z2 are located at 3, 18 and 188 m from the reference point and the height of the antennas is 2m. The frequency set for long-term measurement of RI is 0.475MHz. Six line traps connected in series with the jumper lines of No. 1 dead-end tower would cut off the unwanted radio frequency noise current from the test transformers and hardwares of the insulator strings [4].

To measure TVI, biconical antennas(R/S type HK116) are installed at 40, 80, and 188m from the reference point at 3m above ground. The test receivers using QP detectors, R/S type ESVS30 are tuned to 75MHz according to CISPR standards [5].

4. The result of data analysis

The long term measured data from August, 1993 to March, 1995 have been statistically analyzed to evaluate the

Table 1 Effective data acquisition rate

Items	No.of Measured (Raw) Data		No. of Effective Data (Acquisition Rate)	
	Fair	Rainy	Fair	Rainy
AN	158,902	5,831	83,429(52.5%)	2,294(54.8%)
HN	134,037	4,468	113,864(84.9%)	3,994(89.4%)
WN	138,505		24,511(17.7%)	
RI	134,037	4,468	95,514(71.3%)	2,836(63.5%)
TVI			96,308(71.9%)	2,917(65.3%)

environmental impact due to the corona phenomena of the test line. Especially the AN, HN and TVI analysis of the foul weather condition were emphasized. The test results were compared with the calculated value and the simulated results in the corona cage. Table. 1 shows the number of raw data and effective data. The only effective data were used in each analysis.

Audible Noise

If the measured(raw) data are satisfied with the following conditions, the data are defined as effective data. The other data would be discarded.

a) Wind velocity should be less than 5m/s
b) Test voltage should be in ±1.5% tolerance
c) The measured value should be greater than the ambient noise level(BGN) by 4dB(A)

Then the effective AN data are corrected according to IEEE Std. 656-1992, KSA0701-1987 and JIS Z8731-1983 as following[6].

a) If AN - BGN ≥ 10dB(A), then AN = AN
b) If 6 ≤ AN - BGN ≤ 9, then AN = AN -1
c) If 4 ≤ AN - BGN ≤ 5, then AN = AN -2

These correction criteria prevent the measured data from mixing with the data of high ambient noise and extraneous induced wind noise. The AN probability distributions under the foul weather condition is shown in Fig. 2. The average AN levels (L_{50}) of 4 microphones are 49.4, 49.1, 45.2, and 43.3 dB(A), respectively. Table 2 shows the comparison results between the measured and predicted AN at the evaluation point located at 15 m away from the reference point.

The predicted levels was calculated by the corona and field effects program(COMBINE) of Bonneville Power Administration, U.S.A. In Table 2, it can be known that the measured L_{50} AN level in rain at the test line is well agreed to the predicted level. But the measured level is higher than the value in the corona cage test by 4.2dB(A) due to the difference between natural and artificial rain.

Fig.3 shows the typical ⅓ octave band frequency spectrum of AN3 microphone installed at the evaluation

Table 2 The comparison of AN with the predicted

Weather Conditions		Measured [dB(A)]		Predicted [dB(A)]
		Test Line	Corona Cage	
Rainy	$L_{5\%}$	53.0	52.2	52.0
	$L_{50\%}$	48.8	44.9	48.5
Fair	$L_{50\%}$	41.9	42.7	23.5

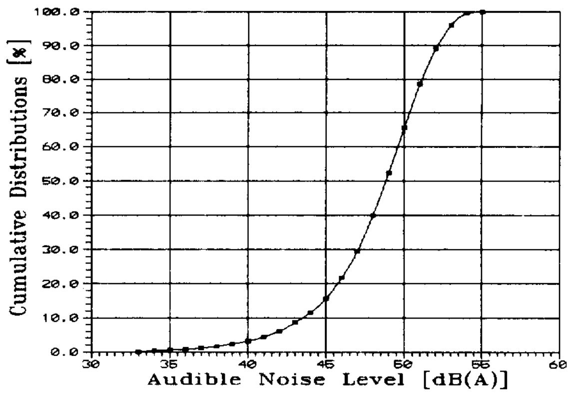

Fig. 2 Audible noise distributions in rainy weather

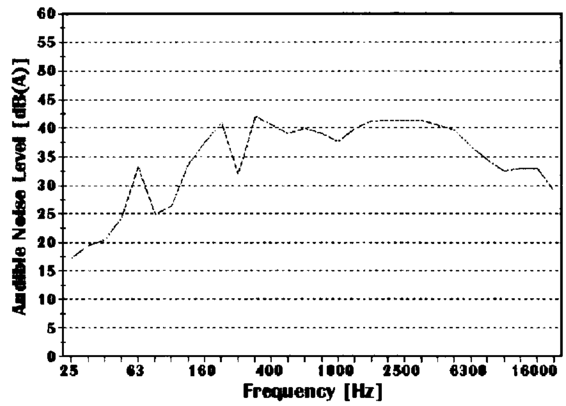

Fig. 3 Audible noise frequency spectrum in rainy weather

level in the fair weather is 45.7dB(μV/m) and the signal point in the rainy weather. In this figure 120Hz tonal component is not so high as typical frequency spectrum of the transmission line audible noise.

Hum Noise

The average hum noise level(L_{50}) in the rainy weather at 18m from the reference point is 47.1dB. And this value is equivalent to 30.5dB(A) in time averaging (L_{ti}) and to 31.8 dB(A) in spacing averaging value(L_s). A L_s was calculated from the equation(1)[8]. The typical frequency spectrum of HN in rainy weather is shown in Fig. 4.

$$L_s = 10\log \left\{ \frac{\sum_{i=1}^{N} (10^{\frac{L_{ti}}{20}})^2}{N} \right\} \ [dB] \qquad (1)$$

where L_{ti} : L_{t50i} at i th measuring point
N : Number of measuring points

Aeolian Noise

The average conductor noise (CN) and tower noise(TN) level in windy weather is 61.2 and 64.9 dB(C) respectively. These values are equivalent to 33.2 and 45.9dB(A) by the

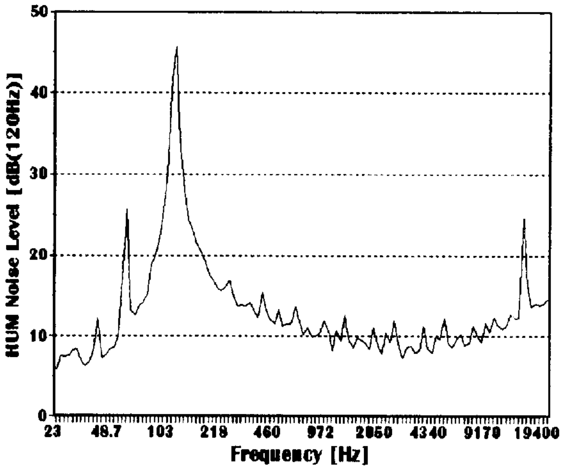

Fig. 4 Hum noise frequency spectrum in rainy weather

equation(2)[8]. The average wind speed and wind direction in this measurements was 7.3m/s and 53.7°, respectively.

$$V_A\ [dB(A)] = V_M\ [dB] + 30 \log f - 79 \qquad (2)$$

where,

V_A [dB(A)] : Converted A weighting value
V_M [dB] : Measured with C weighting value
f : Dominant frequency (≤250Hz)

Radio Interference

Manual measurements were conducted to get the correction factor to a long transmission line from the test line. The measured correction factor is 6dB(μV/m). RI L_{50} level in the fair weather is 45.7dB(μV/m) and the signal to noise ratio(SNR) is 25.3dB. Fig. 6 shows the RI distribution measured at 18m from reference point. The shield rings was attached to the hardware of the insulator string at the dead-end tower(#4) to eliminate corona discharges. The line filters were installed to block the noise from uninterrupted power supply(UPS).

Electric Field Strength

The electric field along the lateral line at 765kV was measured and compared with the calculated. Very good agreement was obtained between the measured and calculated performances, showing in Fig. 7.

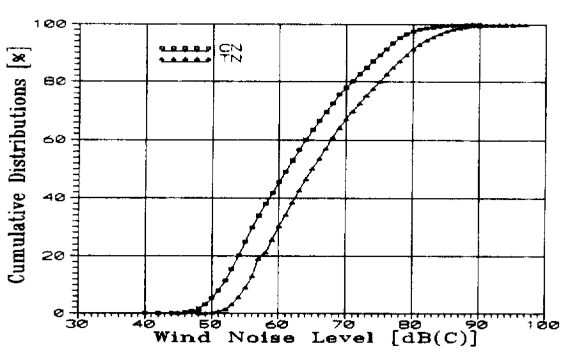

Fig. 5 Wind noise distributions in windy weather

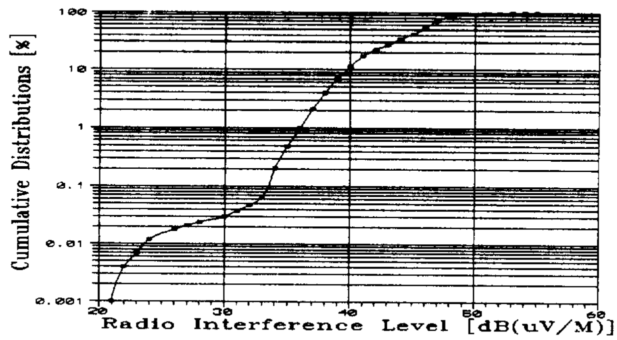

Fig. 6 Fair weather RI(QP) distribution at 765kV

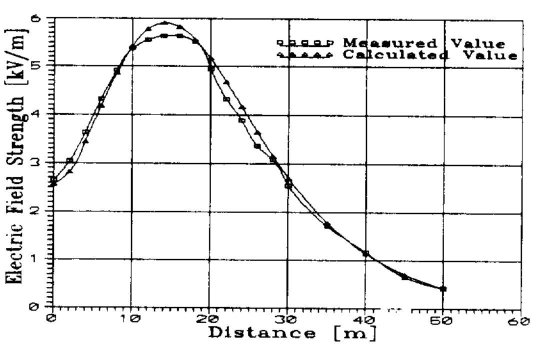

Fig. 7 Lateral electric field strength profiles

5. Discussion & Conclusions

From the long term test using 765kV full scale test line for a 16 months period, the result have been obtained as follows.

(1) The average audible noise of 6-Rail conductor bundle in the foul weather is 48.8dB(A) and in the fair weather is 42.1dB(A). This conductor bundle satisfies the design criteria of 50dB(A).

(2) Radio interference L_{50} level in the fair weather is 45.7dB(μV/m) which satisfies the design criteria SNR 24dB (μV/m).

(3) The electric field comparison between the measured and the calculated is very close to each other at maximum voltage 800kV.

(4) Aeolian noise seems like no problem because the aeolian noise is lower than audible noise in foul weather.

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