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A Simulator for Calculating Normal Induced Voltage on Communication Line

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Abstract – The current flowing through the overhead transmission lines causes induced voltage on the communication lines, which can be prevented by calculating the induced voltage at the planning stage for overhead transmission line installment through an agreement between the communication and electric power companies. The procedures to calculate the induced voltages, however, are complicated due to the variety of parameters and tower types of the overhead transmission lines. The difficulty necessitates the development of a simulator to measure the induced voltage on the communication lines. This paper presents two simulators developed for this purpose; one using the Data Base (DB) index method and the other using the Graphic User Interface (GUI) method. The simulators described in this paper have been implemented by the EMTP (Electromagnetic Transient Program).

Keywords: Communication line, EMTP, Induced voltage, Simulator, Transmission lines

1. Introduction

The rapid growth of modern technology has brought about unprecedented expansion of public facilities such as electrical power transmission lines and communication lines. One subsequent problem with high voltage (HV) transmission lines installed near communication lines is that it can cause induced voltage on communication lines. This induced voltage threatens the safety of maintenance workers and may also cause noise in communication facilities or even lead to equipment malfunction [1-3].

The induced voltage should be calculated on the basis of agreements between communication companies and electric power companies when designing HV power transmission lines. If the calculated induction voltage exceeds a set value, appropriate measures should be taken to reduce the induced voltage. However, the calculation procedures these companies adopt are complicated due to the variety of parameters and tower types in overhead transmission lines.

Much research has been conducted on the induced voltage on communication lines and pipelines using Electromagnetic Transient Program (EMTP) [4-7]. The complex nature of electromagnetic transient phenomena, the lack of background knowledge on EMTP, and non-user friendly interfaces make it difficult for beginners to use EMTP.

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To solve the problem, two simulators for calculation of the normal induced voltage on a communication line have been developed using the Data Base (DB) index method and Graphic User Interface (GUI) method respectively in this paper. The simulators described in this paper have been implemented by EMTP. Users can calculate the induced voltage on a communication line using the simulators that have been developed very easily by clicking execute button after choosing each simulation condition and providing design guidelines for the construction or relocation of communication and electric power facilities.

2. Calculation of Induced Voltage on a Communication Line

Fig. 1 illustrates overhead transmission lines that run parallel to the communication line.

An induced voltage on a communication line can be calculated using the relations between the voltage and current derived from Carson's formula. Relations between

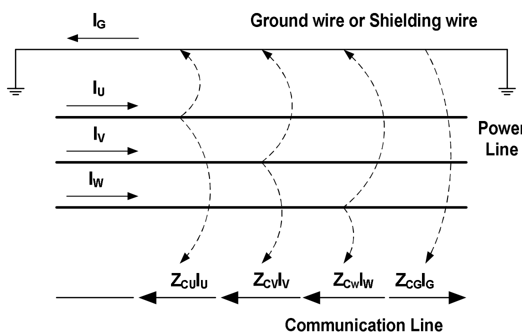


Fig. 1. Induced voltage on a communication line

voltage and current from Fig. 1 are shown in (1).

$$\begin{bmatrix} V_G \\ V_U \\ V_V \\ V_W \\ V_C \end{bmatrix} = \begin{bmatrix} Z_{GG} & Z_{GU} & Z_{GV} & Z_{GW} & Z_{GC} \\ Z_{UG} & Z_{UU} & Z_{UV} & Z_{UW} & Z_{UC} \\ Z_{VG} & Z_{VU} & Z_{VV} & Z_{VW} & Z_{VC} \\ Z_{WG} & Z_{WU} & Z_{WV} & Z_{WW} & Z_{WC} \\ Z_{CG} & Z_{CU} & Z_{CV} & Z_{CW} & Z_{CC} \end{bmatrix} \begin{bmatrix} I_G \\ I_U \\ I_V \\ I_W \\ I_C \end{bmatrix} \quad (1)$$

In (1), G indicates the overhead ground wire, U, V, and W indicate the phase conductors, and C indicates the communication line. The self and mutual impedance are obtained using Carson's formula (2) [7, 8].

$$Z_{ii} = R + 1.588\,e^{-3} f + 2.022\,e^{-3} f \left(\ln \frac{1}{GMR} + 7.6786 + \frac{1}{2} \ln \frac{\rho}{f} \right) [\Omega/\text{mile}]$$

$$Z_{ij} = 1.588\,e^{-3} f + 2.022\,e^{-3} f \left(\ln \frac{1}{D_{ij}} + 7.6786 + \frac{1}{2} \ln \frac{\rho}{f} \right) [\Omega/\text{mile}] \quad (2)$$

where

R = resistance of the conductor i
GMR = geometric mean radius of the conductor
ρ = earth resistivity, f = system frequency
D_{ij} = distance from conductor i to conductor j
Z_{ii} = self impedance of the conductor i
Z_{ij} = mutual impedance between conductors i and j

Voltage of overhead ground wire (V_G) is represented by (1).

$$V_G = Z_{GG} I_G + Z_{GU} I_U + Z_{GV} I_V + Z_{GW} I_W \quad (3)$$

Overhead ground wire laid on the top of the transmission lines is installed to prevent the damage from lightning. Being grounded, V_G can be assumed to be almost zero. Accordingly, the current of the overhead ground wire (I_G) can be obtained from (3).

$$I_G = -\frac{Z_{GU} I_U + Z_{GV} I_V + Z_{GW} I_W}{Z_{GG}} \quad (4)$$

Induced voltage on communication line (V_C) is represented by (1). In shorthand form, V_C can be calculated using (5).

$$V_C = Z_{CG} I_G + Z_{CU} I_U + Z_{CV} I_V + Z_{CW} I_W \quad (5)$$

3. Simulator Based on the DB Index Method [9]

3.1 Configuration of the simulator

This section presents a simulator based on the DB index

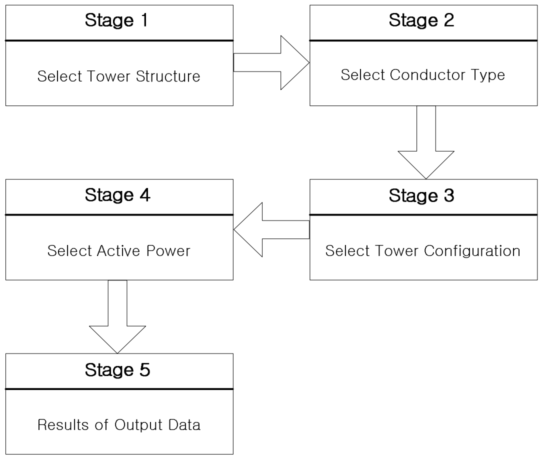


Fig. 2. Execution diagram of the DB index method

Table 1. Conditions of the simulation

	Tower Structure	Conductor Type	Tower Configuration	Active Power [MW]
1	154 kV 2-circuit ACSR 330 & 410 mm^2 Single	ACSR 330 mm^2 (Single) ACSR 410 mm^2 (Single)	A, F, SF, B, C, E, D (7 types)	100~ 400
2	154 kV 2-circuit ACSR 330 & 410 mm^2 Bundle	ACSR 330 mm^2 (Bundle) ACSR 410 mm^2 (Bundle)	A, F, SF, B, C, E, D (7 types)	100~ 700 100~ 800
3	154 kV 2-circuit ACSR 330 & 410 mm^2	ACSR 330 mm^2 ACSR 410 mm^2	Single &Bundle (2 types)	100~400 100~700
4	154 kV 4-circuit ACSR 330 & 410 mm^2 Single-Single	ACSR 330 mm^2 (Single-Single) ACSR 410 mm^2 (Single-Single)	F, SF, B, C, E, D (6 types)	100~ 800 100~ 1100
5	154 kV 4-circuit ACSR 330 & 410 mm^2 Single-Bundle	ACSR 330 mm^2 (Bundle-Single) ACSR 410 mm^2 (Bundle-Single)	F, SF, B, C, E, D (6 types)	100~ 1200 100~ 1100
6	154 kV 4-circuit ACSR 330 & 410mm^2 Bundle-Single	ACSR 330 mm^2 (Single-Bundle) ACSR 410 mm^2 (Single-Bundle)	F, SF, B, C, E, D (6 types)	100~ 1200 100~ 1400
7	154 kV 4-circuit ACSR 330& 410 mm^2 Bundle-Bundle	ACSR 330 mm^2 (Bundle-Bundle) ACSR 410 mm^2 (Bundle-Bundle)	F, SF, B,C, E, D (6 types)	100~ 1600
8	345 kV 2-circuit ACSR 480 mm^2 RAIL 4-Bundle	ACSR 480 mm^2 RAIL (Bundle)	A, F,SF, B, C, E, D (7 types)	200~ 2000
9	345 kV 4-circuit ACSR 480 mm^2 RAIL Upper-Side (US), Lower-Side (LS)	ACSR 480 mm^2 US 4, LS 4-Bundle US4,LS2-Bundle, US 2, LS 4-Bundle, US 2, LS 2-Bundle	A, F, SF, B, C, E, D (7 types)	200 ~ 2000
10	765 kV 2-circuit 480mm^2 CARDINAL 6-Bundle Type a	ACSR 480 mm^2 CADINAL	Aa, LA, Ba, Ca, Ea, Ga, Da (7 types)	200~ 1200
11	765 kV 2-circuit 480mm^2 CARDINAL 6-Bundle Type b	ACSR 480 mm^2 CADINAL	Aa, LA, Bb, Cb, Eb, Gb, Db (7 types)	200~ 1200
12	765 kV 1-circuit 480mm^2 CARDINAL 6-Bundle	ACSR 480 mm^2 CADINAL	A, LA, B, C, E, G, D (7 types)	200~ 2400

method for induced voltage on a communication line. The DB index method described in this paper has been made using EMTP simulation results. Fig. 2 shows the execution process of the DB index method.

This simulator is implemented in approximately 3,500,000 cases, which are grouped (classified) by existing transmission line types of the Korea Electric Power Corporation (KEPCO) in Table 1. The conditions of the simulator are applied to the various heights of transmission lines (5~70 m), the height of the communication line (5 m), the parallel length (1 km), and various separations between transmission and communication lines (-3~3km).

3.2 Example of Simulator

The following paragraph describes an example of the simulator process from the initial startup screen to the results of the output data.

(1) Select a tower structure

The initial screen appears as shown in Fig. 3. There are several tower structures listed in Table 1. When a user selects "154 kV 2-circuit ACSR Single," the screen in Fig. 4 will automatically appear.

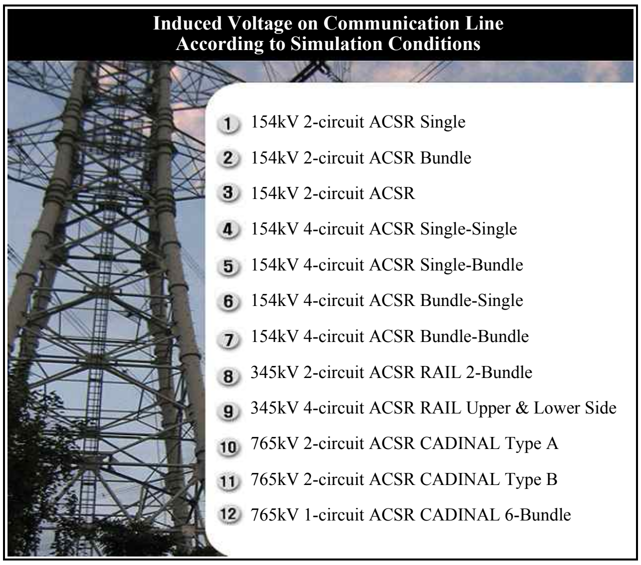


Fig. 3. Initial screen of the simulator

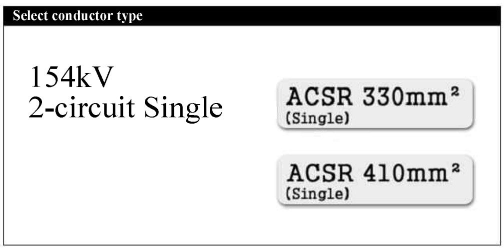


Fig. 4. Selection of the conductor type

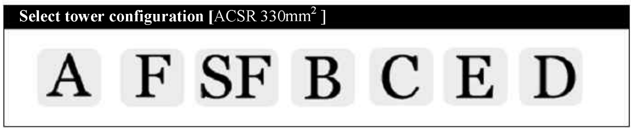


Fig. 5. Selection of the tower configuration

Fig. 6. Selection of the active power

(2) Select a conductor type

Fig. 4 shows conductors of two types for the previously selected "154 kV 2-circuit ACSR Single." By selecting "ACSR 330 mm^2 (Single)," a user moves to the next stage, as shown in Fig. 5.

(3) Select a tower configuration

Fig. 5 shows the various configuration types for "154 kV 2-circuit ACSR Single" (shown in Fig. 3). When "A" type selected, and then the screen will appear as it does in Fig. 6.

(4) Select an active power

The various options of the active power associated with selected tower configuration are shown in Fig. 6. If "100" is selected in Fig. 6, a zip file is generated.

(5) Results of the output data

When the generated zip file is opened in the last stage of simulator, the results, including a text file and associated graph, appear on the screen. The zip file has the results according to the height ranges of the transmission lines, from 5 to 70 m. Table 2 and Fig. 7 show the results of the transmission lines with a height of 5 m as an example. The separation length and induced voltage are D and V_C, respectively, in Table 2.

This simulator gives quick access to the complex and

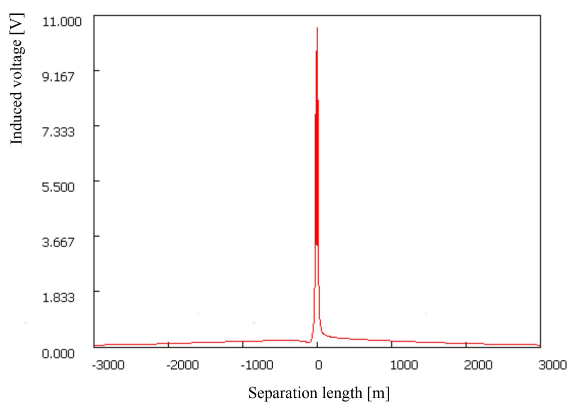


Fig. 7. Graphical result of the simulator

Table 2. Text based result of the simulator

D[m]	V_C [V]	D [m]	V_C [V]	D [m]	V_C [V]
-3000	0.063	8	10.485	55	0.637
⋮	⋮	9	10.563	60	0.581
-1	3.446	10	10.202	65	0.539
0	3.352	15	6.190	70	0.507
1	3.792	20	3.659	75	0.482
2	4.621	25	2.375	80	0.463
3	5.674	30	1.669	85	0.447
4	6.835	35	1.254	90	0.433
5	8.010	40	0.996	95	0.422
6	9.097	45	0.829	⋮	⋮
7	9.966	50	0.716	3000	0.064

difficult computation needed to determine the induced voltage on a communication line. The results are stored in a file, which facilitates the users to compare various results.

4. Simulator Based on the GUI Method [10]

4.1 Configuration of the Simulation

This section presents the simulator based on the GUI method for calculating the induced voltage on a communication line. Fig. 8 shows the configuration of the GUI method for induced voltage calculation.

As shown in Fig. 8, the graphic functions of the GUI method are developed using EMTP and the Microsoft Foundation Class (MFC) provided by Visual C++. The development environment of the simulator is summarized in Table 3.

Fig. 9 illustrates the operation process of the GUI method. As shown in Fig. 9, it is made up of two programs: the simulator and EMTP. The simulator and EMTP are coupled to each other to calculate the induced voltage. An EMTP Branch Card, which is used to process the LINE CONSTANT routine in EMTP, and an EMTP Source Card are created automatically by the conditions of the simulator. The EMTP Branch Card and EMTP Source Card are used

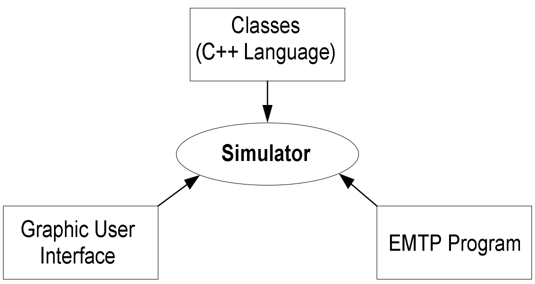


Fig. 8. Configuration of the simulator

Table 3. Development Environment of the Simulator

Operating System	Windows XP
Programming Language	Visual C++ 6.0
Miscellaneous	EMTP, Text

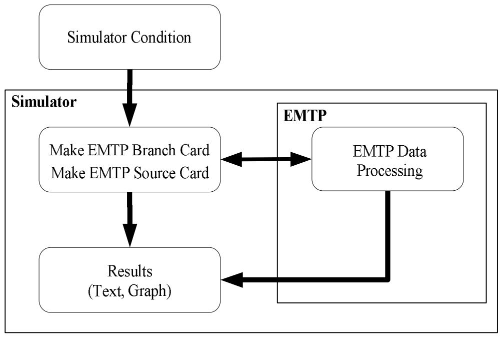


Fig. 9. Operation process diagram of the GUI method

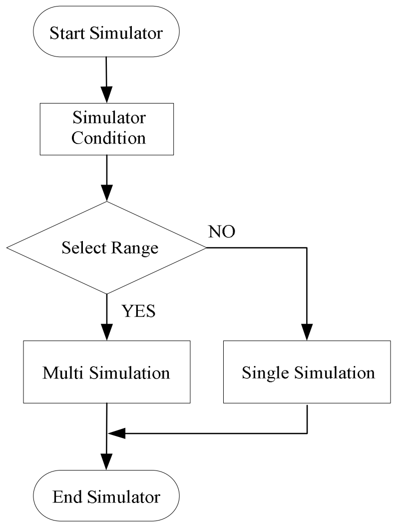


Fig. 10. Execution diagram of the simulation methods

to calculate the induced voltage on the communication line. The simulator's results are split into a text file and an associated graph.

Fig. 10 shows the simulation methods. It consists of single and multi-simulations. If a range from the simulation condition is selected, the simulator will be executed using multi-simulation; otherwise, it carries out single simulations.

4.2 The layout of the control panel

Fig. 11 shows the control panel of the simulator. The control panel requires the tower type, the conductor type, the parameter of the voltage source, and the simulation condition. The tower type is currently used for the parameters of KEPCO's transmission lines (Table 1). A user can calculate the induced voltage easily using this control panel. By clicking on the menu bar and inputting the parameter of simulation condition in the control panel, an EMTP data card is automatically created. This means that there is no need for the user to enter the simulation condition to the EMTP data card manually.

If a user selects the range of the simulation condition and clicks the “Simulation Option” button in Fig. 11, the simulator will automatically show the multi-simulation

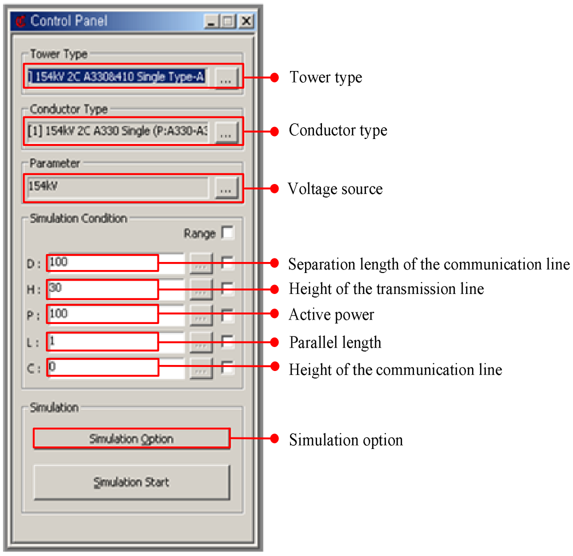


Fig. 11. Simulator control panel

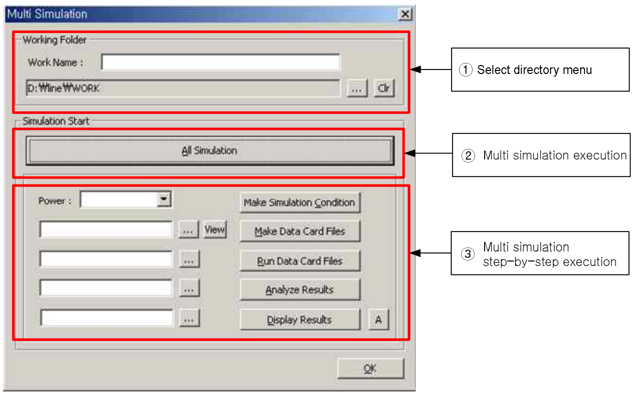


Fig. 12. Multi-simulation panel

window. Multi-simulation may be divided into three parts, as shown in Fig. 12.

4.3 The layout of the control panel

The simulator results consist of single and multi-simulations for the calculation of the induced voltage on the communication line.

(1) Single simulation

In order to run a single simulation, the following input conditions are applied.

- Tower type: 154 kV 2-circuit ACSR 330&410 mm^2 Single Type-A
- Conductor type: ACSR 330 mm^2 Single
- Voltage source: 154 [kV]
- Separation range of the communication line (D): 500 [m]
- Height of the transmission line (H): 50 [m]
- Active power (P): 100 [MW]
- Parallel length (L): 1 [km]
- Height of communication line (C): 5 [m]

Fig. 13 shows the single simulation result using the GUI method. By using this method, the user can easily determine the induced voltage.

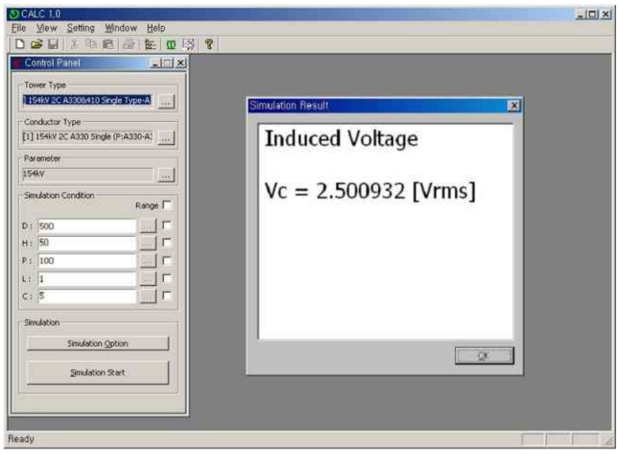
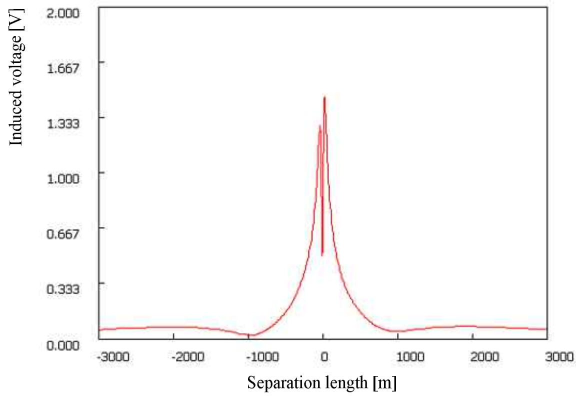
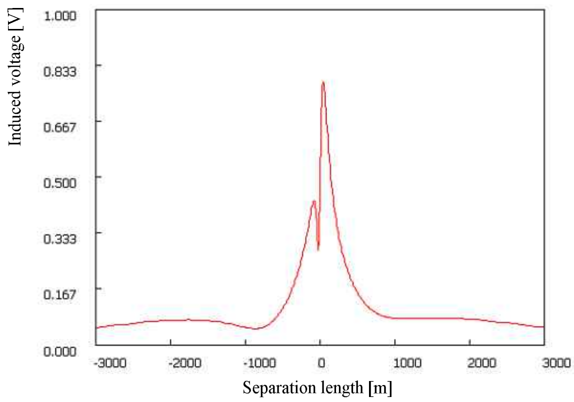


Fig. 13. Single simulation result



(a) Height of the transmission lines: 35 [m]



(b) Height of the transmission lines: 70 [m]

Fig. 14. Multi-simulation results according to separation length and height of the transmission lines

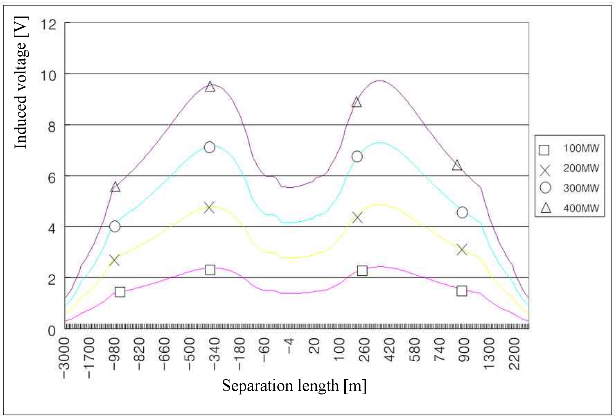


Fig. 15. Multi-simulation results according to separation length and active power

(2) Multi-simulation

Multi-simulation is applied to the same input conditions as single simulation (Fig. 13), such as tower type, conductor type and voltage source. However, range input conditions are applied as follows:

- Separation range of the communication line (D): -3~3 [km]
- Height of the transmission lines (H): 35, 70 [m]
- Active power: 100 ~ 400 [MW]

Fig. 14 shows multi-simulation results according to the separation range and height of the transmission lines. Fig. 15 shows multi-simulation results according to the separation length and active power. According to the input conditions, there are many different results with which multi-simulation allows the user to compare.

Users of this simulator can calculate line parameters, according to arbitrary input conditions, and the induced voltage easily by clicking the executive button ("Simulation Start" button) after choosing each simulation condition.

5. Conclusion

This paper introduced two simulators developed using the DB index method and GUI method to calculate the induced voltage on the communication line in the steady state.

In existing methods, users have to make EMTP line parameter routine data card (EMTP data card) using configurations of tower, specifications of cable and the distance between tower and communication line. However, with the world's first developed simulator for calculating the induced voltage presented in this paper, suitable EMTP data cards are automatically created if the user input the simulation conditions. Created EMTP data cards then can calculate the induced voltage of communication line by performing the simulator. The advantages of this simulator are summarized as follows.

① Users do not need to make the EMTP data card
② Users can confirm the created EMTP data card in real time

Characteristics of the developed simulators are summarized as follows.

The DB index method gives quick access to complicated computations to determine the induced voltage on a communication line associated with tower types specified in the simulator. The calculated results are stored as a file, for the user to compare various results. Therefore, the DB index method can be used consistently by adding new transmission parameters to the DB.

The GUI method enables users to easily calculate the induced voltage by just clicking the execute button ("Simulation Start") after selecting and inputting each simulation condition. This simulator can compute line parameters associated with arbitrary input conditions.

The newly developed simulators are expected to provide design guidelines for future construction or relocation of communication lines and electric power lines.

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