Paper

A New Environmentally Friendly Design Program, TLCALC 2001 for High Voltage AC Transmission Lines

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Various noises produced by corona discharges from high voltage transmission lines are the important considerations in line design. HVAC transmission lines must be designed to satisfy national environmental regulations too. Therefore, it is necessary for line designers to pre-evaluate environmental problems using prediction tools. In this paper, an environmental design software, TLCALC 2001 for AC transmission lines as a comprehensive window program is introduced. It has 6 modules including audible noise, radio noise, television noise, magnetic field, electric field and conductor surface gradient module. TLCALC 2001 has solved some of the problems of the existing foreign tools and has several advantages over those. 1) It is a common tool that has solved calculating limitations of foreign formulas. 2) It has a wide application range and enhanced prediction accuracy. 3) It can be applied to almost all transmission line configurations in Korea. 4) Experienced designers can get calculation results within about 15 minutes. As the use of TLCALC 2001 is easy and practical, it will be applied to the environmentally friendly design and construction of transmission lines. It is expected that public complaints and social environmental costs will be considerably reduced by the use of TLCALC 2001 in the future.

Keywords: transmission line, environmentally friendly design software, regulations, audible noise, radio noise, television noise, magnetic field, electric field and conductor surface gradient

1. The Background and Purpose of Program Development

TLCALC 2001, an environmentally friendly design program for high voltage transmission lines (T/Ls) is the first of its kind developed in Korea and it is a part of the 765 kV transmission technology development project [1]. Line designers can utilize this program for the evaluation of environmental effects of existing transmission lines. In addition, they can estimate the levels of environmental effects and problems along the planned line routes and carry out more effective environmental line design by using the results.

As the calculation programs used up to now are from other countries and inappropriate for Korean situation, and have many limitations in use, there have been demands for domestically developed common calculation tools that have a wider range of application and enhanced prediction accuracy [2]~[6]. As TLCALC 2001, which has better prediction accuracy than foreign made programs, is easy to use and practical, it will be utilized for the design, construction, and operation of environmentally friendly transmission lines by estimating the level of environmental effects of transmission lines and establishing countermeasures to reduce noises through the identification of their field distribution characteristics. And it is expected that preventing environmental public complaints at the source will reduce social environmental costs.

2. Program Use and Features

2.1 Program Use The uses of TLCALC 2001 can be summarized as follows. 1) Assisting transmission line designers in planning for environmental countermeasures for the construction of new transmission lines, 2) Evaluation of environmental effects of existing transmission lines for after management, 3) Minimization of environmentally public complaints and social environmental costs by estimating and evaluating environmental interferences from transmission lines, 4) Construction of high voltage transmission utilities that are economic and satisfy environment regulations, and increasing its operation efficiency.

2.2 Program Features TLCALC 2001 has improved some of the disadvantages of previously used foreign prediction formulas and calculation programs, and has many advantages and special features. The major features of the program are as follows.

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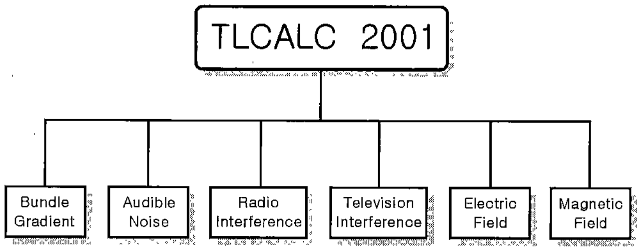


Fig. 1. Composition of calculation modules in TLCALC 2001

(1) It is a common calculation tool that has resolved the limitations of existing foreign formulas.

(2) It has a wider range of application in the aspects of line voltage, diameter, and the number of subconductor, and it has enhanced prediction accuracy.

(3) It is made for the analysis of vertical 2-circuit and 4-circuit, but it can be used for the analysis of triangle and horizontal single circuit also.

(4) As shown in Fig. 1, the calculation module consists of 6 components; audible noise (AN), radio noise (RI), television noise (TVI), electromagnetic field intensity and conductor surface gradient (G).

(5) For the calculation of audible noise and radio noise, the formulas developed in Korea are applied. The audible noise formulas developed in 1998 was the first of its kind in Korea and the 7th in the world. And the radio noise formulas developed in 1999 was the first of its kind in Korea and the 10th in the world.

(6) An experienced designer can obtain a calculation result within 15 minutes approximately.

3. Prediction Formulas for Corona Noises

For the development of TLCALC 2001, internally developed audible noise and radio noise prediction formulas are used [7][8], and the Bonneville Power Administration (BPA) formula, which is used throughout the world, is applied as the television noise prediction formula.

3.1 Audible Noise Formulas

3.1.1 AN formula for L5% level in rain

General Formulation							
$K_1 \cdot \log G + K_2 \cdot \log N + K_3 \cdot \log d + K_4 \cdot \log K_5 + K_6$							
Ph.=1,3,6	N	K_1	K_2	K_3	K_4	K_5	K_6
L_5 (1)	<3	179.23	0	58.71	−55.02	2 DG + 206 G	−3.81
	≧3	174.07	59.06	57.73	−57.89	2 DG + 97 GN + 206 G + DN	$0.9\frac{GN}{D}+3.7$

3.1.2 AN formula for L50% level in rain

$$SLT_{L50} = 122.68 \log G + K_1 \log N + 58.68 \log d - 10.53 \log D + K_2 \quad \cdots\cdots (2)$$

Ph.	N	K_1	K_2
1, 3, 6	< 3	0	−122.73
	≧ 3	24.99	−133.89

The application conditions are as follows.

- Application: Vertical AC 3-phase 2 and 4-circuit T/L
- Noise Measure: L5% and L50% in rain
- D (m): The radial distance from the phase under consideration to a calculating point
- G (kV/cm): Average-maximum bundle gradient
- N: Number of subconductor in a bundle
- d (cm): Diameter of a subconductor
- Range of Validity: $235 \leq kV_{L-L} \leq 1690\,\text{kV}$
  $1 \leq N \leq 16$
  $2.35 \leq d \leq 5.59\,\text{cm}$

3.2 Radio Noise Formulas

3.2.1 RI formula for L50% level in fair weather

$$RI_{FL50} = -105.81 + 117.41 \log G + 40.38 \log d + 1.54 \log N - 10.22 \log D - 27.10 \log f \quad \cdots\cdots (3)$$

where RI_{FL50} (dBμV/m) : Radio noise from a model T/Lf (MHz): Radio frequency

3.2.2 RI formula for L50% level in rain

$$RI_{RL50} = -81.98 + 119.56 \log G + 43.57 \log d + 3.97 \log N - 19.05 \log D - 25.07 \log f \quad \cdots\cdots (4)$$

The application conditions are as follows.

- Application: Vertical AC 3-phase 2 and 4-circuit T/L
- Noise Measure: L50% levels in fair and rainy weather
- Range of Validity: $230 \leq kV_{L-L} \leq 1200\,\text{kV}$
  $1 \leq N \leq 8$
  $2.24 \leq d \leq 6.35\,\text{cm}$ (in fair weather)
  $2.72 \leq d \leq 6.35\,\text{cm}$ (in rain)
  $0.475 \leq f \leq 1.0\,\text{MHz}$

3.3 Television Noise Formulas

Eq. (5) is the BPA formula to calculate L50% television noise in rain. Of the results calculated on each phase, the maximum value is used as the final number.

$$TVI_{RL50} = 10 + 120 \log \frac{G}{16.3} + 40 \log \frac{d}{30.4} + 20 \log \frac{75}{f} + \frac{q}{300} + F \quad \cdots\cdots (5)$$

where q: Correction coefficient for above the sea, $<$ 3000 m

F in Eq. (5) is subject to the following.

- if (D AND 61) $\leqq A$,
  then $F = 20 \log \frac{61}{D}$
- if ($D \geqq A$) AND ($61 \leqq A$),
  then $F = 20 \log \frac{61}{A} + 40 \log \frac{A}{D}$
- if ($D \leqq A$) AND ($61 \geqq A$),
  then $F = 20 \log \frac{A}{D} + 40 \log \frac{61}{A}$

- if $(D \text{ AND } 61) \geqq A$, then $F = 40 \log \frac{61}{D}$

where $\lambda = \frac{3 \times 10^8}{f \times 10^6}$ [m]

$$A = \frac{12 \times \text{Height of Antenna} \times \text{Height of } T/L}{\lambda} \text{ [m]}$$

4. Major Functions and Configuration of TLCALC 2001

4.1 Calculation Functions of the Program TLCALC 2001 has following major functions.

(1) Creation of input file: The user can enter, store and control line specifications and various calculation conditions by using menus.

(2) Types of calculation: Calculation of the noise amount and field profile at a random point and height.

(3) Line specifications: Vertical arrangement of 2-circuit and 4-circuit. It can be applied to all kinds of transmission lines in Korea.

(4) Output of calculation result: Able to select whether to produce the result in numbers or in a graph

(5) A module that enables the calculation of conductor surface gradient

(6) Calculation of environmental interferences: Produce 5 items including audible noise and others by weather condition and by distance from the line.

4.2 Program Configuration TLCALC 2001 consists of data input area, calculation area, output area and other auxiliary windows as shown in Fig. 2 of Appendix, and the program help contains information on these.

It is the actual screen shot of program operation. In Appendix, Fig. 3 shows the initial screen. The main menu window shown in Fig. 4 has input data creation, execution of prediction calculation, control of calculation result file and help. Fig. 5 shows an input window. Even a novice can easily create and control 2-circuit and 4-circuit input data. The user just needs to enter the coordinates of the right circuit. If the user makes an input error, an error message appears since valid application ranges have been specified. For the line height, enter the average height. However, when calculating the electric field, the minimum height is applied to the maximum voltage automatically. In other cases, the average height is applied to the nominal voltage. As for the number of subconductor (N), in the case of audible noise, whether $N < 3$ or $N \geq 3$ is assessed first, then different formula

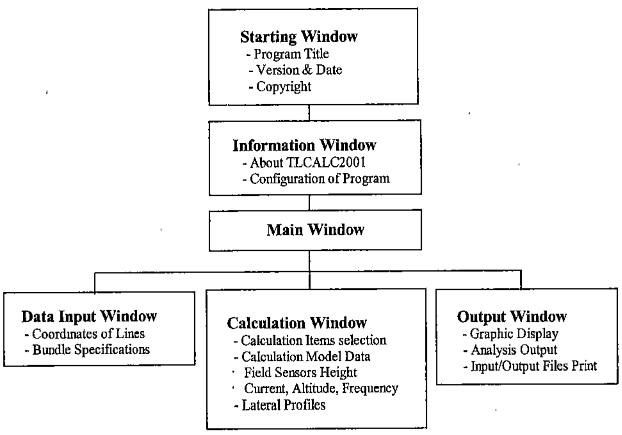


Fig. 2. Configuration of TLCALC 2001

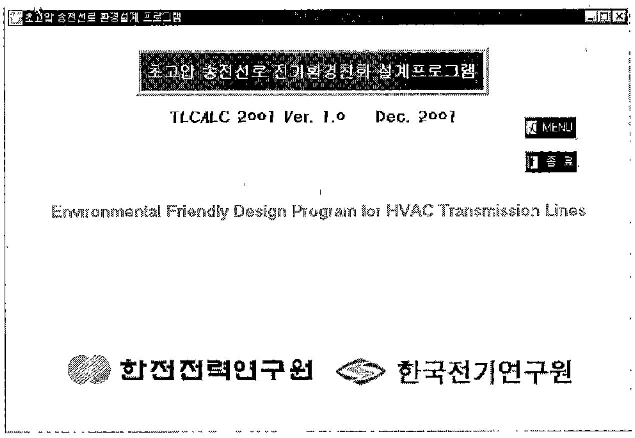


Fig. 3. The initial screen of TLCAL 2001

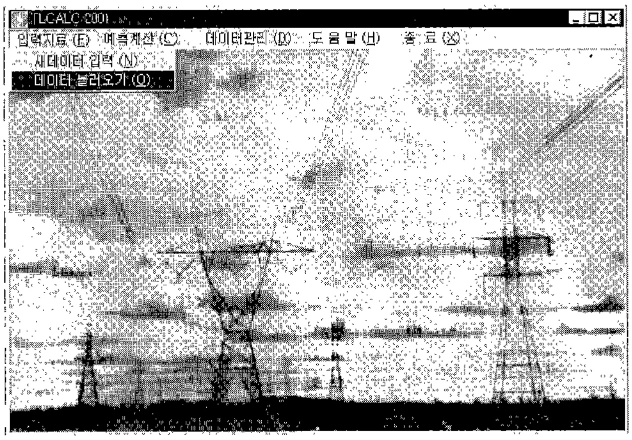


Fig. 4. Main menu window of TLCALC 2001

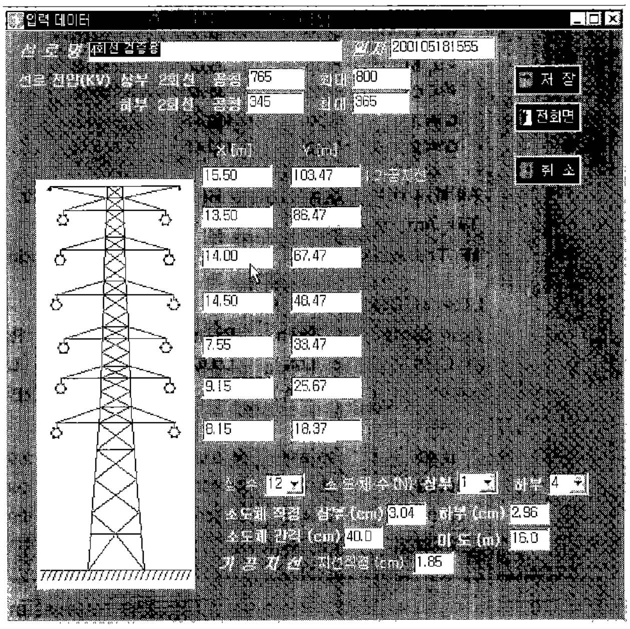


Fig. 5. Example of 4-circuit data input window

is applied to increase prediction accuracy.

Fig. 6 shows the input of calculation conditions and the main operation area. The interference items for the calculation and various calculation conditions are specified. The calculation conditions include the height of calculation point, calculation frequency, height above sea level, and load current of upper and lower lines. The output of calculation can be produced in a lateral numeric display as shown in Fig. 7 or a lateral graphic display, which shows the field distribution around the lines. To get a graphic output, select 'Graph output (*G*)' from the 'Data control (*D*)' menu. It shows the lateral profile of the corresponding interference item in a graph. There are 2 ways of display; one is 'the general output' that shows only 1-circuit profile, and the other is 'the symmetrical output' that shows symmetric 2-circuit profile as shown in Fig. 8. It is possible to print the output and save it in a BMP file. It is also possible to view a

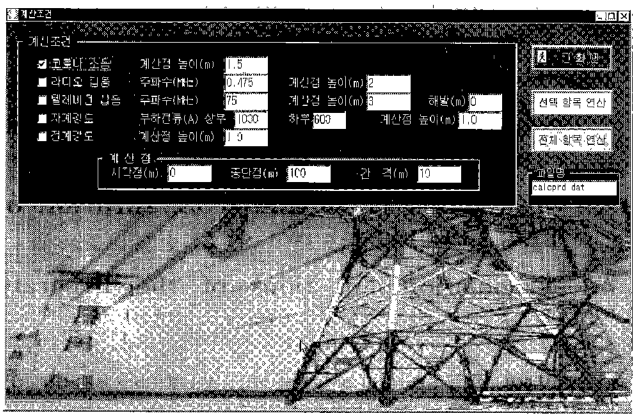
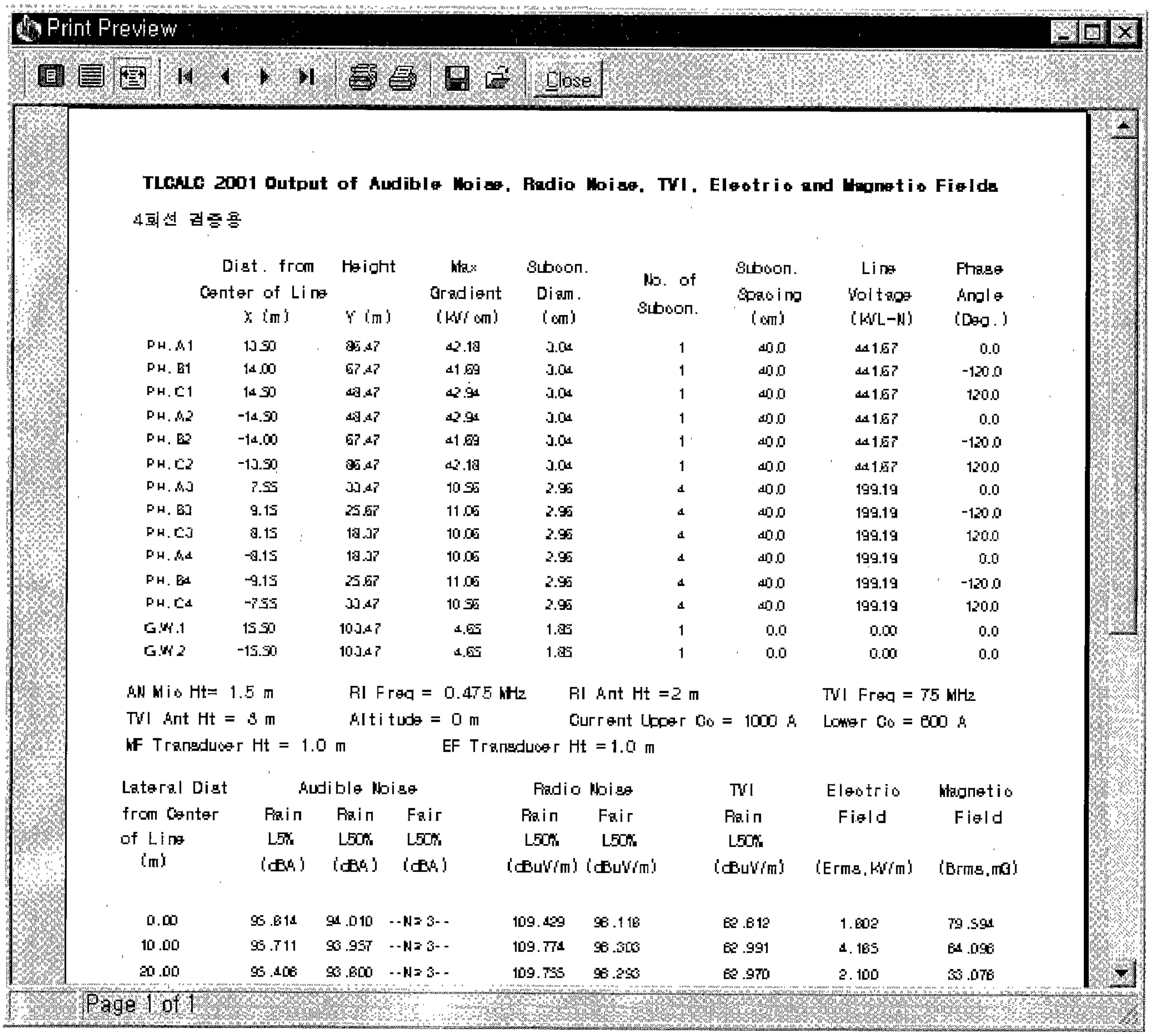


Fig. 6. Window for calculation conditions and the main operation



Print Preview

Close

TLCALC 2001 Output of Audible Noise, Radio Noise, TVI, Electric and Magnetic Fields

4회선 검증용

	Dist. from Center of Line X (m)	Height Y (m)	Max Gradient (kV/cm)	Subcon. Diam. (cm)	No. of Subcon.	Subcon. Spacing (cm)	Line Voltage (kV/L-N)	Phase Angle (Deg.)
PH.A1	13.50	86.47	42.18	3.04	1	40.0	441.67	0.0
PH.B1	14.00	67.47	41.69	3.04	1	40.0	441.67	-120.0
PH.C1	14.50	48.47	42.94	3.04	1	40.0	441.67	120.0
PH.A2	-14.50	48.47	42.94	3.04	1	40.0	441.67	0.0
PH.B2	-14.00	67.47	41.69	3.04	1	40.0	441.67	-120.0
PH.C2	-13.50	86.47	42.18	3.04	1	40.0	441.67	120.0
PH.A3	7.55	33.47	10.56	2.96	4	40.0	199.19	0.0
PH.B3	9.15	25.67	11.06	2.96	4	40.0	199.19	-120.0
PH.C3	8.15	18.37	10.06	2.96	4	40.0	199.19	120.0
PH.A4	-8.15	18.37	10.06	2.96	4	40.0	199.19	0.0
PH.B4	-9.15	25.67	11.06	2.96	4	40.0	199.19	-120.0
PH.C4	-7.55	33.47	10.56	2.96	4	40.0	199.19	120.0
G.W.1	15.50	103.47	4.65	1.85	1	0.0	0.00	0.0
G.W.2	-15.50	103.47	4.65	1.85	1	0.0	0.00	0.0

AN Mic Ht= 1.5 m RI Freq = 0.475 MHz RI Ant Ht =2 m TVI Freq = 75 MHz
TVI Ant Ht = 3 m Altitude = 0 m Current Upper Cc = 1000 A Lower Cc = 600 A
MF Transducer Ht = 1.0 m EF Transducer Ht =1.0 m

Lateral Dist from Center of Line (m)	Audible Noise Rain L5% (dBA)	Audible Noise Rain L50% (dBA)	Audible Noise Fair L50% (dBA)	Radio Noise Rain L50% (dBuV/m)	Radio Noise Fair L50% (dBuV/m)	TVI Rain L50% (dBuV/m)	Electric Field (Erms,kV/m)	Magnetic Field (Brms,mG)
0.00	95.814	94.010	--N≥3--	109.429	98.118	62.612	1.802	79.594
10.00	95.711	93.957	--N≥3--	109.774	98.303	62.991	4.165	64.098
20.00	95.406	93.800	--N≥3--	109.735	98.293	62.970	2.100	33.078

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Fig. 7. Lateral numeric output data display

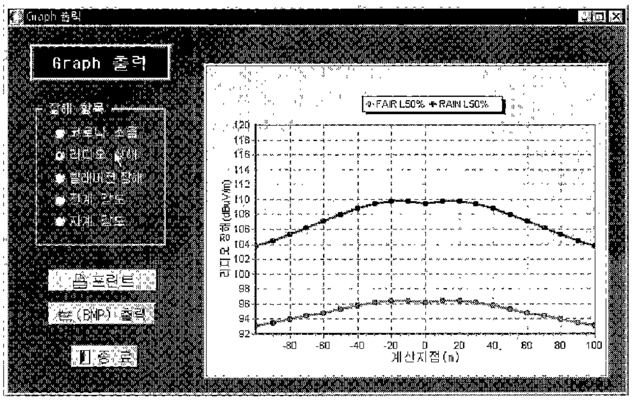

Fig. 8. Graphic output data display

specified area in detail by setting a zooming area in the graph, Fig. 8.

5. Technology Transfer and Utilization Method

About 50 people working in the field of transmission line design from Korea Electric Power Company, KEPCO received training on TLCALC 2001 in December 2001 through a seminar, and CDs and user manuals were distributed. The program has been put into practice and publicized through user registration and control program. In addition, the program was registered (No.2001-01-12-7479) to the Ministry of Information and Communication in November 2001.

6. Conclusion

When we consider the current social background where people demand comfortable living environment, government imposes strict environmental regulations, and power companies are required to construct and operate environmentally friendly power utilities, TLCALC 2001, an environmentally friendly high voltage transmission line design program introduced in this paper will be utilized actively by transmission line designers. The significance of TLCALC 2001 and the effects expected from it can be summarized as follows.

(1) TLCALC 2001 is the first environmentally friendly design program developed for high voltage transmission lines in Korea.

(2) Compared to similar calculation programs developed in other countries, it has less restrictive conditions, wider application ranges, and enhanced prediction accuracy.

(3) As it is easy to use and practical, its active use in the environmental evaluation of existing transmission lines and the design of new environmentally friendly transmission lines is expected.

(4) It can be utilized for the establishment of proper countermeasures to reduce environmental problems by estimating the environmental interferences caused by transmission lines and identifying the characteristics of field distribution.

(5) Prevention of environmental public complaints at the source and reduction of social environmental costs caused by transmission utilities is expected.

(6) At present, the user registration control program is in operation to protect TLCALC 2001 and to support the users.

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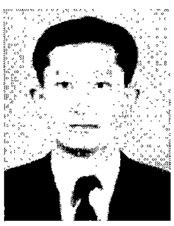

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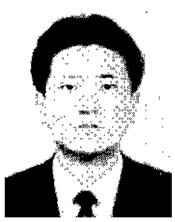

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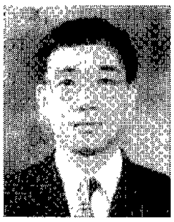

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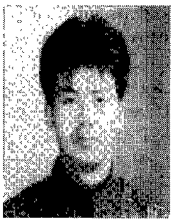

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