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Development of Structure of Expert System on the Basis of Solution of Conflicts among Production Rules

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Abstract

Article considers the structure of expert system for effective management of normal daily regimes of Georgian power system. In contrast to existing structure, this structure includes the block of solution of conflicts among production rules. This block with blocks of logical output and calculation forms one big block. Advantage of such method is that solution of conflicts among rules takes place in the process of logical output. Therefore, process of making effective decisions is faster.

Keywords: *expert system, power system, technologist, production rules*

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Introduction

As we know, upon management of regimes of power system, territorial and temporal hierarchical levels are considered. Each level has corresponding goals, facts and set of production rules. We consider the daily regime of temporal and territorial hierarchy of regional power system. We have set of production rules at the selected level and therefore, existence of conflicting set of production rules is inevitable. Conflicting set of production rules often occurs upon solving hard tasks and such case is management of daily regimes of power system.

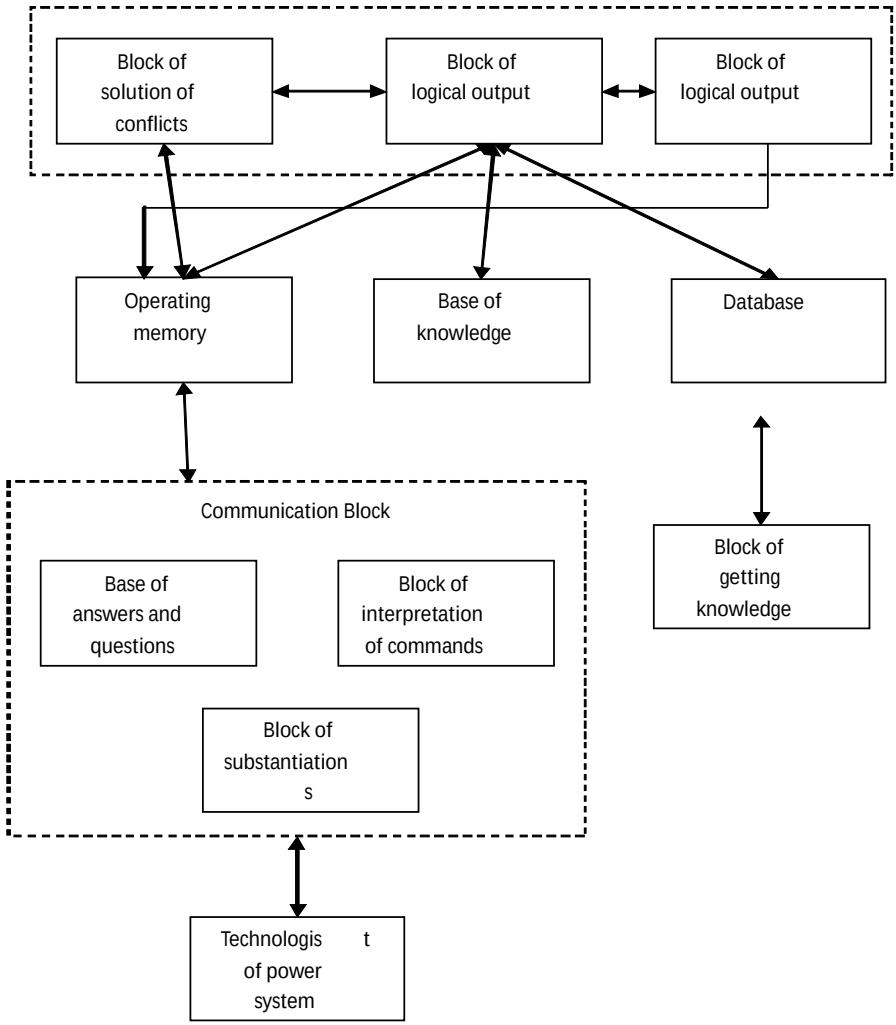
The structure of expert system was created for effective management of normal daily regimes of Georgian power system (fig. 1). System consists of several blocks [1]: block of solution of conflicts among production rules, block of logical output [2], block of calculation, base of knowledge, operating memory, block of getting knowledge, block of communication with technologist, which consists of base of answers and questions, block of interpretation of commands and block of substantiation. We will describe each block.

Block of solution of conflicts among production rules divide the conflicting set into subsets. Each subset corresponds to the condition of power system and is determined on the basis of expert knowledge. As the quantity of goals in power system increases, composition of production rules and quantity of subsets may change. As soon as ultimate result is fixed and it is acceptable for dispatcher of power system, process of discussion is saved. Afterwards, when the same or similar condition is fixed, result is selected without the process of logical output.

Base of knowledge includes the information about daily regimes of power system, facts and rules. Facts look like these:

1. Enguri's output is 800 megawatt at 12 p.m.
2. Tkibuli is disconnected at 3 p.m.
3. Regulation level of Enguri is high
4. Energy usage is high at peak hours.
5. In spring water is abundant in rivers
6. In winter water is shallow in rivers.

Figure 1. Structure of expert system for management of daily regimes of Georgian power system



Part of rules look like these:

1. Hydroelectric power station works with maximal power at peak hours

2. If water is abundant in hydroelectric power station, then (power station is switched on with maximal power every hour) or (power station doesn't participate in regulation of load)

3. If we have lack of water in hydroelectric power station, then power station covers the peak of graph at first and then rest of it.

4. If requirement of waterworks facility is met, then water flow is minimized in hydroelectric power station or power station doesn't participate in regulation of load.

5. If at t time $\Psi(t)>0$ and $N_{HPSi}(t)=N^{min}_{HPSi}$, then $N_{HPSi}(t)=0$

6. If at t time $\Psi(t)>0$ and $N_{HPSi}(t)=0$, then $N_{TPSj}(t)=N^{min}_{TPSj}$

7. If at t time $\Psi(t)>0$ and $N_{TPSj}(t)= N^{min}_{TPSj}$, then dispatcher of power system begins to manage.

8. If $Q<24N^{min}_{HPSi}$, then the water is abundant in hydroelectric power station (i).

9. If the water is abundant in hydroelectric power station (i), then $NHPSi(tn)=N^{min}_{HPSi}$ and power station (i) doesn's participate in regulation of load.

Communication block connects the technologist of power system and expert system. It ensures the dialogue between expert system and dispatcher of power system in restricted Georgian language i.e. technologist of power system uses the predetermined sentences. Communication block interprets questions and commands.

Communication block includes the bases of questions, corresponding answers and commands. It also contains the block of substantiation of decisions. List of commands includes the commands of technologist towards the expert system. If command of technologist coincides with command in the base, then the block of calculation begins to manage and takes corresponding actions. If command is not in the base, then engineer of knowledge adds the command to the base and determines corresponding actions.

Command can be following sentence:

1. Switch off Xrami-1 during the days
2. Switch on Vardnili with minimal power
3. Switch off Tkibuli at 1, 4 and 10p.m.
4. Switch on Xrami-2 with maximal power

Base of questions includes the possible questions of technologist of power system. If question is in the base, then corresponding answer is given. If question isn't in the base, then engineer of knowledge adds the question to the base and determines the corresponding answer with technologist of power system. Base may include part of answers and the other part will get there after calculations.

Questions may have the following form:

1. What is output of Enguri at 7p.m.?
2. What is minimal positive imbalance?
3. What is consumption at peak?
4. What is maximal negative imbalance?
5. What is maximal positive imbalance?
6. What is minimal negative imbalance?
7. What is average negative imbalance?

Answers may have the following form:

1. Tkibuli is switched off during the days
2. Xrami-1 is switched off at 4 a.m. 8 a.m. and 5 p.m.
3. Daily regime is in short supply

Communication block demands necessary data from technologist of power system. Demand may have the following form:

1. Enter the maximal power of Vardnili
2. Enter the maximal desired power of thermoelectric power station
3. Enter the minimal power of Enguri until zone of interruption
4. When must be Shaori switched off?

Substantiation block gives the substantiation of decisions and recommendations. It explains to technologist of power system how the decision or recommendation was made. Block of explanation considers the elements of decisions. Consideration begins from conclusion and then the data which was the basis of decision is considered. Intermediate conclusions are translated to Georgian for dispatcher of power system.

Let's ask the question:

How was the imbalance liquidated at 9p.m.?

Answer: By means of rule-2 which states that thermoelectric power station (j) must produce minimal power at 9p.m. for liquidation of positive imbalance. If every hydroelectric power station is switched off then we have rule-1 which states that hydroelectric power station (i) must be switched off at 9p.m. if it produces minimal power

Let's ask the question:

Why doesn't Tkibuli participate in regulation of load?

Answer: By means of rule-5 which states that Tkibuli has the lack of

water and therefore produces the minimal power only at peak hours. By means of rule-5 which states that Tkibuli has the lack of power because planned daily water flow is less than or equal to $24\,N_{HPSi}^{min}$.

Communication block publishes intermediate decisions, conclusions and data once an hour. Such data are magnitudes of imbalances, regimes of each hydroelectric and thermoelectric power station, consumption of fuel by thermoelectric power station, water flow of hydroelectric power station and etc. Therefore, communication block gives the data, facts, production rules and information about decision-making to technologist of power system.

Calculation block calculates the magnitudes of imbalances, power output of hydroelectric and thermoelectric power station, defines the deficit and not deficit regimes of power system and also carries out the commands of technologist of power system. Block of knowledge uses the standard methods and algorithms. In our case engineer of knowledge and technologist of power system supplement database with additional rules and corresponding actions.

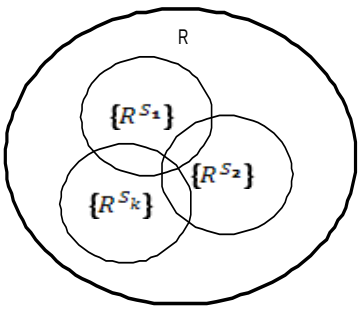
Let's describe the work of block of conflict solution in detail. Power system may be in one condition out of many [2]. Let's designate the set of conditions with S:

$$S = \{S_1, S_2, \dots, S_k\}, k = \overline{1,K}.$$

Certain set of production rules corresponds to each condition. These rules are in conflict. Let's designate the set of production rules with R:

$$R = \{\{R^{S_1}\}, \{R^{S_2}\}, \dots, \{R^{S_k}\}\}, k = \overline{1,K}.$$

Figure 2



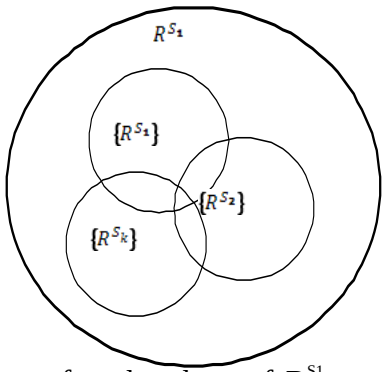
Here $\{R^{S1}\}$ is set of conflicting production rules which corresponds to condition S_1, $\{R^{S2}\}$ is set of conflicting production rules which corresponds to condition S1 and etc. Subsets of R set may intersect i.e. include the same rules (Fig. 1).

Each set of conflicting production rules corresponds to certain condition of power system and is divided to subsets (Fig. 2):

$$R^{S_1} = \left\{\left\{R_1^{S_1}\right\}, \left\{R_2^{S_1}\right\}, \ldots, \left\{R_{k_1}^{S_1}\right\}\right\}, k_1 = \overline{1, K}, K_1 \in K,$$
$$R^{S_2} = \left\{\left\{R_1^{S_2}\right\}, \left\{R_2^{S_2}\right\}, \ldots, \left\{R_{k_2}^{S_2}\right\}\right\}, k_2 = \overline{1, K}, K_2 \in K,$$
$$\ldots$$
$$R^{S_k} = \left\{\left\{R_1^{S_k}\right\}, \left\{R_2^{S_k}\right\}, \ldots, \left\{R_{k_k}^{S_k}\right\}\right\}, k_k = \overline{1, K}, K_k \in K.$$

As you see, we have several sets of conflicting production rules in conditions S_1, S_2 and etc.

Figure 3.



Composition of each subset of R^{S1} set of conflicting production rules is such:

$$R_1^{S_1} = \left\{R_{11}^{S_1}, R_{12}^{S_1}, \ldots, R_{1n_{11}}^{S_1}\right\}, n_{11} = \overline{1, N_{11}}, N_{11} \in N,$$
$$R_2^{S_1} = \left\{R_{21}^{S_1}, R_{22}^{S_1}, \ldots, R_{2n_{12}}^{S_1}\right\}, n_{12} = \overline{1, N_{12}}, N_{12} \in N,$$
$$\ldots$$
$$R_{k_1}^{S_1} = \left\{R_{k_11}^{S_1}, R_{k_12}^{S_1}, \ldots, R_{k_1n_{1k_1}}^{S_1}\right\}, n_{1k_1} = \overline{1, N_{1k_1}}, N_{1k_1} \in N,$$

Therefore, composition of each subset of R^{SK} set of conflicting production rules is such:

$$R_1^{S_k} = \left\{R_{11}^{S_k}, R_{12}^{S_k}, \dots, R_{1n_{k1}}^{S_k}\right\}, n_{k1} = \overline{1, N_{k1}}, N_{k1} \in N,$$
$$R_2^{S_k} = \left\{R_{21}^{S_k}, R_{22}^{S_k}, \dots, R_{2n_{k2}}^{S_k}\right\}, n_{k2} = \overline{1, N_{k2}}, N_{k2} \in N,$$
$$\dots$$
$$R_{k_k}^{S_k} = \left\{R_{k_k1}^{S_k}, R_{k_k2}^{S_k}, \dots, R_{k_kn_{kk_k}}^{S_k}\right\}, n_{kk_k} = \overline{1, N_{kk_k}}, N_{1kk_k} \in N,$$

Condition of power system is defined on the basis of analysis of original data. Each condition has corresponding set of conflicting production rules. Subsets of this set are arranged according with priorities. We choose the priority subset and use its rules for getting logical output. Production rules are also arranged in subsets and they are used according with priorities. Such method reduces the considered set of conflicting rules and the process of decision-making is faster.

We developed the algorithm on the basis of model of solution of conflicts among production rules. Assume power system is in S_1 condition and operating memory of expert system includes 5 production rules:

$$R^{S_1} = \left\{R_1^{S_1}, R_2^{S_1}, R_3^{S_1}, R_4^{S_1}, R_5^{S_1}\right\}$$

We may use $R_1^{S_1}$, $R_2^{S_1}$ production rules i.e. these rules are conflicting. Process of logical output may begin from $R_1^{S_1}$ or $R_2^{S_1}$ rule. This happens when we have set of conflicting production rules after the analysis of original data. Process of logical output may continue with $R_1^{S_1}$ or $R_2^{S_1}$ rule. This happens when we have many conflicting productions rules in the process of logical output. Production rules are arranged according with priority when the power system in S_1 condition. Then we understand from which rule process of logical output must continue and we choose the priority production rule. If in S_1 condition $R_1^{S_1}$ and $R_2^{S_1}$ rules are of equal priority than rule is chosen randomly.

The concluding part of $R_1^{S_1}$ production rule is saved in operating memory and compared with conditional parts of $R_3^{S_1}$, $R_4^{S_1}$ and $R_5^{S_1}$ rules. If there is no coincidence, then $R_1^{S_1}$ rule leaves the operating memory and $R_2^{S_1}$ rule is considered i.e. it's concluding part is compared with conditional parts of $R_3^{S_1}$, $R_4^{S_1}$ and $R_5^{S_1}$ rules. If concluding part of $R_1^{S_1}$ rule coincides with conditional part of some production rule (for example $R_5^{S_1}$), then $R_1^{S_1}$ rule is used. Lately we check if $R_5^{S_1}$ is usable. If it has one condition, then it's usable. If it has two conditions and the second condition is not met, then $R_2^{S_1}$ rule is considered. If both conditions of $R_1^{S_1}$ rule are met, then this rule is used.

If conditional part of $R_1^{S_1}$ rule coincides with conditional parts of $R_3^{S_1}$ and $R_4^{S_1}$ rules and doesn't coincide with conditional part of $R_5^{S_1}$ rule, then we check which rule can be used - $R_3^{S_1}$ or $R_4^{S_1}$. If both rules are usable, then priority is important. If $R_3^{S_1}$ and $R_4^{S_1}$ rules are of equal priority, then selection is random. If $R_3^{S_1}$ and $R_4^{S_1}$ rules aren't usable, then the process of logical output is finished or $R_2^{S_1}$ rule is considered.

Algorithm foresees priorities of goals of power system upon managing of daily regimes. Competent technologists (dispatchers) of power system arrange the production rules according with priorities by means of expert knowledge. For example, if G_1 goal is priority (daily requirement of electric power must be maximally satisfied), then the power system is in S_1 condition and the corresponding R^{S_1} subset of production rules is chosen. If G_2 goal is priority (economy of water resources for non-energetic goals), then the power system is in

S_2 condition and the corresponding $\perp R^{S_2}$ subset of production rules is chosen. Rules are arranged according with priority in each subset and arrangement is based upon expert knowledge of qualified technologists of power system.

Production rules correspond with the conditions of power system and are pre-determined on the basis of expert knowledge. As the quantity of goals of power system increases, composition and quantity of production rules may also change. If some goal isn't considered, then corresponding set isn't considered too.

Set of conflicting rules includes some rules which have several conclusions in concluding part. This fact also increases the quantity of conflicting rules. Example of such rule:

If hydroelectric power station (i) has the abundance of water, **then**

Hydroelectric power station (i) doesn't participate in regulation of load **or**

Hydroelectric power station (i) is switched off **or**

Hydroelectric power station (i) covers only peak **or**

Hydroelectric power station (i) produces minimal power.

One of the conclusions is selected on the basis of condition of power system. As soon as final result is fixed and it's acceptable for dispatcher of power system, result is saved and used for discussions. Lately, when we have the same or similar condition of power system, result is selected without the process of logical output.

Article considers the new structure of expert system. In this structure mechanism of solution of conflicts among production rules is separated block. Demonstrational prototype of expert system is built on the basis of considered structure and model. Aim of expert system

is management of regional power systems and particularly Georgian power system in normal daily regimes.

Conclusion

Article considers the structure of expert system for effective management of normal daily regimes of Georgian power system. In contrast to existing structure, this structure includes the block of solution of conflicts among production rules. This block with blocks of logical output and calculation forms one big block. Advantage of such method is that solution of conflicts among rules takes place in the process of logical output. Therefore, process of making effective decisions is faster.

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