A Simulator for Calculating Normal Induced Voltage on Communication Line

Jeong-Yong Heo*, Hun-Chul Seo**, Soon-Jeong Lee***, Yoon Sang Kim**** and Chul-Hwan Kim†

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.

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).

\[
\begin{bmatrix}
V_G \\
v_U \\
v_V \\
v_W \\
v_C
\end{bmatrix}
= \begin{bmatrix}
Z_{GG} & Z_{GU} & Z_{GV} & Z_{GW} & Z_{GC} \\
Z_{UG} & Z_{UU} & Z_{UV} & Z_{UW} & Z_{UC} \\
Z_{VG} & Z_{VU} & Z_{VV} & Z_{VW} & Z_{VC} \\
Z_{WG} & Z_{WU} & Z_{WW} & Z_{WV} & Z_{WC} \\
Z_{CG} & Z_{CU} & Z_{CW} & Z_{CV} & Z_{CC}
\end{bmatrix}
\begin{bmatrix}
I_G \\
I_U \\
I_V \\
I_W \\
I_C
\end{bmatrix}
\] (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) \[7, 8\].

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

where

- \( R \) = resistance of the conductor \( i \)
- GM = geometric mean radius of the conductor
- \( \rho \) = earth resistivity, \( f \) = system frequency
- \( D_{ij} \) = distance from conductor \( i \) to conductor \( j \)
- \( Z_i \) = 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).

\[
V_G = Z_{GG} I_G + Z_{GU} I_U + Z_{GV} I_V + Z_{GW} I_W
\] (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).

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

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

\[
V_C = Z_{CG} I_G + Z_{CU} I_U + Z_{CV} I_V + Z_{CW} I_W
\] (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](image)

Table 1. Conditions of the simulation

<table>
<thead>
<tr>
<th>Tower Structure</th>
<th>Conductor Type</th>
<th>Tower Configuration</th>
<th>Active Power [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>154 kV 2-circuit ACSR 330 &amp; 410 mm² (Single)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–400</td>
</tr>
<tr>
<td>2</td>
<td>154 kV 2-circuit ACSR 330 &amp; 410 mm² (Bundle)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–700</td>
</tr>
<tr>
<td>3</td>
<td>154 kV 2-circuit ACSR 330 &amp; 410 mm² (Single-Single)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–400</td>
</tr>
<tr>
<td>4</td>
<td>154 kV 4-circuit ACSR 330 &amp; 410 mm² (Single-Single)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–400</td>
</tr>
<tr>
<td>5</td>
<td>154 kV 4-circuit ACSR 330 &amp; 410 mm² (Single-Bundle)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–1200</td>
</tr>
<tr>
<td>6</td>
<td>154 kV 4-circuit ACSR 330 &amp; 410 mm² (Bundle-Bundle)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–1400</td>
</tr>
<tr>
<td>7</td>
<td>154 kV 4-circuit ACSR 330 &amp; 410 mm² (Bundle-Single)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>100–1600</td>
</tr>
<tr>
<td>8</td>
<td>345 kV 2-circuit ACSR 480 mm² RAIL 4-Bundle</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>200–2400</td>
</tr>
<tr>
<td>9</td>
<td>345 kV 4-circuit ACSR 480 mm² RAIL Upper-Side (US), Lower-Side (LS)</td>
<td>A, F, SF, B, C, E, D (7 types)</td>
<td>200–2400</td>
</tr>
<tr>
<td>10</td>
<td>765 kV 2-circuit ACSR 480 mm² CARDINAL 6-Bundle Type a</td>
<td>Aa, LA, Ba, Ca, Ea, Ga, Da (7 types)</td>
<td>200–1200</td>
</tr>
<tr>
<td>11</td>
<td>765 kV 2-circuit ACSR 480 mm² CARDINAL 6-Bundle Type b</td>
<td>Aa, LA, Bb, Cb, Eb, Gb, Db (7 types)</td>
<td>200–1200</td>
</tr>
<tr>
<td>12</td>
<td>480 mm² CARDINAL 6-Bundle</td>
<td>Aa, LA, Bb, Cb, E, G, D (7 types)</td>
<td>200–2400</td>
</tr>
</tbody>
</table>
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.

(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 mm² (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
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 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...
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 mm² Single Type-A
- Conductor type: ACSR 330 mm² 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.
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.

References


Fig. 15. Multi-simulation results according to separation length and active power
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EEUG, Canadian/American EMTP User Group.

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