Topology Processor design for EHV Substations

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Abstract— The intelligent application is one of the major issues in power system research. The topology identification is one of the most important modules to develop intelligent system such as fault diagnosis and restoration expert system. This paper presents the topology processor in order to identify topology effectively in a practical 765kV substation in Korea composed of the double-bus and 1.5 CB, which is the typical structure of EHV substations. The proposed topology processor redefines switching group composed of circuit breaker, disconnecting switches and ground switches as aggregated circuit breaker. The proposed system remarkably reduces the search space and search time for topology identification. The proposed topology processor is developed using the data of a practical 765kV substation in Korea. The proposed system can be applied to intelligent systems such as fault diagnosis and restoration expert system and contribute to improving the performance of intelligent systems.

Keywords—Topology Processor, Topology Identification, Aggregated CB, 1.5CB.

I. INTRODUCTION

TOPOLOGY processor is a module to identify the real-time topology determined by the status of various switches such as circuit breaker, disconnecting switch and ground switch. The topology processor emulates the mechanism by which a power system expert identifies the connection structure of substation devices in the diagram. The topology processor is one of the most important modules to develop intelligent system such as fault diagnosis and restoration system. However, the topology identification is a very complicated problem. Up to now, the intelligent systems to be successfully developed does not exist much, which results from the topology identification rather than the complexity of domain knowledge.

Regarding topology processor, various papers have been reported. Ito[1] proposed the algorithm method to reconfigure a mathematical model about the change of a switch. Piereti[2] proposed the a new graph representation method named Node-Depth Representation(NDR). He[3] proposed an efficient topology analysis algorithm to track the network connectivity for distribution system. Yehsakul[4] proposed the NCLU (Network Connectivity Local Update) algorithm using the tree. Lee[5,6] proposed the topology process in double-bus structured distribution substation.

This paper presents the topology processor in order to identify real-time topology effectively of a practical 765kV substation in Korea. A practical 765kV substation is the structure of double-bus and 1.5CB which is a typical structure for EHV(extra high voltage) substations. The devices of substation are connected complicatedly through the interlocked switching group composed of circuit breaker, disconnecting switches and ground switches. Under the complex connection structure of switches, topology identification is very difficult because a possible combination of switches increases exponentially.

The proposed topology processor used the aggregation method and reduced remarkably the search space for topology identification and enhanced the efficiency of identification. The proposed topology processor defines the switching group as an aggregated circuit breaker. The topology processor defines the connection structure between unit devices using the aggregated circuit breaker. As a result of aggregation method, the topology processor remarkably reduces the search space and search time for topology identification and enhances the performance.
The proposed topology processor is developed using the data of a practical 765kV substation in Korea.

II. DEFINITIONS OF AGGREGATED CB

The general structure of a practical 765kV substation in Korea shows in figure 1.

As shown in figure 1, a practical 765kV substation is composed of unit devices such as a few 765kV transmission lines(we define it as HTLs), 1.5 CB structured 765kV double-bus(HBUSes), 2 to 4 of 765kV/345kV transformer(MTRs), 1.5 CB structured 345kV double-bus(LBUSes), a few 345kV transmission lines(LTLs), shunt reactor(SHRs) and switches like circuit breakers(CBs), disconnecting switches(DSs) and ground switches(ESs). The
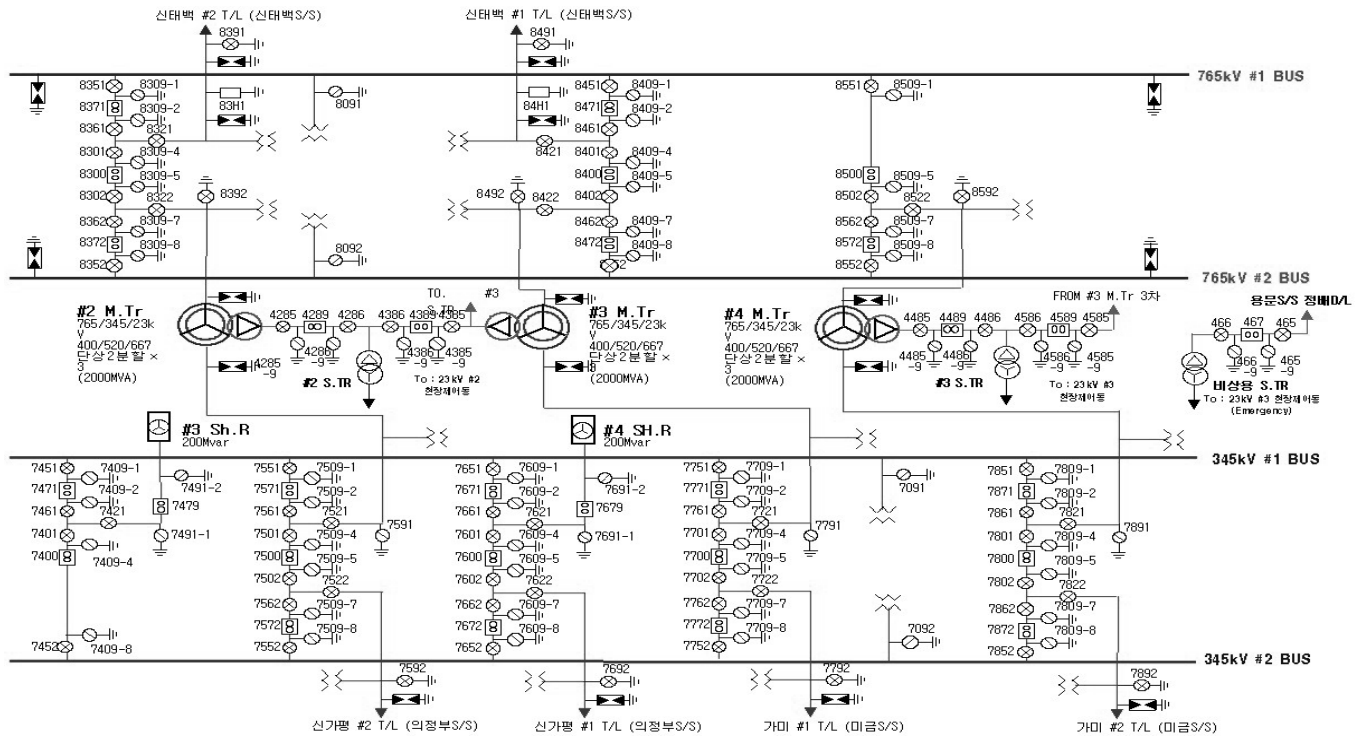
Fig. 1 Structure of a practical 765kV Substation

real-time topology of substation is determined by the ON/OFF status of circuit breaker and disconnecting switches.

As shown in figure 1, each unit devices are connected complicatedly through circuit breaker, disconnecting switch and ground switch. If these switches are used in topology processor, topology identification is very difficult because the possible combination of switches increases exponentially. This paper introduced the new aggregation technique to reduce the possible combination of switches.

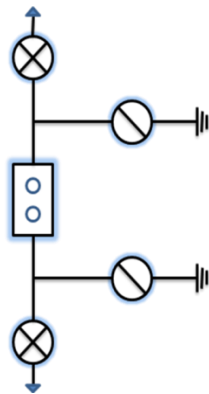Figure 2 shows the structure of switching group of 765kV substation.

Fig. 2 Structure of switching group

As shown in figure 2, a circuit breaker composes a switching group with two series disconnecting switches and two parallel ground switches.

The switches of switching group are interlocked. This paper defines newly a switching group as aggregated circuit breaker(we defines it as Aggregated_CB : A_CB) in order to reduce the searching space and to enhance the efficiency of the representation of connection structure and the topology identification.

In this paper, the predicate of aggregated circuit breaker is defined as follows.

■ a_cb(CB_name, DS_name_list, ES_name_list, status)

Here, 'CB_name' describes the name of circuit breaker and 'DS_name_list' describes a set of disconnecting switch connected to circuit breaker. 'ES_name_list' describes a set of ground switch. 'status' describes ON/OFF status of aggregated circuit breaker. 'status' is determined by the status of circuit breaker and disconnection switches.

PROLOG rules to determine the ON/OFF status of aggregated circuit breaker are as follows.

> a_cb(CB_name,[DS_name1,DS_name2], _,"on")
>   :- cb(CB_name,"on"),ds(DS_name1,"on"),
>   ds(DS_name2,"on").
> a_cb(CB_name,_,_,"off") :- cb(CB_name,"off").
> a_cb(CB_name,[DS_name1,_], _,"off")
>   :-,ds(DS_name1,"off"),
> a_cb(CB_name,[_,DS_name2], _,"off")
>   :-,ds(DS_name2,"off"),

Figure 3 shows the structure of simplified substation using the aggregated circuit breaker. As shown in figure 3, about 100 switches reduced to 22 Aggregated_CBs.

As a result of a new definition, more complex connection structure of figure 1 can be changed into a simple connection structure of figure 3. If aggregated circuit breaker is used, the connection structure of substation can be represented very simple and the time of topology identification can be reduced remarkably. Also, the proposed aggregated circuit breaker can contribute to improving performance of all the developed
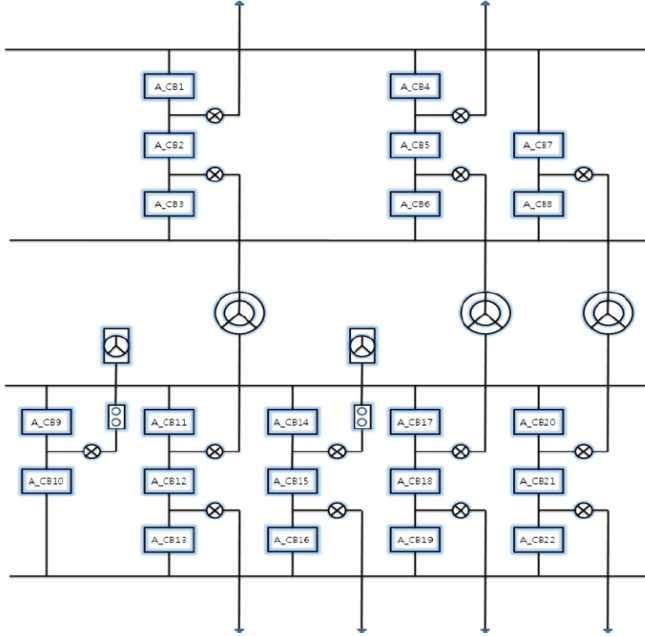

Fig. 3 Structure of aggregated substation

intelligent system for 765kV substation.

III. DATA REPRESENTATION

A. Definition of unit device

Data representation is closely related with proposed topology processor. In this paper, unit devices and switches are described. The predicates of unit devices and switches are as follows.

htl_data(name, voltage, capacity)
ltl_data(name, voltage, capacity)
mtr_data(name, voltage_list, capacity)
shr_data(name, capacity)
cb(name, phase, status)
ds(name, phase, status)
es(name, phase, status)

Here, 'name' describes the name of each unit device and 'voltage' describes the voltage of each unit device. 'capacity' describes the capacity of each unit device and 'voltage_list' in predicate mtr is a set of voltage connected to transformer. 'status' is ON or OFF status of switches.

B. Definition of connection structure between unit devices

As shown in figure 3, this paper changed the complex connection structure of 765kV substation to simple connection
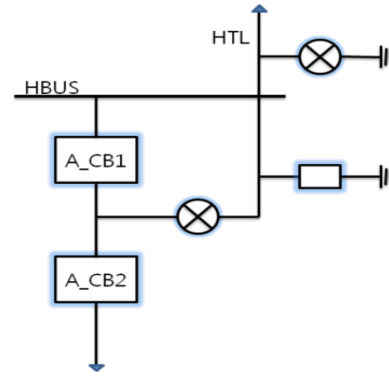

Fig. 4 Connection structure between 765kV TL and bus

structure using the aggregated circuit breaker. This paper described the connection structure of the simple substation in figure 3 as follows.

Connection structure between 765kV transmission line and 765kV bus shows in figure 4.

As shown in figure 4, transmission line is connected to bus through disconnecting switch and Aggregated_CB.

The predicate of connection structure between 765kV transmission line and bus is as follows.

■ tl_hbus_dat(tl_name, ds_name, a_cb_list)

Here, 'ds_name' describes the disconnecting switch connected to transmission line. 'a_cb_list' describes a set of aggregated circuit breaker connected to 765kV bus.

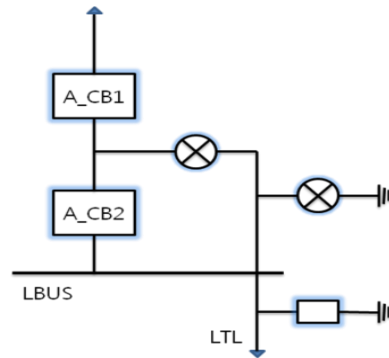Connection structure between 345kV transmission line and

Fig. 5 Connection structure between 345kV TL and bus

765kV bus shows in figure 5.

The predicate of connection structure between 345kV transmission line and bus is as follows.

■ lbus_tl_dat(tl_name, ds_name, a_cb_list)

Here, 'ds_name' describes the disconnecting switch connected to transmission line. 'a_cb_list' describes a set of aggregated circuit breaker connected to 345kV bus. The structure of 765kV and 345kV bus shows in figure 6.

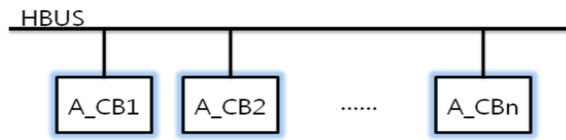The predicates of 765kV and 345kV bus are as follows.

Fig. 6 Structure of bus

■ hbus_daa(hbus_name, a_cb_list)

■ lbus_daa(lbus_name, a_cb_list)

Here, 'a_cb_list' describes a set of aggregated circuit breaker connected to bus.
Connection structure between 765kV bus and transformer
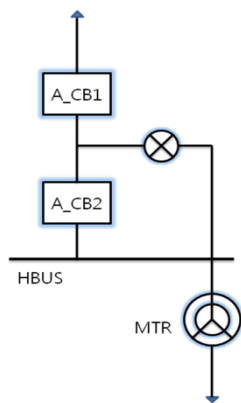

Fig. 7 Connection structure between 765kV bus and MTR

shows in figure 7.
  The predicate of connection structure between 765kV bus and transformer is as follows.

■ hbus_mtr_dat(tr_name, ds_name, a_cb_list)

Here, 'tr_name' describes name of transformer, „ds_name" describes disconnecting switch connected to transformer and „a_cb_list" describes a set of aggregated circuit breaker connected to transformer.
Connection structure between 345kV bus and transformer shows in figure 8.
The predicate of connection structure between 345kV bus and transformer is as follows.

■ mtr_lbus_dat(tr_name, ds_name, a_cb_list)

Here, 'tr_name' describes name of transformer, „ds_name" describes disconnecting switch connected to transformer and „a_cb_list" describes a set of aggregated circuit breaker connected to transformer.

IV. TOPOLOGY IDENTIFICATION

  The above-mentioned definition just describes unit device and all possible connection structure of 765kV substation, but
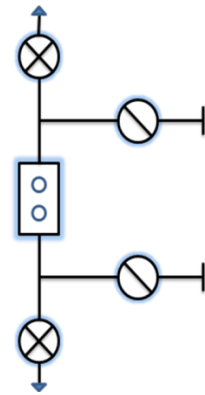

Fig. 8 Connection structure between 345kV bus and MTR

can"t describe real-time topology yet. The real-time topology must be determined by the inference process using the status data of switch such as circuit breaker and disconnecting switch.
  The proposed topology processor identifies topology through the inference process classified into two steps. The first step is determination of the status of aggregated circuit breaker. The second step is topology identification using the aggregated circuit breaker. In the first step, topology processor uses the above-mentioned rules and the status data of switch such as circuit breaker, disconnecting switch and ground switch. In the second step, topology processor uses the duplex searching method. Figure 9 shows duplex searching method including all possible topology of 765kV substation.
  As shown in figure 9, the upper side displays the above-mentioned connection structure between unit devices including aggregated circuit breakers. The lower side shows the intersection between aggregated circuit breakers included at each unit device. Therefore, the real-time topology can be identified through the search of intersection between aggregated circuit breakers. The following predicates describe the real-time topology of 765kV substation and are generated by the result of
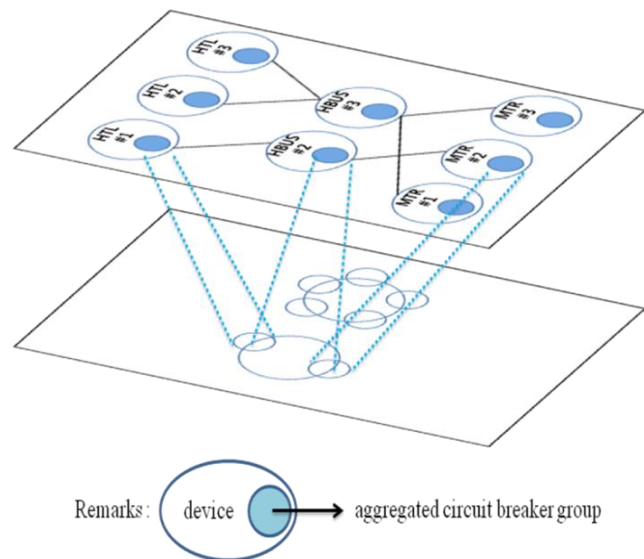

Fig. 9 Duplex searching method

the inference process.

> *htl(name, status)*
> *ltl(name, status)*
> *hbus(name, status, tl_name_list, tr_name_list)*
> *mtr(name, status, hbus_name, lbus_name)*
> *lbus(name, status, tr_name, tl_name_list)*

Here, 'name' describes name of each unit device and 'status' describes 'energized' or 'de-energized' of each unit device. 'tl_name_list' and 'tr_name_list' are sets of devices connected to each unit device These predicates are the output of the proposed topology processor and are used to database of the intelligent system.

V. THE RESULT OF TOPOLOGY PROCESSOR

The topology processor is used to identify the real-time topology of substation. The topology processor generates the predicates which is expressing the topology structure. The generated predicates are not presented to operator and are stored in database of intelligent system.

The predicates which the topology processor generates are as follows.

> *htl("sintaebaek1","on").*
> *htl("sintaebaek2","on").*
> *ltl("singapyung2","on").*
> *ltl("singapyung1","on").*
> *ltl("gamy1","on").*
> *ltl("gamy2","on").*
> *hbus("1",["sintaebaek1"," sintaebaek2"],_).*
> *hbus("2",_,["1","2","3","4"]).*
> *lbus("1",_,["1","2","3","4"]).*
> *lbus("2",["singapyung2","singapyung1","gamy1",*
> *   "gamy2"],_).*
> *mtr("1","2","1").*
> *mtr("2","2","1").*
> *mtr("3","2","1").*
> *mtr("4","2","1").*

VI. CONCULUSION

This paper proposed the topology processor to identify topology of double-bus 1.5 CB structured 765kV substation in Korea. The proposed topology processor redefines switching group as one aggregated circuit breaker and remarkably reduces the searching space and searching time of topology identification. This paper defines connection structure to identification of simplified 765kV substation.

The proposed topology processor is developed using the data of a practical 765kV substation in Korea. The topology processor is indispensable component for intelligent substation automation area, and will improve the performance of various intelligent systems.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

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