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Expert system for the load management, unit commitment and optimised scheduling of power generation at hydel power plants

By

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Abstract:

This paper presents an artificial intelligence based inference system for economic load management and scheduling of power generation. A database is developed in which the whole record of the behavior of a plant, in different situations, is available. The decisions of experts are also fed in the knowledge base. Rule base is developed on the basis of experts decisions, different conditions of load demands, unit commitment and power controlling factors such as discharge rate of water, velocity of water flow, head of water available, requirement of water for irrigation purposes and machines specifications. Then the inferences engine under different conditions fires the appropriate rules from the rule base and controls all the above-mentioned parameters. It also makes decisions to select the optimised machines for power generation to meet the peak and base load power demands. This expert system is developed in Prolog. Simulation results using the data of Mangla Power Station were compared with the actual results of the plant for this purpose and found satisfactory.

Keywords:

Expert system, knowledge base, rule base, rule adjuster, inference engine, data processor, unit commitment, load management and Prolog.

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1. Introduction:

The economic load management and power generation are the core requirements in this era when the world is facing energy crisis. 'Expert Systems (ES)' are being used nowadays for decision managements as they use high-speed computers to solve real-life problems [1]-[3]. Decision-analysis process, depending upon modeling, can solve complex problems. An expert system uses the relationships between operation research, decision-support systems, heuristic programming and artificial intelligence to make a decision. Database related to a particular problem may save the experience of experts in that domain which may be called in any situation for analysis and diagnosis. Load management, unit commitment and generation can be controlled by the expert system which makes appropriate decision using spread sheets, data bases, statistical analysis, simulation results and linear programming [4]-[5].

This paper presents an artificial intelligence based inference system for energy management. A database is developed, in which the whole record of the behavior of a plant in different situations is available. The decisions of experts are also fed in the knowledge base. 'Rule Base' is developed on the basis of experts decisions, different conditions of load demands, unit commitment and power controlling factors such as discharge rate of water, velocity of water flow, head of water available, requirement of water for irrigation purposes and machines specifications. Then the inference engine under different conditions fires appropriate rules from the rule base and controls all the above mentioned parameters. It also makes decisions to select the optimised machines for power generation to meet the peak and base load power demands.

This expert system is developed in Prolog. Results using the data of Mangla Power Plant were compared with the software for this purpose and found satisfactory. The expert system with all above features is most economical solution to meet the energy crisis by controlling the load management, schedules and power generation.

2. Artificial Intelligence and expert system.:

In 'Artificial Intelligence (AI)' is that every aspect of learning or any other feature of human intelligence can be so precisely described that a machine can be made to simulate it [6]. Expert system - which basically consists of inference engine, knowledge base, working memory, database, data-processing analytical methods, rule adjuster and an interface for knowledge engineer and user - is a sub category of AI. Knowledge base being the heart of ES has facts and rules. In our implementation data regarding all generators and turbine units in Mangla Power Station, water level available, flow rate of water and velocity are treated as facts. The rules which represent the heuristic relations are fed in the data base by knowledge engineer or domain experts and control the operation of unit commitment, optimised scheduling of power generation based upon mathematical operations. Inference engine examines the status of knowledge base and working memory, and determines which facts are known and can also add new facts available in knowledge base. New facts are developed by the inference process, which are also stored in working memory while rule adjuster checks the rules for consistency and completeness and can revise the knowledge base. Interface handles the inputs through different sensors and the actuator operates according to the decisions of ES. Fig. 1 shows the typical architecture of the expert system used while Table 1 shows the data of Mangla Power Station i.e., capacity per machine against reservoir level which were used to develop the rule base and facts. Other data gained from experienced engineers were used to make heuristics, which sometimes make decision process easier for the expert system. Cost curves of the units were also fed in knowledge base for optimized operation and control of the system.

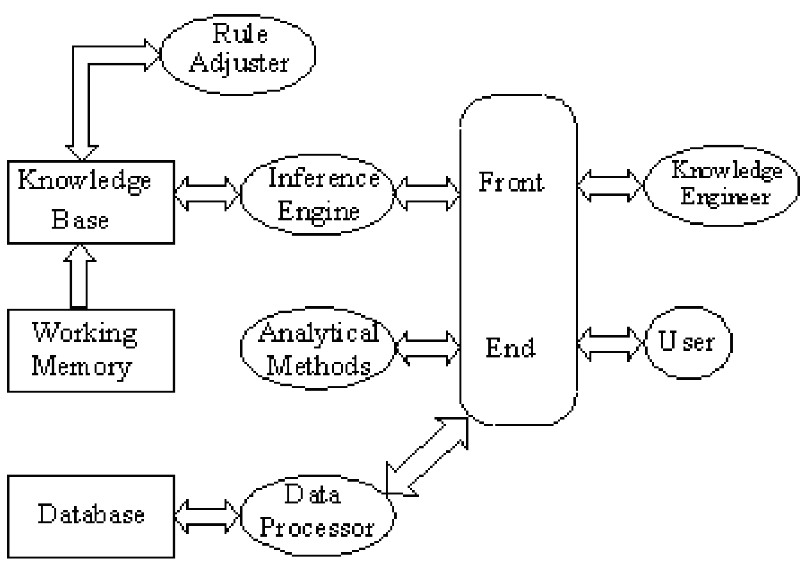

Figure (1): *Architecture of the used expert system*

<u>***3. Load Management and unit commitment:***</u>

'Unit Commitment' means to decide about how many machines will run to fulfill the load requirement in an economical way under certain constraints [7]. For k number of machines there will be 2^k-1 combinations in which machines can run. Expert system first of all decides how many machines will run to meet load requirement with present head available and the rate of discharge of water. For this, different combinations are tested to economize the power generation. Then, according to specifications, load is distributed among the combination of machines selected. The complete algorithm used is shown in the form of a flowchart in Fig. 2. Expert system makes decisions on the basis of facts and rules in its knowledge base. If the load, considered for the reliable system design changes in some specified range, then ES varies power generation from a certain unit such that the overall generation cost remains economical. Data base of the expert system was developed by the facts derived from the data provided by Mangla Power Station as shown in Table 1. During implementation, a number of constraints were considered. Local constraints considered are minimum and maximum load handling capability of a unit, minimum up and down time, hot and cold cost, hot and cold start, unit initial conditions, unit status restriction and unit ramp rate. Constraints on plant crew, stability, security, station and spinning reserve were also considered.

Table (1): *Mangla Power Station' capacity per machine against reservoir level*

Sr. #	HRL SPD (ft)	Net Head (ft)	Units Capacity in MW				Total Capacity in MW	Discharge per MW (CFS)	Total Discharge (CFS)
			Machine 1-4	Machine 5-6	Machine 7-8	Machine 9-10			
1	1050	207	54	55	54	55	544	65	35360
2	1055	212	57	60	60	60	588	64	37632
3	1060	217	58	60	60	60	592	64	37883
4	1065	222	61	64	64	64	628	62	38936
5	1070	227	66	69	68	69	676	6	40560
6	1075	232	68	70	69	70	690	59	40710
7	1080	237	69	71	70	71	700	58	40600
8	1085	242	71	72	71	72	714	57	40698
9	1090	247	75	75	73	75	746	55	41030
10	1095	252	77	78	76	78	772	55	42460
11	1100	257	80	81	80	81	804	54	43416
12	1105	262	82	84	82	84	828	52	43056
13	1110	267	84	87	83	87	850	50	42500
14	1115	272	86	91	84	91	876	49	42924
15	1120	277	88	94	86	94	908	45	40860
16	1125	280	92	97	90	97	936	44	41184
17	1130	282	94	101	93	101	966	44	42504
18	1135	287	96	104	95	104	990	44	43560
19	1140	292	99	108	97	108	1022	44	44968
20	1145	296	102	110	102	110	1052	44	46288
21	1150	297	104	112	104	112	1072	44	47168
22	1155	302	107	115	107	115	1102	43	47386
23	1160	309	110	117	108	117	1124	43	48332
24	1165	312	113	12	110	120	1152	43	49535
25	1169	317	115	125	115	125	1190	42	49980
26	1170	322	115	125	115	125	1190	41	48790
27	1175	327	115	125	115	125	1190	40	47600
28	1180	332	115	125	115	125	1190	39	46410
29	1185	337	115	125	115	125	1190	38	45220
30	1190	342	115	125	115	125	1190	38	45220
31	1195	347	115	125	115	125	1190	37	44030
32	1200	352	115	125	115	125	1190	36	42840

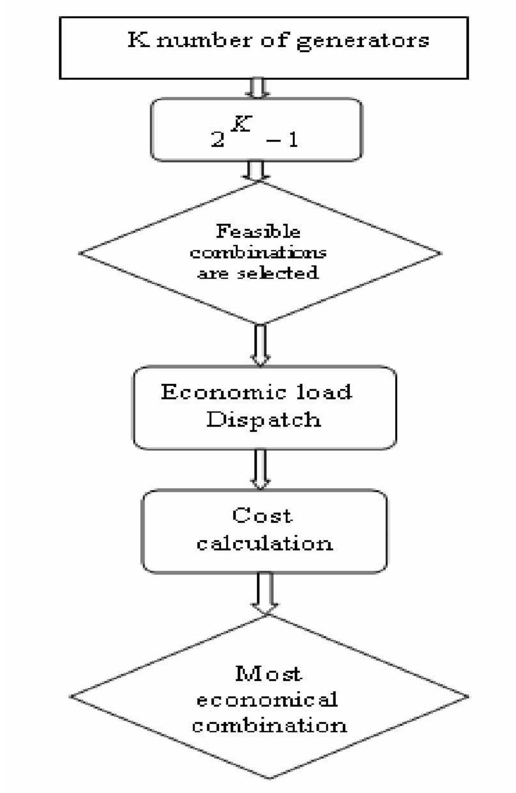

Figure (2): *Flow chart of algorithm used in unit commitment*

4. Simulation results:

The expert system was implemented using Prolog and was tested for number of different conditions under different load demands and gave the satisfactory results which are in correspondence to those which are acquired from the existing system of Mangla Power Station. Simulation was tested with the load demand from 500 MW to 1000 MW under different head available and discharge rate of water. When the expert system was consulted for the economic demand of 630 MW at the head of 278 feet, it committed 8 out of 10 units with the power distribution as given in Table 2, and these are accurate when compared to the data provided by Mangla Power Station.

Table (2): *Results of load demand scheduling*

Machine no.	1	2	3	4	5	8	9	10
Power delivered in MW	75	78.5	72	70.5	75	86	88	85

5. Conclusions:

The expert system presented in the paper can effectively control the operation of power plant by making decisions for unit commitment, load management and optimized power generation. Instead of so much calculations of general procedure adopted for this purpose expert system on the bases of rules and facts and previous decisions of expert in this domain, from the knowledge base, can optimize the performance of a hydral power plant. Decision making ability of ES enhances the performance of the system and reduces the time as taken by other software for the calculation using iterative procedure. The proposed ES is cost and time effective solution for the management of power generation scheduling and for unit commitment. It has shown competitive results in simulations in different consultation sessions under different load demand, head and water level conditions.

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Biographies:

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