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# TWO BASIC FUNCTIONS OF HYBRID SYSTEM FOR ELECTRICAL NETWORK DISPATCHER ASSISTANCE

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*Two basic functions execution by hybrid system for electrical power network dispatcher assistance are discussed: 1) electrical substations switching operations based on the structures of typical elements aggregates belong to electrical substations, and structured knowledge about switching operations; 2) electrical power network faults diagnosis in information incompleteness conditions.*

## INTRODUCTION

Different intelligent knowledge based systems including hybrid systems (HS) are used in practice of electrical power network (EPN) dispatching [1-3]. Such HS in different cases mainly consist of such components as simulator, expert system (ES), artificial neural networks (ANN) and execute of dispatcher assistance functions by different operative control tasks solving. In this paper two basic functions execution by HS are considered. Mentioned above functions are following: 1) electrical substation switching operations in different operational conditions; 2) the diagnosis of EPN faulted elements in EPN post-fault conditions. The first function practicability based on using of information structures of typical elements aggregates belong to electrical substations and structured knowledge about switching operations in such aggregates [4]. As methodological base of proposed approach the algebraic structured theory of sequential machines and resolution principle are used. The second function based on logic approach to analysis of alarm signals about protective relays and circuit breakers operations taking into account the conditions of information incompleteness as well as the probabilities of maloperations and refusals of protective devices and refusals of circuit breakers and telemetry.

## SWITCHING OPERATIONS

Electrical substation switching operations belong to the main functions executed by operative staff in order to provide the possibilities of load-flow and energy supply in different EPN operational conditions, including EPN restoration after hard faults, transformers and substation load balancing etcetera. It must be emphasized that electrical substation switching operations also are need in normal operational conditions because operative staff sometimes puts into operation or puts out of operation the EPN equipment and devices (lead to reserve or repair), and circuit diagram always has a differences compared with a normal EPN circuit diagram (above all such differences are in substations circuit diagrams). In those cases the operative staff has necessary time in order to prepare and to coordinate (to get a confirmation) special blank of switching operations (this is a special form of switching operations algorithm). But in the cases of EPN post-fault conditions existing this function is very sharp because an operative staff (dispatcher) has not time to find right (optimal) variant of switching operations as well as has not time to prepare mentioned above blank . It must be noted that every switching operations task has to be solved with a minimum number of switching operations taking into account breaker lifetime expectancy.

In different EPN operational conditions every electrical substation can be represented as variable structure object. But in every case there are operational condition limitations those cause an impossibility of several switching operations in concrete situation. In order to solve the switching operations task in concrete operational conditions situation it is necessary to take into account a great number of limitations and switching operations variants. To this task solving a lots of publications were devoted, for example [5-7]. Here we propose a new approach, based on using of information structures of typical elements hierarchical aggregates belong to different electrical power substations, and knowledge in the rules form about switching operations in such aggregates.

Let us take into consideration as example a typical 2-transformers electrical substation (Fig. 1), that has two systems of buses (B): 110 kV (HV) and 10 kV (LV).

As well as every substation it consists of different elements including such switching devices as circuit breakers (b) and disconnectors (D). Mentioned above devices can be divided into the breakers for bus connection (BCb), main bus disconnectors (MBD) those are connected to main bus (MB), reserve bus disconnectors (RBD) those are connected to reserve bus (RB).

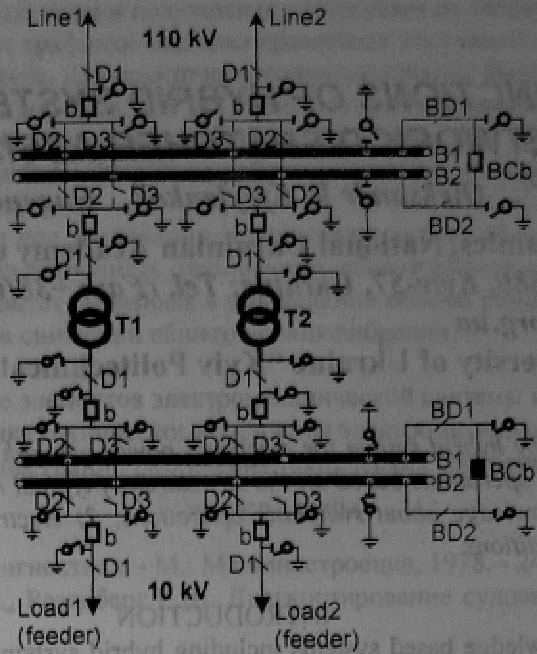


Fig. 1. 2-transformers electrical substation.

Every substation can be represented as connection of typical aggregates (TA). An examples of such TA are given in Fig. 2 and Fig. 3.

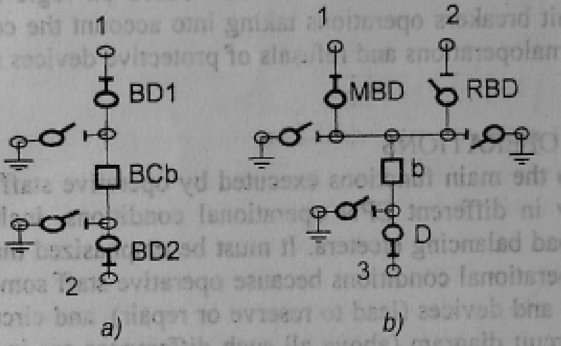


Fig. 2. Typical elementary aggregates of elements.

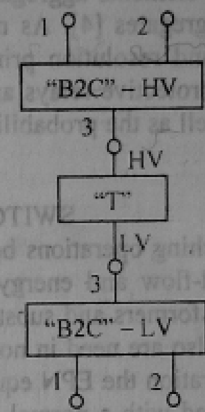


Fig. 3. Typical 2[nd] level aggregates.

There are switching operations rules for every TA those establish the switching operations succession (order) taking into account the operational condition limitations. Switching operations tasks in such TA are elementary tasks. Those tasks executing can be represented by change tables (from one state to another). As example, the circuit breaker states diagram is given in Fig. 4, and its change table is numbered as Table 1.

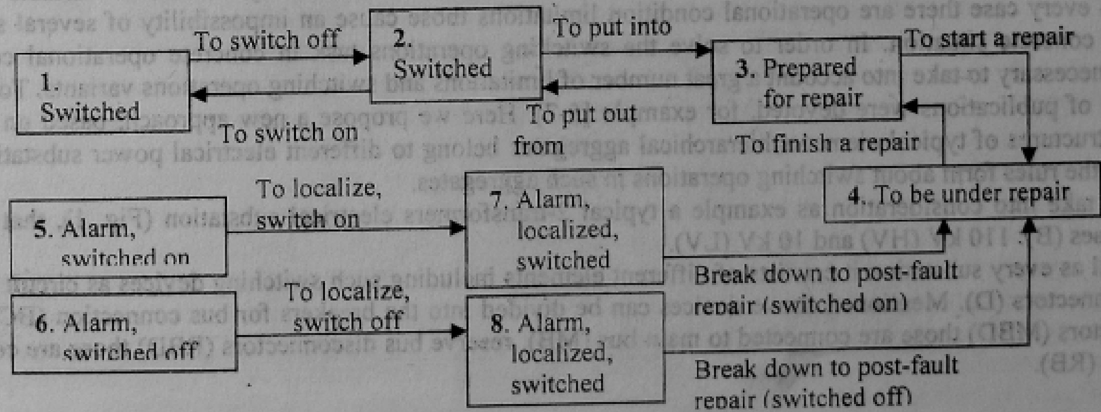


Fig. 4. The circuit breaker states diagram.

Table 1.

The circuit breaker states change table

| Breaker states | | Breaker state changes | | | |
|---|---|---|---|---|---|
| State number | State | Number of change | Start state number | Finish state number | Operation |
| 1 | Switched on | 1 | 1 | 2 | To switch off |
| 2 | Switched off | 2 | 2 | 1 | To switch on |
| 3 | Prepared for repair | 3 | 2 | 3 | To put into repair |
| 4 | To be under repair | 4 | 3 | 2 | To put out from repair |
| 5 | Alarm, switched on | 5 | 3 | 4 | To start a repair |
| 6 | Alarm, switched off | 6 | 4 | 3 | To finish a repair |
| 7 | Alarm, localized, switched on | 7 | 5 | 7 | To localize, switch on |
| 8 | Alarm, localized, switched off | 8 | 6 | 8 | To localize, switch off |
| | | 9 | 7 | 4 | Break down to post-fault repair (switched on) |
| | | 10 | 8 | 4 | Break down to post-fault repair (switched off) |

For every TA such tables were developed. But every complicated switching operations task consists of a number of elementary tasks. In those cases we deal with aggregates of TA, i.e. with next (higher) level of aggregates. In order to execute different technological switching operations tasks a number of typical second level aggregates were formed. An example of such aggregates is given in Fig 3, where are represented: "T"– transformer aggregate; "B2C"-HV, "B2C"-LV – typical aggregates (accordingly HighVoltage and LowVoltage levels) consist of TA those are shown in Fig. 2 b).

Thus, electrical substation (Fig. 1) for switching operations task solving can be represented as hierarchical aggregation of TA (Fig. 5), where second level TA TS-1 or TS-2 representation is given in Fig.3. An example of typical aggregates DD2B-1 or DD2B (Fig. 5) representation by first and second levels TA is given in Fig 6, where TA "BC" is shown in Fig. 2 a).

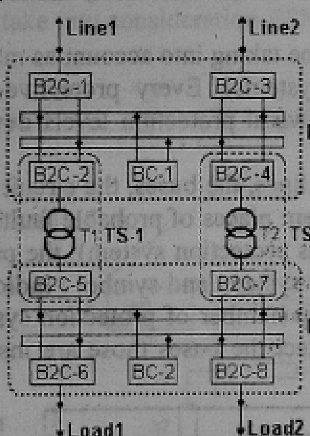


Fig. 5. Typical substation hierarchical aggregates.

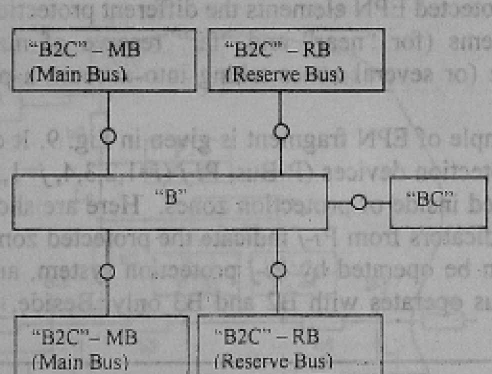


Fig. 6. DD2B-representation by first and second levels TA.

It is necessary for complicated switching operations tasks solving to use the switching operations rules taking into account hierarchical TA, operational condition limitations and possibilities of solutions coordination between different hierarchical TA mentioned above. An example of switching operations rules representation is given in Fig. 7.

```
Allow
        List "AND"
                TA(TS)->Element(T)
                        TA(T)-> Element(T)
                                TA(T)->Change(put_into_repair)
        If exists
                List "AND"
                        TA(TS)->Element(B2C-HV)
                                TA(B2C)->State(under_repair_MB)
Allow
        List "AND"
```

```
                TA(TS)->Element(B2C-HV)
                        TA(B2C)->Change (put_into_repair_MB)
        If exists
                Vector "OR"
                        TA(FS)->Element(B2C-LV)
                                TA(B2C)->State(under_repair_MB)
                        TA(TS)->Element(B2C-LV)
                                TA(B2C)->State(under_repair_RB)
```

Fig. 7. Switching operations rules fragment.

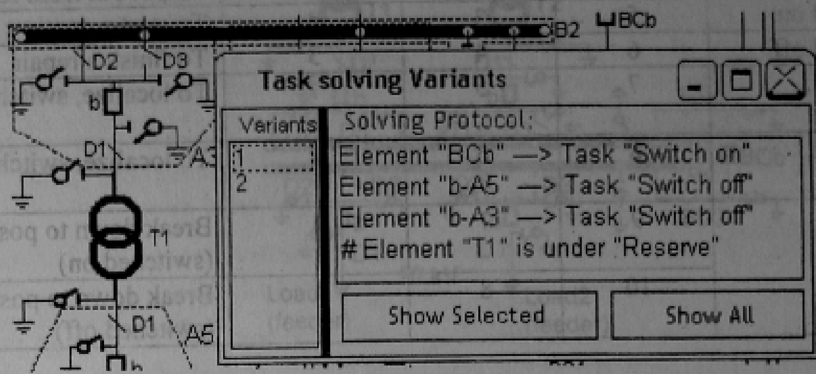


Fig. 8. Switching operations task solution representation.

## ELECTRICAL POWER NETWORK FAULTS DIAGNOSIS

The fault conditions of EPN usually are quickly eliminated by operations of protection and automation systems. However, for some cases including refusals and maloperations of protective devices as well as refusals of circuit breakers result to large area of blackout and loosing load. In 6-9 cases from 10 a reason of the damage development is the unexpected operations of protective devices (maloperations and refusals). As a result, the industrial and other activities in the outage area will be seriously negatively influenced. In post-fault conditions EPN dispatchers have alarm signals to keep track of the interpretation of EPN conditions following faults and to determine faults EPN elements. In order to solve this task on-line HS is used.

As to protected EPN elements the different protection systems may be taking into account as main and additional protection systems (for "near" and "far" reserve of main protection systems). Every protective device has own protection zone (or several zones taking into account a possibilities of several protection levels developed for some devices).

An example of EPN fragment is given in Fig. 9. It consists of EPN lines, the buses, the circuit breakers (b1, b2, b3, b4), the protection devices (P-Bus, P*i*-*j* ($i$=1,2,3,4, $j$=1,2,3)), and different places of probable faults (S*i*, $i$=1,2,3,4,5) those are situated inside of protection zones. Here are shown P-Bus (a bus protection system); the protection systems P*i*-*j* (sagittal indicators from P*i*-*j* indicate the protected zones by protection system, and symbol $i$ indicates a number of breaker that can be operated by P*i*-*j* protection system, and $j$ points a step number of protection system). It must be noted that P-Bus operates with B2 and B3 only. Beside, P*i*-*j* ($j$=2,3) protect the buses those are inside of protection zones.

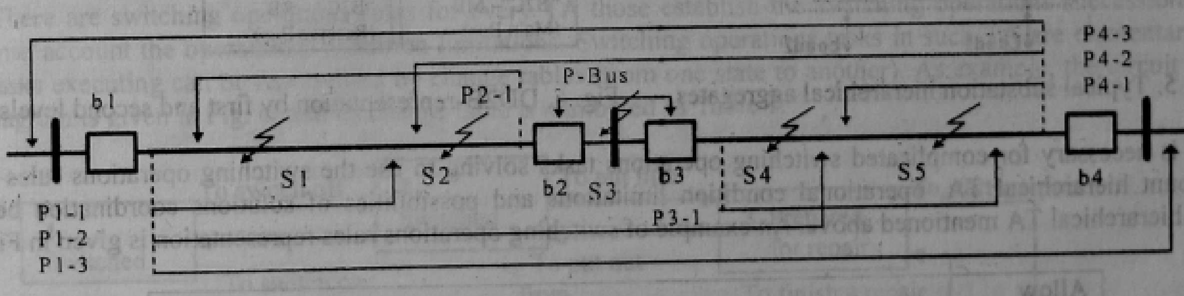


Fig. 9. EPN fragment.

The task is divided into two subtasks. The first task deals with hypotheses production about EPN fault elements. Every hypothesis production based on alarm signals interpretation, and every alarm signal (from protection system or breaker operation) takes part into hypotheses "weight" formingю As to every element as "expectant to be fault element" the different alarm signals have different "weight". In other words the same alarm signal has a different "weight" for each element that is an "expectant to be fault element". And a signal "weight" of main protection system is more than additional protection system signal "weight" for the same EPN element. During hypotheses production different additions to every hypothesis (to every element as "expectant to be fault element") summary "weight" are used taking into account the relations between alarm signals and protection zones:

$W_B$ – an addition to some bus "weight" in the case of alarm signal about this P-BUS operation is received;

$W_{P3b}$ – an addition to some bus "weight" when alarm signals about P-BUS operation and breaker operation (this breaker operation can be influenced by P-BUS) are received;

$W_{12}$ – an addition to "weight" of every EPN element is situated inside of 1st- or 2nd protection zones of Pi-j when alarm signal about this Pi-j operation is received;

$W_P$ – an addition to "weight" of every EPN element is situated inside of 3rd- Pi-j protection zone when alarm signal about this Pi-j operation is received;

$W_{Pb12}$ – an addition to "weight" of every EPN element is situated inside of 1st- or 2nd Pi-j protection zones when alarm signals about this Pi-j operation and breaker operation (this breaker operation can be influenced by this Pi-j) are received;

$W_{Pb3}$ – an addition to "weight" of every EPN element is situated inside of 3rd- Pi-j protection zone when alarm signals about this Pi-j operation and breaker operation (this breaker operation can be influenced by this Pi-j ) are received;

$W_{Pn}$ – an addition to "weight" of every EPN element is situated inside of Pi-j protection zone when alarm signal about this Pi-j operation is received and this Pi-j is a "near" reserve protection system as to those EPN elements;

$W_{Pnb}$ – an addition to "weight" of every EPN element is situated inside of Pi-j protection zone when alarm signals about this Pi-j operation and breaker operation (this breaker operation can be influenced by this Pi-j ) are received, and this Pi-j is a "near" reserve protection system as to those EPN elements;

$W_{b12}$ – an addition to "weight" of every EPN element is situated inside of 1st- or 2nd Pi-j protection zones when alarm signal about this Pi-j operation is absent but there is alarm signal about breaker operation (this breaker operation can be influenced by this Pi-j);

$W_{bB}$ – an addition to some bus "weight" when alarm signal about P-Bus operation is absent but alarm signal about breaker operation (this breaker operation can be influenced by P-Bus) is received;

$W_{b3}$ – an addition to "weight" of every EPN element is situated inside of 3rd- Pi-j protection zone when alarm signal about this Pi-j operation is absent but there is alarm signal about breaker operation (this breaker operation can be influenced by this Pi-j).

Mentioned above additions have following values (as the base values): $W_B = 10$; $W_{P3b} = 4$; $W_{12} = 8$; $W_P=6$; $W_{Pb12} = 2$; $W_{Pb3} = 2$; $W_{Pn} = 9$; $W_{Pnb} = 2$; $W_{b12} = 8$; $W_{bB} = 1$; $W_{b3} = 6$.

After hypotheses production by special algorithm we have also every hypothesis "weight". In order to illustrate such result let us take into consideration EPN fragment is given in Fig. 10.

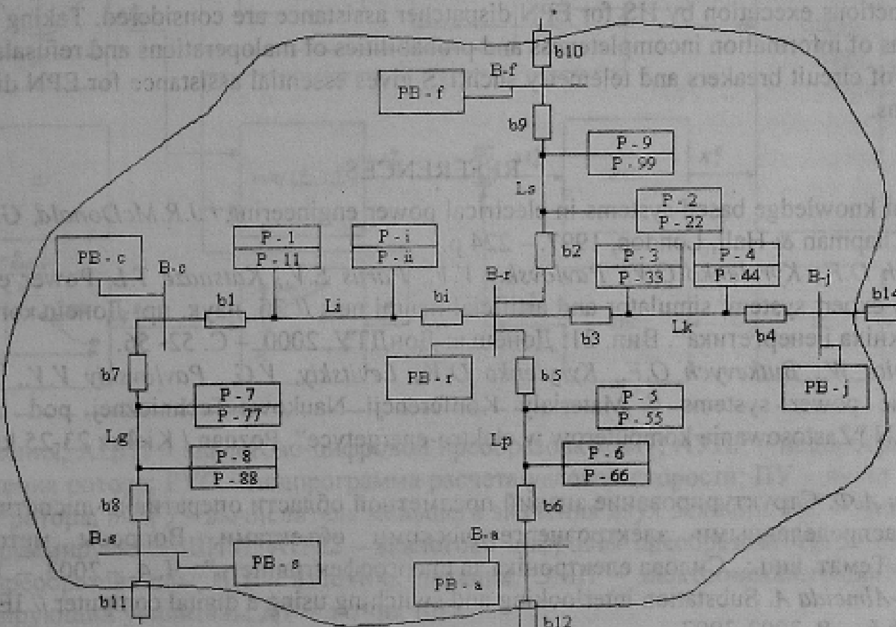


Fig. 10. EPN fragment.

There are lines (noted by Li, where *i* is in general case a line's "symbol-name"), the breakers (noted by *b-i*, where *i* is a breaker's number), the buses (noted by *B-i*, where *i* is in general case a "symbol-name" of a bus), protection devices (noted by symbols P-*i*, where *i* is in general case a protection device number), bus protection systems (noted by symbols PB-*j*,. where *j* gets the same "symbol-name" as the bus protected by this protection system). There are shown main protection systems in apper parts of rectangles and additional protection systems ("near" reserve) in lower parts of same rectangles.

Let assume that line Li was faulted and protection devices P-1 and P-i operate but there were refusals of breakers b1 and bi. Also there was telemetry refusal and information about P-4 operation was loosed. In assumption that other refusals as well as protection systems maloperations were absent there were such alarm signals in EPN dispatching centre (alarm signals are noted as corresponding devices notations): P-1, P-i, P-8, P-9, P-6, b8, b9, b4, b6.

Based on these signals ten hypotheses were produced. Every hypothesis has the same name as the EPN element that is an "expectant to be fault element" (a hypothesis "weight" is into brackets): Li(46), B-r(44), B-c (40), Ls (30), Lк (30), Lp (30), B-f (20), B-a (20), Lg(16), B-j(6).

Alarm signals participation in every hypothesis "weight" forming is shown in the Table 2.

Table 2.
Alarm signals participation in hypotheses "weight" forming
(the additions to hypotheses "weight" are produced by alarm signals)

| Hypotheses | Alarm signals | | | | | | | | | Hypotheses "weight" |
|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | Pi | P8 | P9 | P6 | b8 | b9 | b4 | b6 | |
| Li | $W_{12}$ | $W_{12}$ | $W_P$ | $W_P$ | $W_P$ | $W_{Pb3}$ | $W_{Pb3}$ | $W_{b3}$ | $W_{Pb3}$ | 46 |
| B-r | $W_{12}$ | | $W_P$ | $W_{12}$ | $W_{12}$ | $W_{Pb3}$ | $W_{Pb12}$ | $W_{b12}$ | $W_{Pb12}$ | 44 |
| B-c | | $W_{12}$ | $W_{12}$ | $W_P$ | $W_P$ | $W_{Pb12}$ | $W_{Pb3}$ | $W_{b3}$ | $W_{Pb3}$ | 40 |
| Ls | $W_P$ | | | $W_{12}$ | $W_P$ | | $W_{Pb12}$ | $W_{b3}$ | $W_{Pb3}$ | 30 |
| Lк | $W_P$ | | | $W_P$ | $W_P$ | | $W_{Pb3}$ | $W_{b12}$ | $W_{Pb3}$ | 30 |
| Lp | $W_P$ | | | $W_P$ | $W_{12}$ | | $W_{Pb3}$ | $W_{b3}$ | $W_{Pb12}$ | 30 |
| B-f | $W_P$ | | | | $W_P$ | | | $W_{b3}$ | $W_{Pb3}$ | 20 |
| B-a | $W_P$ | | | $W_P$ | | | $W_{Pb3}$ | $W_{b3}$ | | 20 |
| Lg | | $W_P$ | $W_{12}$ | | | $W_{Pb12}$ | | | | 16 |
| B-j | $W_P$ | | | | | | | | | 6 |

It must be noted that such approach to hypotheses production takes into account all possible fault elements. After hypotheses production they would be verified in order to determine the fault elements. It is second subtask. For this purpose the ES based on the logic-structured approach [8] is used. For additional verification of protection systems operations it is possible to use ANN [2, 9] but in that case it is necessary to prepare ensembles of ANN, taking into account that for this purpose EPN dimension must be not large.

## CONCLUSION

Two basic functions execution by HS for EPN dispatcher assistance are considered. Taking into account practical tasks and conditions of information incompleteness and probabilities of maloperations and refusals of protective devices as well as refusals of circuit breakers and telemetry such HS gives essential assistance for EPN dispatcher especially in post-fault conditions.

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