A Study on the Expert System to Identify Topological Errors in Distribution Automation Systems

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Abstract: - Topology processing is indispensable basic function in order to generate a real-time BUS-BRANCH model in Energy Management Systems, because this model is necessary to the operation of application software such as state estimation and etc. At this time, if an error occurs in status information of switch, the result of state estimation is seriously influenced. This paper proposes a topological error identification expert system to identify and correct an error of status information of switch for 154kV distribution substation. The proposed expert system will be a main part to apply topology processing to distribution automation system.

Key-Words: - Expert System, Topology Error, Distribution Automation System

1 Introduction

Power system is the motive power sustaining a modern industrial society and national key industries. Power system is continuously growing according to gradual increase of electric power demand with economy and social developments. All nations in the world have tried to improve reliability and stability of electric power supply. In the technical point of view, one of great changes in the 21st century is that the process of establishing and merging a large scale sensor-network system in all industry fields is being progressed, because of the progress of computer and communication network and the cost reduction by the automation system. In power system, research and introduction of various monitoring and control equipments are being carried out actively to improve the above-mentioned reliability and stability. Recently, to keep up with the world wide tendency, the Korean government started to develop the advanced substation automation system based on the digital control technology. This development includes digital relay, communication network construction based on IEC 61850 and HMI platform to operate substation automation system. State estimation system which improves accuracy and reliability of measured data is going to be developed and then applied to this HMI platform.

State estimation is the function for an error correction of an analog data measured in Energy Management System.[1] This function should be certainly applied to a distribution substation. State estimation has to be performed after topology identification of a substation since topological structure is determined by real-time ON/OFF status of switch. However, topological errors occurred by an error of status information of switch can exist. In this case, if these errors are not corrected, the result of state estimation is seriously influenced. Therefore, the function to identify topological errors occurred by an error of status information of switch is indispensable to state estimation.[2, 3, 4]

This paper proposes the topology error identification expert system to identify and correct an error of status information of switch for distribution substation. This expert system is a main part of pre-processor in state estimation. And this expert system will be applied and tested in the HMI platform with generation system, which makes a system matrix for state estimation automatically. A brief overview of topological error identification is that an error of status information of switch is identified through the inference processes in artificial intelligence state space, after real-time status information of switch such as circuit breaker and line switch is inputted. This expert system will be expected to contribute to improving reliability of distribution substation with state estimation.

2 Data structure of substation

The general basic structure of distribution substation is shown in fig. 1.

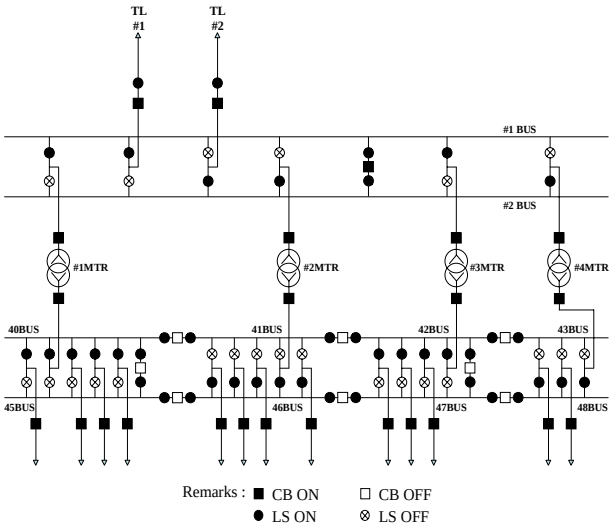

Fig. 1 Basic structure of distribution substation

As shown in fig. 1, distribution substation is composed of devices such as transmission lines(TLs), 154kV double buses(HBUSes), 154kV/22.9kV main transformers(MTRs), 22.9kV double structured distribution buses(LBUSes), distribution lines(DLs), and switching devices like circuit breakers(CBs) and line switches(LSs). Real-time topological structure of distribution substation is determined by ON/OFF status of switches.

In this paper, devices, connection structure between devices and switches are described to identify topological errors. The predicates required to identify topological errors are described as follows.

tl_hbus_data(tl_name, ls_no, cb_no, ls_no_list)
hbus_data(hbus_name, ls_no_list)
hbus_tr_data(tr_name, cb_no, ls_no_list)
tr_lbus_data(tr_name, cb_no, ls_no_list)
lbus_data(lbus_name, ls_no_list)
dl_data(dl_name, priority, ls_no_list, cb_no)
hbus_tie_data(cb_no, ls_no_list)
lbus_tie_data(lbus_name_list, cb_no, ls_no_list)
cb(cb_name, status)
ls(ls_name, status)

Here, 'ls_no_list' is a set of line switches connected to substation devices, 'lbus_name_list' is a set of 22.9kV buses connected to lbus_tie and 'status' is ON or OFF status of switching devices.

Topological error identification is progressed through inference processes in artificial intelligence state space using the above-mentioned predicates. And real-time topological structure is determined in this process. Each predicate which describes real-time topological structure of distribution substation is as follows. This predicate is generated by the result of the topology processing that includes topological error identification.

tl(name, status)
hbus(name, status, tl_name_list, tr_name_list)
mtr(name, status, lbus_name_list)
lbus(name, status, tr_name, dl_name_list)
dl(name, status)

Here, 'name' describes name of each substation device and 'tl_name_list', 'tr_name_list', 'tr_name' and 'dl_name_list' are sets of devices connected to the each unit device. 'status' describes 'energized' or 'de-energized' of each device. 'lbus_name_list' in predicate mtr is a set of lbuses which can be directly connected to the main transformer through a line switch.

3 Identify topological errors

3.1 The rule of topological error identification

Fig. 2 shows a sample network to identify topological errors in main transformer.

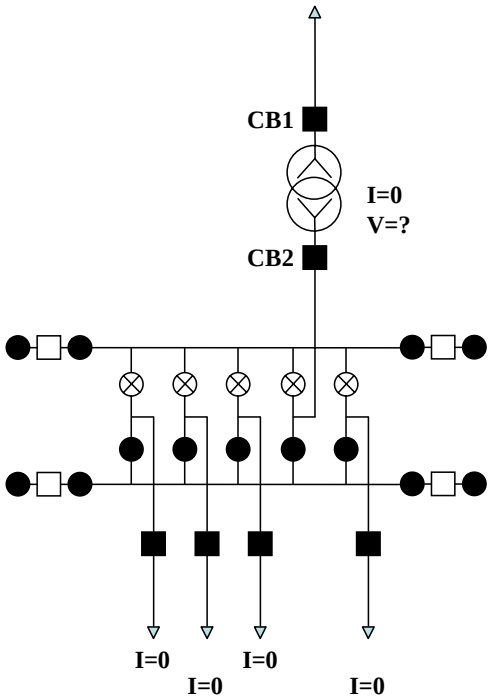

Fig. 2 Sample network to identify an error at MTR

As shown in fig. 2, CB1 and CB2 are ON status and current of main transformer and distribution lines is zero. In this case, if HBUS that main transformer connected with is de-energized, status information of switch can be inferred normally. However, if HBUS is energized, status information of switch connected in main transformer can be inferred with an error. If voltage of main transformer is zero, status information of switch connected to a primary part in main transformer can be inferred with an error and CB1 should be corrected to OFF status. If voltage of main transformer is non-zero, status information of switch connected to a secondary part in main transformer can be inferred with an error and CB2 should be corrected to OFF status.

Fig. 3 shows a sample network to identify topological errors in the distribution lines.

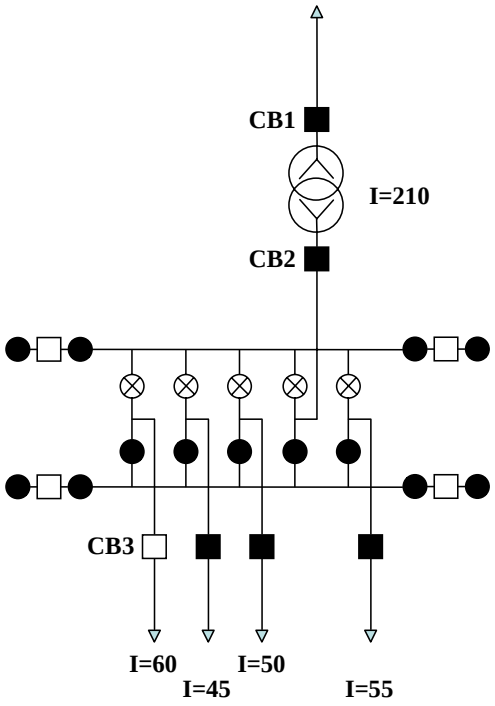

Fig. 3 Sample network to identify an error at DLs

As shown in fig. 3, current of main transformer and current of distribution lines is non-zero and CB3 is OFF status. In this case, status information of switch connected to distribution line can be inferred with an error and CB3 should be corrected to ON status.

Some major linguistic rules to identify topological errors are as follows.

• If status of switch connected to transmission line is OFF and current of transmission line is non-zero, then status information of switch is an error.

• If status of switch connected to a primary part in main transformer is ON and current of distribution lines is zero and HBUS that main transformer connected with is energized, then status information of switch is an error.

• If status of switch connected to a primary part in main transformer is OFF and current of main transformer and distribution lines is non-zero, then status information of switch is an error.

• If status of switch connected to a secondary part in main transformer is ON and main transformer is energized and current of distribution lines is zero, then status information of switch is an error.

• If status of switch connected to a secondary part in main transformer is OFF and current of distribution lines is non-zero, then status information of switch is an error.

• If status of switch connected to distribution line is OFF and current of distribution line is non-zero, then status of switch is an error.

3.2 Exclude in topological error identification

Fig. 4 shows a sample network to identify topological errors in the transmission lines.

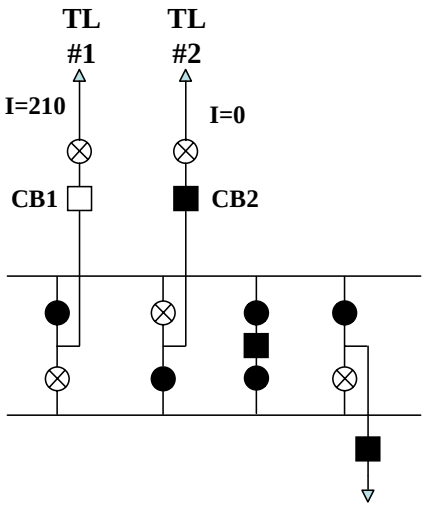

Fig. 4 Sample network to identify error an at TLs

As shown in fig. 4, #1 transmission line is connected to switch on OFF status and current of #1 transmission line is 210[A]. #2 transmission line is connected to switch on ON status and current of #2 transmission line is 0[A]. In case of #1 transmission line, an error of status information of switch can be inferred using the above-mentioned topological error identification rules and CB1 should be corrected to ON status. However, in case of #2 transmission line, if current of

transmission line is zero and switch is ON status, it is impossible to identify topological errors, because of the possibility that neighboring substation connected to the transmission line is isolated from power system. Therefore, if current of transmission line is zero and switch is ON status, this case is excluded out of the objects of this paper.

4 Case study

In order to verify efficiency of expert system to identify and correct topological errors, case study for practical Korean distribution substation is carried out.

4.1 Scenario #1

Scenario #1 is the case that an error occurs in status information of one switch. As shown in fig. 5, CB 617 is OFF status, and current of transmission line is 1,256[A].

In this case, because current of transmission line is non-zero and status information of switch is OFF, status information of CB 617 is inferred with an error and CB 617 is corrected to ON status.

The text output of expert system to identify topological errors is as follows.

▣ Topological Error Device : CB 617
▣ Current Status : OFF
▣ Correction Status : ON

4.2 Scenario #2

Scenario #2 is the case that an error occurs in status information of two switches. As shown in fig. 6, CB 6233 and CB 4244 are OFF status and current of main transformer is 608.5[A].

In this case, because current of main transformer and distribution lines is non-zero and status information of switch connected to a primary part of main transformer is OFF, status information of CB 6233 is inferred with an error and CB 6233 is corrected to ON status. And, because main transformer is energized and current of distribution lines is non-zero, the status information of CB 4244 is inferred with an error and CB 4244 is corrected to ON status.

The text output of expert system to identify topological errors is as follows.

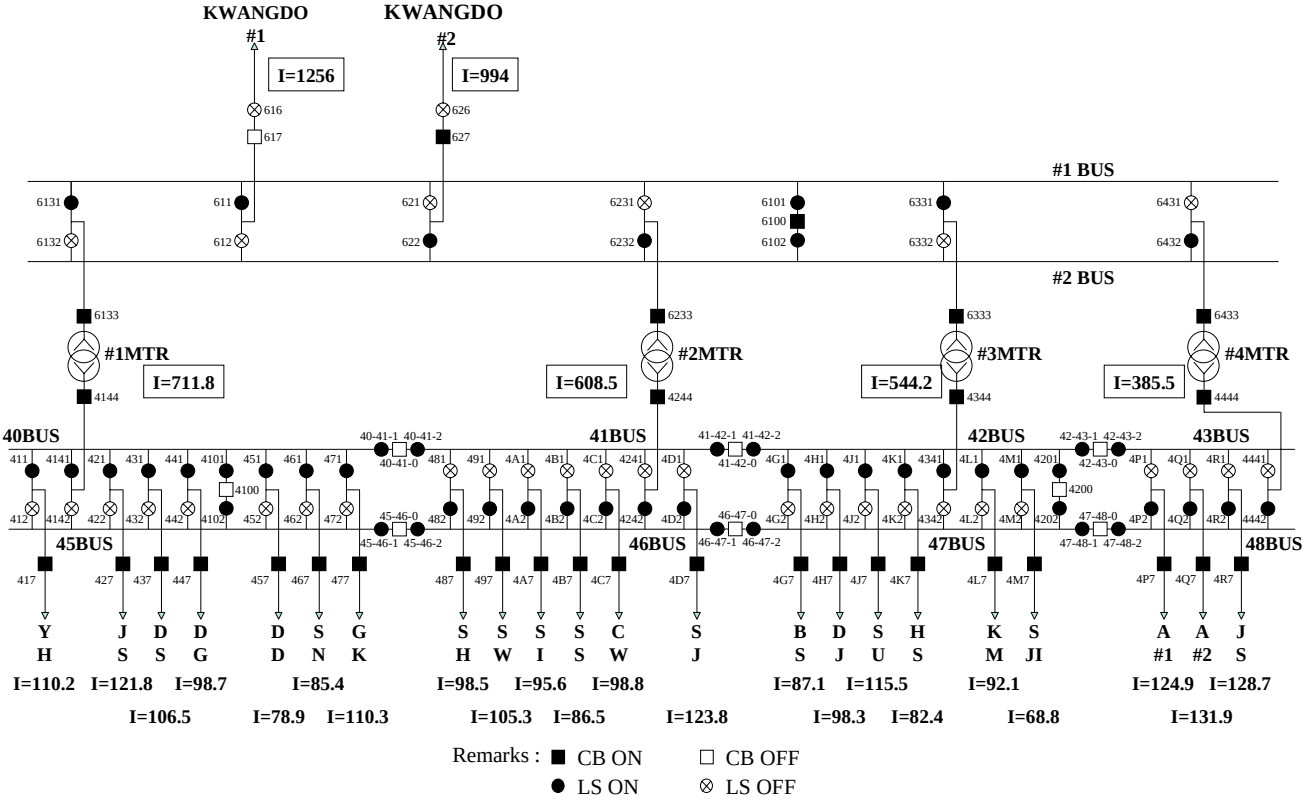

Fig. 5 Structure of distribution Substation for scenario #1

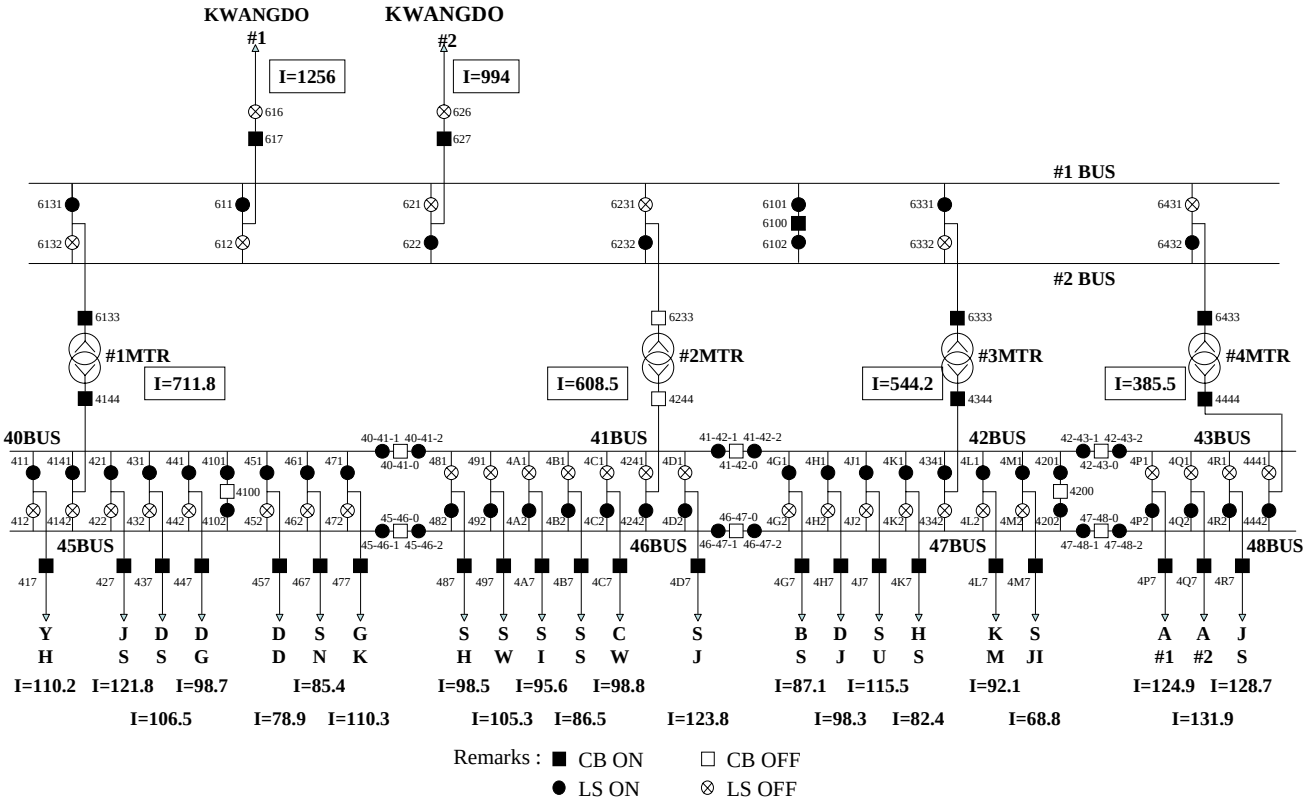

Fig. 6 Structure of distribution Substation for scenario #2

▣ *Topological Error Device : CB 6233*
▣ *Current Status : OFF*
▣ *Correction Status : ON*

▣ *Topological Error Device : CB 4244*
▣ *Current Status : OFF*
▣ *Correction Status : ON*

5 Conclusion

This paper proposed the expert system to identify and correct an error of status information of switch. The proposed expert system describes topological structure of substation such as switches and connection structure between devices. Also, the rule-base of this expert system is composed of basic rules suggested by Korean electric power company, including topological error identification rules, topology identification rules and heuristic rules. The proposed expert system will be a main part of pre-process in state estimation, and contribute to improving the reliability of substation automation.

Acknowledgement

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