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Comparative Analysis of the Power Cable Impact between Aboveground and Underground Conduit

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Abstract: This research presents a comparative analysis of the cables within aboveground and underground conduits. The study aimed at the thermal impact, electric fields, and magnetic fields to provide supporting information in considering the suitability of conduits construct methods. The paper used the finite element method to simulate the cable of the different construction methods. The study results showed that the cable ampacity within the aboveground conduit better than the underground conduit. In contrast, the electric and magnetic fields that were likely to be touched by people were greater than the underground conduit.

Keywords—aboveground conduit, ampacity, electric field, magnetic field, underground conduit.

I. INTRODUCTION

Installation of cable in non-metallic conduits can be installed according to the Thai Electrical Cade 2013 [1], which consists of aboveground and underground installations. The aboveground conduits must have flame retardant properties and are resistant to sunlight. Underground conduits must be moisture resistant and able to withstand the stress of the surrounding soil.

The cable ampacity installed inside the conduit depends on many factors, including the conductor temperature, Insulation thermal resistance, free space inside the conduit, conduit thermal resistance, soil thermal resistance, and air thermal resistance [2]. Heat is the main factor in determining the cable ampacity; particularly, the heat from sunlight affects the cable ampacity more than the conductor heat [3], [4]. The moisture in the soil affects the cable ampacity. If the humidity increases, the cable ampacity increases [5], [6]. The depth of the conduit affects the cable ampacity. If the depth is greater, the cable ampacity is reduced [7], [8]. Different conduit types have different thermal resistances that will affect the cable ampacity [7]. This research was interested in studying and comparing the cable ampacity installed in aboveground and underground cables from the aforementioned.

This paper is organized as follows: first, the theory related to research is shown in section II. Second, the research methodology is explained in section III. Third, the simulation result is proposed in section IV. Finally; The conclusion is presented in section V.

II. RELATED THEORY

Theories involved in this research consist of 1) ampacity, 2) heat transfer, 3) electric fields, and 4) magnetic fields. This can be shown as follows:

A. Ampacity

Ampacity calculation of underground cable can be calculated according to the standard IEC 60287-2-1 [9], which is shown in the equation

$$I=\sqrt{\frac{\Delta\theta - W_d\left[0.5T_1+n\left(T_2+T_3+T_4\right)\right]}{RT_1+nR\left(1+\lambda_1\right)T_2+nR\left(1+\lambda_1+\lambda_2\right)\left(T_3+T_4\right)}} \quad (1)$$

where

I is the current flowing in one conductor (A)

$\Delta\theta$ is the conductor temperature rise above the ambient temperature ($°C$)

W_d is the dielectric loss for the insulation surrounding the conductor (W/m)

n is the number of load-carrying conductors in the cable

R is the alternating current resistance of the conductor at maximum operating temperature (Ω/m)

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T_1	Is the thermal resistance between one conductor and the sheath ($K.m/W$)
T_2	is the thermal resistance of the bedding between sheath and armor ($K.m/W$)
T_3	is the thermal resistance of the external serving of the cable ($K.m/W$)
T_4	is the thermal resistance between the cable surface and the surrounding medium ($K.m/W$)
λ_1	is the ratio of loss in the metal sheath to total losses in all conductors in that cable
λ_2	is the ratio of loss in the armoring to total losses in all conductors in that cable

B. Heat Transfer

Conductor heat transfer through insulation, conduit walls, and the soil layer to the soil surface can be calculated according to IEC TR62095 [10], shown in the equation.

$$\frac{\partial^2\theta}{\partial x^2}+\frac{\partial^2\theta}{\partial y^2}+W_{\text{int}}\rho=\frac{1}{\delta}\frac{\partial^2\theta}{\partial\tau} \qquad (2)$$

where

θ	is the unknown temperature ($°C$)
$\delta=1/\rho c$	is the thermal diffusivity of the medium (m^2/s)
c	is the volumetric specific heat of the material (J/m^3)
ρ	is the thermal resistivity of the material ($K\cdot m/W$)
W_{int}	Is the heat generation rate in the cable (W/m)

C. Electric Fields

Electric field analysis of cable is based on divergence and the gradient of electric potential can be expressed as follows:

$$E=-\nabla V \qquad (3)$$

$$\nabla D=\rho_V \qquad (4)$$

where

E	is the electric field (V/m)
∇	is the vector operator
V	is the electric potential (V)
D	is the electric flux density
ρ_V	is the electric charge density (C/m^3)

D.Magnetic Fields

Cable magnetic field analysis based on magnetization and permeability can be expressed as follows:

$$B=\mu_o\mu_r H \qquad (5)$$

where

B	is the magnetic flux density (T)
μ_o	is the permeability of air
μ_r	is the relative permeability

III. METHODOLOGY

A comparative analysis of the thermal effect on electric current in aboveground and underground conduits conduct by simulating the finite element method. The average ambient temperature in Thailand is 40 ˚C. Underground conduits used HDPE conduit to be buried underground depth 60 cm. Aboveground conduits used HDPE conduit to be placed on the support height 10 cm. The cable used CV type, 240 sq. mm., 380 volts, 3 phase, 3 wires.

A. Aboveground Conduits

Cables are installed inside the aboveground conduits. The installation dimensions are shown in Figure 1.

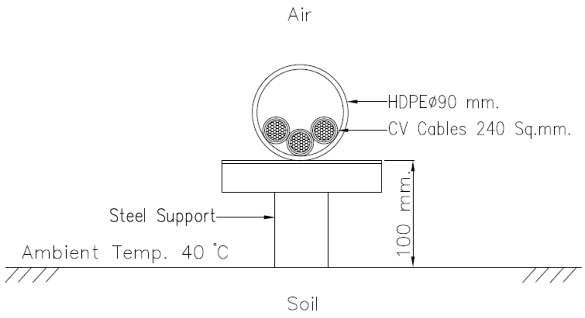


Fig. 1. Aboveground cables section plan.

B. Underground Conduits

Cables are installed inside the underground conduits. The installation dimensions are shown in Figure 2.

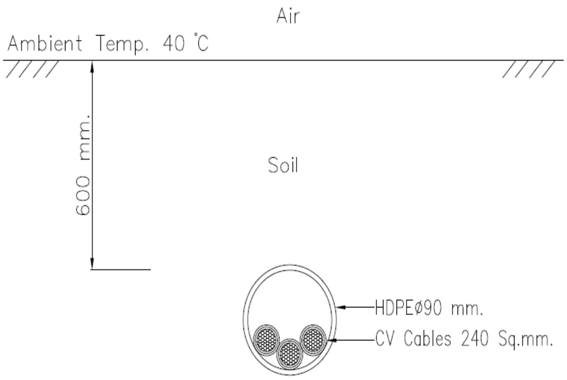


Fig. 2. Underground cables section plan.

C. Underground Cables

Low voltage cable produced according to IEC 60502-1 standard [10]. The construction of the cable consists of 1) Conductor, 2) Insulation, and 3) Sheath, as shown in Figure 3.

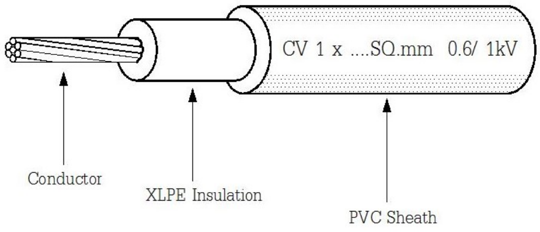


Fig. 3. Construction of cable.

D. Material Thermal Resistance

Cables ampacity calculation and heat transfer simulation by finite element method. It is necessary to determine the properties of different materials, which are detailed as in Table I.

TABLE I
MATERIAL PROPERTIES

Items	Description	Thermal Resistance ($K\cdot$)
1	HDPE	3.50
2	Copper conductor	2.50×10^{-3}
3	XLPE insulation	3.50
4	PVC jacket	5.00
5	Air	40.00
6	Soil	1.00

The thermal resistance of the material will affect the heat transfer, the higher the thermal resistance, the less the heat transfer.

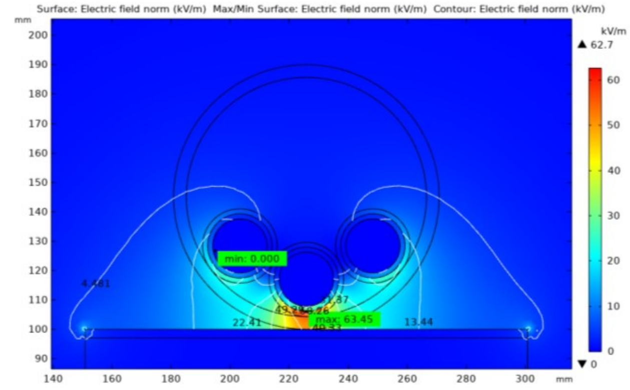
IV. SIMULATION RESULTS

The simulation results of this research consist of three parts, which are detailed as follows:

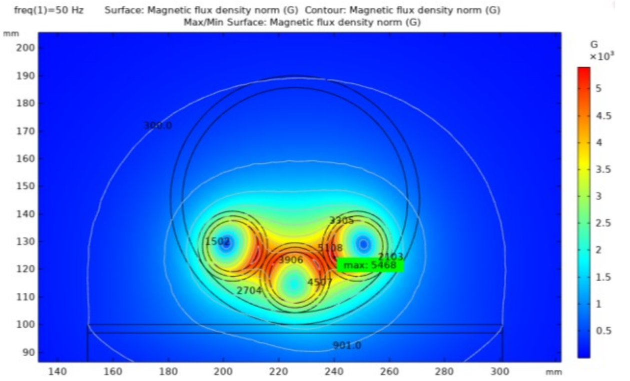
A. Simulation Result of Aboveground Conduits

Installation of cable within aboveground conduits can simulate electric fields, magnetic field, and heat transfer are as follows:

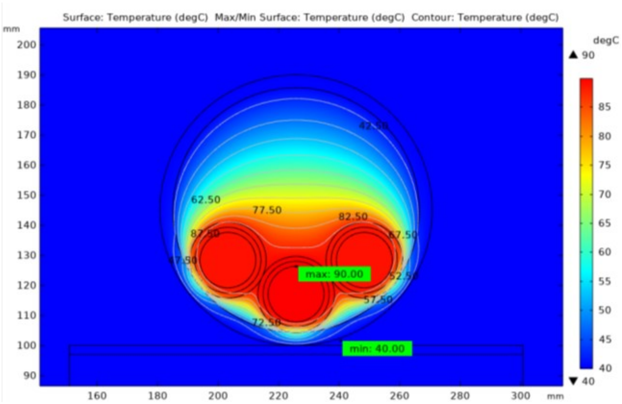
The electric field was very high near the conductor. It decreased as the distance from the conductor increased. The electric field simulation result was 4.48 kV/m on the conduit surface and steel support. The magnetic field was the same as the electric field. The magnetic field decreased as the distance from the conductor increased. The magnetic fields simulation result was 300.00 G on the conduit surface and steel support. The heat dissipated from the conductor to the ambient as well. The temperature at the surface of the conduit was equal to the ambient temperature.



a) Electric fields simulation



b) Magnetic fields simulation



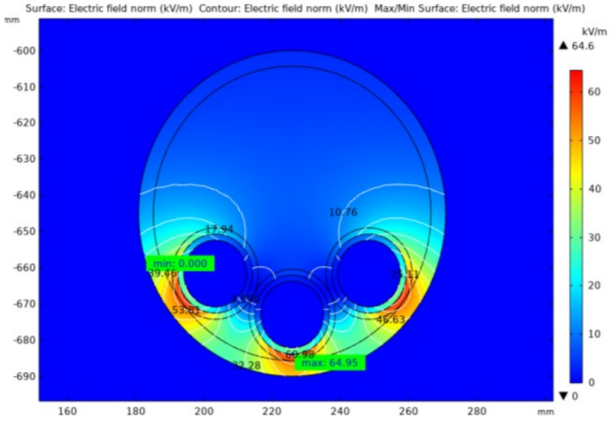
C) Heat transfer simulation

Fig.4. Simulation results of aboveground conduits

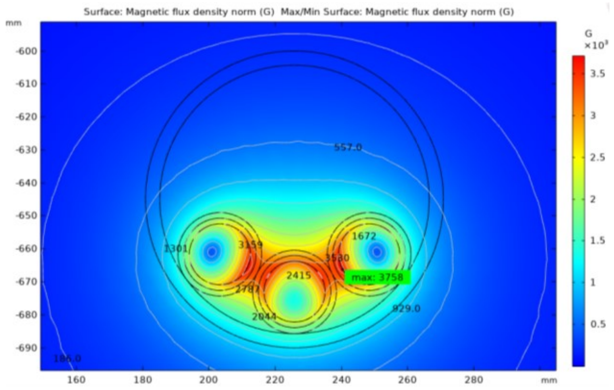
B. Simulation Result of Underground Conduits

Installation of cable within underground conduits can simulate electric fields, magnetic field, and heat transfer are as follows:

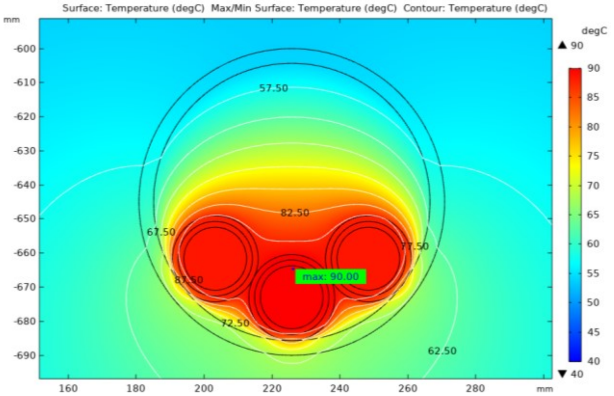
The electric field was very high near the conductor. It decreased as the distance from the conductor increased. The electric field simulation result was 0.00 kV/m on the ground surface. The magnetic field was the same as the electric field. The magnetic field decreased as the distance from the conductor increased. The magnetic field simulation result was 2.65 G on the ground surface.



a) Electric fields simulation



b) Magnetic fields simulation



C) Heat transfer simulation

Fig.5. Simulation results of underground conduits

The heat dissipates from the conductor to the ambient as inferior. Therefore, the temperature at the surface of the conduit was 57.5 degrees Celsius.

C. Simulation Result Comparison between Aboveground and Underground Conduits

The simulation results showed the impact between installing cable inside the aboveground conduit and the underground conduit consisted of 1) the electric field at touchpoint 2) the magnetic field at a touchpoint, and 3) electric current is shown in Figure 4-5.

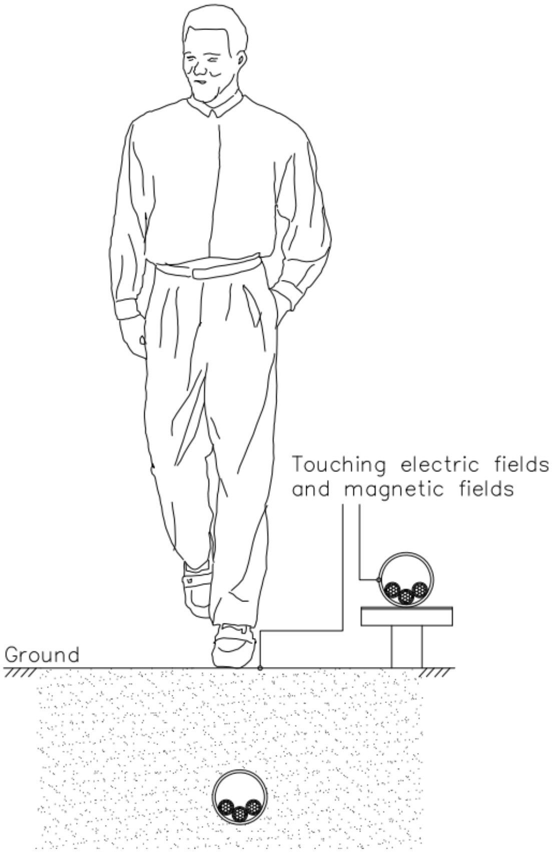


Fig.6. Installation plan

Figure 6 shows the aboveground installation point that people can touch, or reach the surface of the conduit, while the underground conduit cannot. The simulation results can be shown in Table II.

TABLE II
AMPACITY, ELECTRIC FIELDS, AND MAGNETIC FIELDS

Items	Description	Aboveground	Underground
1	Maximum ampacity (A)	514.63	349.00
2	Touching electric fields (kV/m)	4.48	0.00
3	Touching magnetic fields (G)	300.00	2.65

V. CONCLUSION

This research presents a comparative analysis of the cable within aboveground and underground conduits. Cables installed inside an aboveground conduit can carry more loads than cables installed within an underground conduit because the heat dissipation was better. This is consistent with research [3-4]. Touching electric fields of cables within the aboveground conduit was greater than the underground conduit. Furthermore, touching magnetic fields of cables within the aboveground conduit was greater than the underground conduit. Therefore, the selection of construction method of electrical conduit must be carefully considered. Installing cable inside an aboveground conduit has the advantage of being able to carry more loads. In comparison, underground cable installations are more safety from electric and magnetic fields. In addition, the installation of an aboveground electrical conduit requires consideration of the use of a fire-resistant conduit.

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