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PSCAD/EMTDC를 이용한 교류 전철급전시스템 모델링

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Modelling AC Electric Railway System using the PSCAD/EMTDC

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Abstract - This study presents a AC electric railway system model using PSCAD/EMTDC. Ver.3.08 for circuit analysis and fault studies.
This system model made by PSCAD/EMTDC is composed of feeder, contact line, rails, Scott-transformer, Auto-transformer. This model is based on four-port network which is an extension of two-port network theory.
In order to verify the proposed model, each voltage of feeder-rail, contact line-rail and feeder-contact line is measured and fault studies are also simulated.

1. Introduction

Electric Railway System has a number of advantages in terms of traffic capability, energy efficiency, operational cost, and environmental friendliness in comparison with other transportation systems. Nonetheless, it still has various matters like the line-to-line fault, the line-to-ground fault and the surge voltage when a braker operates bring about various problems regarding the safety of passengers and facilities().

To analyze various matters, we should understand and design this system.

This AC electric railway system is mass and complex. The systems are based on single phase 27.5kV/55kV and composed of feeder, contact line, rails, Scott-transformer and Auto-transformer(AT). The traction loads need a single phase current of large capacity converted from three phase power supply.

Therefor, this paper represented AC electric railway system which is modeled by four-port network and used PSCAD/EMTDC in order to approach easily to this complex system.

2. AC electric railway system

The usual AC electric railway systems are based on single phase 27.5kV/55kV. The system is connected to three-phase power system to be supplied with large single-phase load. AC feeding circuits supply vehicles with the power by 3 to 2 phase Scott transformer through feeder, contact wire and rail. ATs are installed about every ten kilometers with circuit breakers which connect adjacent up and down tracks at sub-sectioning post(SSP). Substations (SS) are located about fifty kilometers and there is a sectioning post(SP) midway between two substations. SP has circuit breakers which enable one feeding circuit to electrically separate from the other. They may be closed in case adjacent SS is out of service. The AC electric railway system modeled by PSCAD/EMTDC is shown in Fig 1.

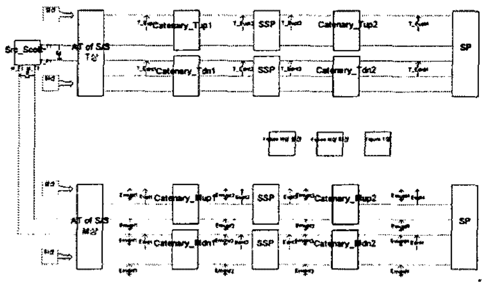

Fig 1. The AC electric railway system model

The module of Src_Scott includes three-phase power system and 3 to 2 phase Scott transformer. The module of SSP, SP and AT of SS includes Auto-transformer.

The module of the Catenary_{Tup1(2), Mup1(2), Tdn1(2) and Mdn1(2)} represents feeder, contact line, rail.

Each module of the AC electric railway system is defined as a four-port network model. The equivalent circuit to the entire system is also composed by making series connection of these modules.

3. Four-port network

The system model is based on four-port representation which is an extension of two-port network theory. The four-port representation makes it possible to make up of the AC electric railway system easily. Fig 2 shows the entire system by four-port network.

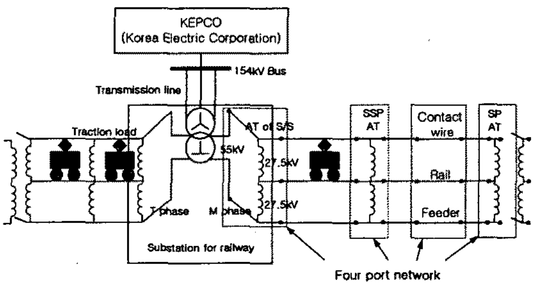

Fig 2. The entire system by four-port network

4. The modelling of the system

4.1 The Modelling of a substation

Fig 3 illustrates the equivalent circuit of a power utility and Scott-transformer.

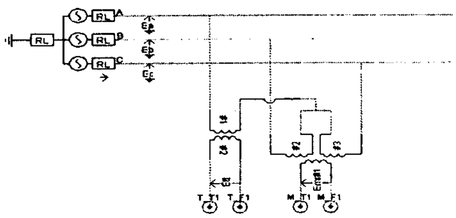

Fig 3. Power utility and Scott-transformer

The power utility in this paper simply represents a source which supplies 154kV(line-to-line voltage).

One of the most common scheme of Scott-transformer at a substation is configured. This transformer is connected line-to-line at 3-phase network as shown in Fig 3.

According to Fig 3 the turn ratios of phase T and phase M of a Scott-transformer are $\sqrt{3}/2N_1{:}N_2$ and $N_1{:}N_2$ respectively.

4.2 The Modelling of a Auto-transformer

The equivalent circuits of an AT for phase M(or T) in a SS, a SSP and a SP are shown in Fig 4, Fig 5 and Fig 6 respectively.

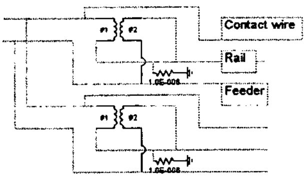

Fig 4. AT of SS

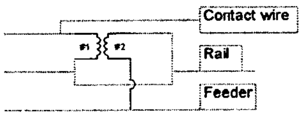

Fig 5. AT of SSP

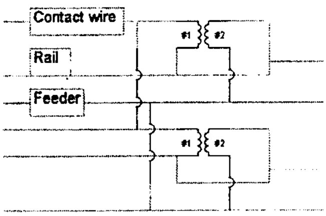

Fig 6. AT of SP

4.3 The Modelling of a Catenary System

The catenary consists of three conductors. One is made up of a contact wire. The other is made up of rails. Another one is a feeder. The equivalent model for the catenary system is illustrated as Fig 7.

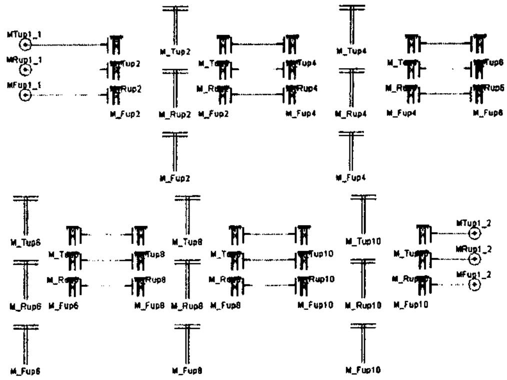

Fig 7. Catenary system model

Fig 8 is a detailed model of the feeder. The models of the contact wire and the rail are also composed as Fig 8. The impedances of each conductor are represented in Table 1.

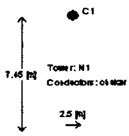

Fig 8. Detailed model of the catenary system

4.4 The Modelling of Traction Load

The equivalent model for traction load is represented by a resistor. A traction load presents EL8100 which consumes a power of 5200kW.

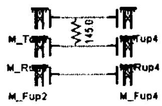

Fig 9. Model of traction load

5. Case Studies

5.1 Input data

Table 1 shows the details on 3-phase power supply system and AC electric railway system.

Table 1. Details for AC electric railway system

Category		Values
3 phase power system	3-phase voltage(kV)	154
	Positive(negative) sequence impedance(%)	0.272+j1.535
	Zero sequence impedance(%)	0.842+j4.227
Scott-transformer	Rating MVA	22.5
	Rating kV	154/55
	leakage reactance(pu)	0.1
Auto-transformer	Rating MVA	10
	Rating kV	55/27.5
	leakage reactance(pu)	0.1
Impedance	Contact wire (Ω/km)	0.194+j0.731
	Rail (Ω/km)	0.009+j0.467
	Feeder (Ω/km)	0.122+j0.587
Train	Resistor(Ω)	145

5.2 Results

The AC electric railway system is made up of Table 1.

AC feeding circuits supply vehicles with the power by 3 to 2 phase Scott-transformer through feeder, contact wire and rail. So the secondary voltage of Scott-transformer, that is the voltage of M phase(or T phase), is measured as shown in Fig 10 assuming the traction loads are not operated. Fig 11 shows the measured voltage between each conductor at the same time.

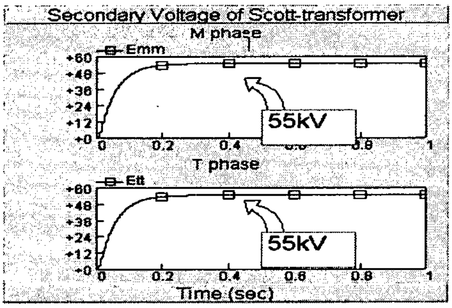

Fig 10. Secondary voltage of Scott transformer

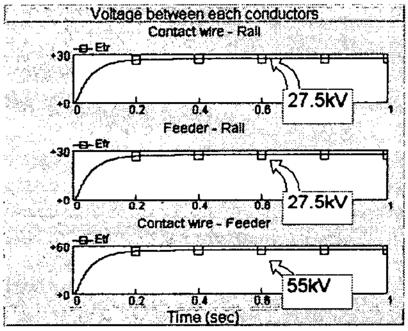

Fig 11. Voltage between each conductor

The voltage of contact wire is measured at several points as shown in Fig 12, assuming the four traction loads are operated from SS to SP.

The voltage drop is a little bit occurred exhibiting the characteristic of increasing voltage at AT.

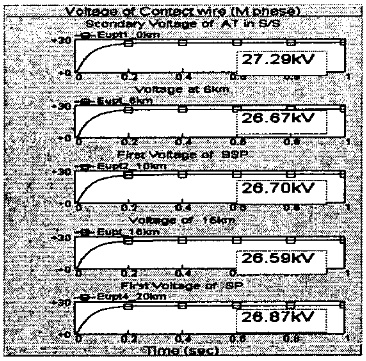

Fig 12. The voltages of contact wire are measured at several points

We simulated a fault study of line(contact wire)-to-ground. Fig 13 shows the measured data at ATs when the fault current is distributed.

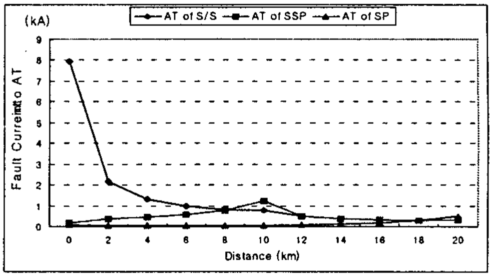

Fig 13. A fault study of contact wire -to-ground

The X axis presents the point that the fault occurred , the Y axis presents the fault current flowing into AT. As a result, Fig 13 shows the general characteristic of fault current flowing into AT. The general characteristic is that The fault current flowing into AT increase from source to the point of AT and decrease at the points except AT. The fault current is maximum at the AT.

6. Conclusion

This paper presented the AC electric railway system model using PSCAD/EMTDC. Ver.3.08.

Each component of this model was defined as a four-port network model and made by series connection. These enabled the AC electric railway system to be composed simply. In order to verify the proposed model, we confirmed that the voltages between each conductor and the fault characteristic of the AC electric railway system were same to the real system.

[References]

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