Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 8; October, 2014 pp. 36-40
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http://www.krishisanskriti.org/jbaer.html

An Expert System for Site Selection of Thermal Power Plants

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Abstract: **Energy, known as Strategic Commodity, is critical and any uncertainty about its supply can threaten the functioning of the economy. Thermal power plants are base load plants which meets three-fourth of the total power requirement. Selection of site for thermal power plant is vital for its overall efficiency during its entire period of operation. This paper proposes an expert system for site selection of thermal power plants. We use Flex Expert System Shell in which production rules are framed based on regulatory criteria. The system analyses the proposed site based on criteria laid down by governing bodies and decides its suitability for commissioning the plant. The system automates the decision making process, thereby eliminating the human intervention. The expert system also provides suggestions to the user on latest technologies for optimal utilization of resources.**

Keywords: **Thermal Power Plant, Site Selection, Expert Sys-tem, Flex, Decision Support System**

1. INTRODUCTION

Considering the uncertain economic conditions of state electricity boards (SEBs), the power market dynamics, the fundamental changes in the attitudes, aspirations and needs of the consumers along with the strong growth of political role and interventions in the power sector, increase in demand and fill the demand and supply gap, currently characterizing the power production plants depending on site selection, it can be said that the need for expert systems method of strategic planning was never so acute as now. The power sector is an integral part of the country's economic growth and sustainable development. The Power sector in India has an installed capacity of 2, 34, 60194 Mega Watt (MW) as of 31st Jan, 2014 recording an increase of 14% over that of March 2013[1]. Thermal power plants accounted for an overwhelming 66% of the total installed capacity in the country, with an installed capacity of 1, 60, 483.99 MW. Total Aggregate Technical and Commercial losses stands at an average of 28%. In order to overcome the ATC losses, the government introduced Restructured Accelerated Power Development Reforms Program (R-APDRP). Demand supply gap between electricity generation and demand touched 8% in April 2013 according to the Central Electricity Authority (CEA). Although the usage of renewable energy have been increasing in the past couple of years, thermal power plants with bulk capacities continues to be the potential solution to meet the increased demand due to its viability and availability of fuel. Inorder to meet the demand and increase the power production, Ministry of Power (MoP) took initiative to develop Ultra Mega Power Projects (UMPPs). These are very large sized projects, each project approximately taking inputs as Rs. 260 billions, 4000 MW and 2500 acres of land, adopting supercritical technology with a view to achieve higher levels of fuel efficiency, which results in fuel saving and lower green-house gas emissions[2].

Improving energy efficiency is one of the most desirable options for bridging the gap between demand and supply. Unlike other power plants, thermal power plants need a large amount of land as it requires large machineries to generate bulk amount of power. The disposal of the increasing amounts of solid waste from coal-fired thermal power plants is becoming a serious concern to the environmentalists. Since selection of a plant site has a significant influence on the design, construction and operating costs of a power plant, it has to be conducted in a precise manner taking into consideration of all factors which will have a profound impact on its operation. Inorder to boost the power production in the country, Electricity Act 2003 made generation free from licensing, but so far sixty five clearances are made mandatory like Environmental, Pollution, and Forest etc. Land acquisition has a major role to play besides selecting a particular place for project.

Expert Systems are intelligent systems that encapsulate specialized knowledge about a particular domain of expertise and are capable of making intelligent decisions within that domain. Any area in which human experts solve problems is a potential area for the use of expert systems. Expert Systems successfully tackled the complex problems of various areas include medical diagnosis, geological exploration, fault diagnosis in electronic equipment. In this paper, Rule Based Expert System is used to make Intelligent Decisions for the site selection of Thermal Power Plants.

The organization of the paper is as follows. Section 2 discusses the previous contributions towards the site selection

of Thermal Power Plant. Section 3 introduces the criteria considered for the Site Selection. FLEX Expert System Shell is introduced in Section 4. The Methodology and Decision tree are presented in Section 5. Section 6 shows the Results and Discussion. Finally, the paper is concluded in Section 7.

2. RELATED WORK

There are a couple of works, which are involved in the evaluation of potential sites for commissioning thermal power plants. A Decision Support System for thermal power plant siting(SDSS) aids decision makers to make individual decision and multiple decision on the site alternatives, in the stage of preliminary feasibility study. The SDSS frames the knowledge in the knowledge base by means of 500 rules and outputs the decision results based on user inputs [3]. Geospatial information (GIS) is used in evaluation of potential site for coal-based thermal power plants. Multi-spectral satellite data and other related data were used to create a database, which then suitably combined with regulatory conditions to rank the sites based on a Site Suitability Index (SSI)[4]. Researchers have also tried using geospatial data along with collateral data on geology, topography, hydrology, meteorology and other regulatory considerations in identifying potential sites for pit-head coal-based thermal power stations. The sites were then ranked using an SSI and decisions are made according to that [5].

3. SITE SELECTION CRITERIA

Selecting a proper site for a thermal power plant is vital for its long term efficiency and a lot many factors come into play when deciding where to install the plant. Of course it may not be possible to get everything which is desirable at a single place but still the location should contain an optimum mix of the requirements for the settings to be feasible for long term economic justification of the plant. In general, both the construction and operation of a power plant requires the existence of some conditions such as water resources and stable soil type. Still there are other criteria that although not required for the power plant, yet should be considered because they will be affected by either the construction or operation of the plants such as population and protected areas. The following list covers most of the factors that should be studied and considered in selection of proper sites for power plant construction:

1. Supply of Fuel
2. Geology and Soil Type
3. Availability of Water
4. Availability of Land
5. Transportation Facilities
6. Nearness to Load Centers
7. Distance from Populated Areas

A. Guidelines of Ministry of Environment and Forests

Ministry of Environment Forest (MoEF) has laid down some regulations for Site Selection of Coal based Thermal Power Plants [6]. Those are as follows:

1. Locations of thermal power stations are avoided within 25 km of the outer periphery of the following:
2. Metropolitan cities
3. National park and wildlife sanctuaries
4. Ecologically sensitive areas like tropical forest, biosphere reserve, important lake and coastal areas rich in coral formation
5. The sites should be chosen in such a way that chimneys of the power plants does not fall within the approach funnel of the runway of the nearest airport
6. Those sites should be chosen which are at least 500 m away from the flood plain of river system
7. Location of the sites are avoided in the vicinity (say 10 km) of places of archaeological, historical, cultural/religious/tourist importance and defense installations

B. Guidelines of Central Electrical Authority

Forest or prime agriculture lands are avoided for setting up of thermal power houses or ash disposal.

1. Choice of location is based on the following [7] : - Nearness to coal source
   - Accessibility by road and rail
   - Availability of land, water and coal for the final installation capacity
   - Coal transportation logistics
   - Power evacuation facilities
   - Availability of construction material, power and water
   - Preliminary environmental feasibility including re-habilitation and resettlement requirements, if any
2. Land requirement for large capacity power plant is about $0{:}2km^2$ per 100 MW for the main power house only excluding land for water reservoir (required if any).
3. The land for housing is taken as $0{:}4km^2$ per project.
4. Land requirement for ash pond is about $0{:}2km^2$ per 100 MW considering 50% of ash utilization. Land for ash pond is considered near the main plant area (say 5 to 10

km away). In case of non-availability of low lying ash pond area at one place, the possibility of having two areas in close proximity is considered.

5. Water requirement is about 40 cusecs per 1000 MW.
6. First priority is given to the sites those are free from forest, habitation and irrigated/agricultural land. Second priority is given to those sites that are barren, i.e., wasteland, intermixed with any other land type, which amounts to 20% of the total land identified for the purpose.
7. Location of thermal power station is avoided in the coal-bearing area.
8. Coal transportation is preferred by dedicated marry-go-round (MGR) rail system. The availability of corridor for the MGR need to be addressed while selecting the sites.

4. EXPERT SYSTEMS

Expert Systems (ES) are intelligent systems that emulate the behavior of a human expert as he attempts to solve some complex problem in a particular domain [8]. Expert Systems is historically considered as a branch of Artificial Intelligence, which is an Intelligent Computer program that uses knowledge and Inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions. Expert Systems use knowledge rather than data for controlling the solution process. Knowledge is separated from the control program. So, knowledge can be constantly refined and updated without actually affecting the software. The most popular expert systems are rule-based systems. Rules can represent relations, recommendations, directives, strategies and heuristics. A rule-based expert system consists of five components - the knowledge base, the database, the inference engine, the explanation facilities, and the user interface. The knowledge base contains the domain knowledge useful for problem solving. The knowledge is represented as a set of rules in the form of IF (condition) THEN (action) structure [9]. When the condition part of a rule is satisfied, the rule is said to fire and the action part is executed. The inference engine carries out the reasoning whereby the expert system reaches a solution. The inference engine links the rules given in the knowledge base with facts provided in the database and uses two main strategies to operate - the forward chaining strategy and the backward chaining strategy.

A. Flex

An Expert System Shell can be considered as an Expert System with the knowledge removed. Therefore, all the user has to do is to add the knowledge in the form of rules and provide relevant data to solve a problem[10]. Many Expert Systems are now developed on personal computers using shells. This can eliminate the need for the programmer and also reduce the role of the knowledge engineer. Expert System Shells offer a dramatic reduction in the development time of Expert Systems.

FLEX is an Expert System Shell which is implemented in Prolog. It uses Knowledge Specification Language (KSL) looks much more like Standard English than a programming language. FLEX contains many constructs ideal for building knowledge based systems such as frames, instances, rules, relations, groups, questions, answers, demons, actions, functions etc. FLEX can compile both FLEX and Prolog files.

5. METHODOLOGY

Expert System for Site Selection is developed by using FLEX Expert System Shell. All set of information affecting the selection of site is framed as production rules and fed into the system. The rule only which is relevant to the current context can be applied at a time. The development of Site Selection Expert System has three main phases - Knowledge Acquisition, Knowledge Organization and Knowledge Representation.

All the information such as Regulations laid down by Ministry of Environment Forest, Regulations laid down by Central Electrical Authority, Environmental Impact Assessment Reports of various existing plants, Reports by Central Electrical Authority about Land Requirement Water Requirement, Coastal Regulation Zone Notification from Ministry of Environment Forest for Coastal Power Plants, National Rehabilitation Resettlement Policy from Ministry of Rural Development and advanced technologies recommended for optimization of available resources are gathered as a part of Knowledge Acquisition.

The knowledge acquired from the domain expert and various sources should be organized well in the knowledge base for fast and accurate responses. The knowledge collected from different sources is of different forms. All the knowledge collected in various forms is encoded into production rules. All the knowledge collected from various sources is organized into five modules. The first two modules are of strictly exclusionary criteria whereas the remaining three modules are of details regarding fuel and water availability and accessibility of site. Knowledge is primarily represented in the form of IF ! THEN rules. The if part of the rule is also called as antecedent which contains the condition and the then part is called as consequent consisting of conclusions, which the rule will execute when it is selected and fired.

All the relevant rules are grouped in a rule group and all sets of rules are contained in the ruleset. Action, which acts as the main program for the system prompts the user window in which the end user enters the facts in response to questions and invoke the ruleset which contains relevant rule groupings for the current context.

Forward chaining method of inference is applied for the system which reasons with facts and knowledge available and comes up with accurate solution. The expert system is also able to explain its line of reasoning to the user as part of its inherent characteristics.

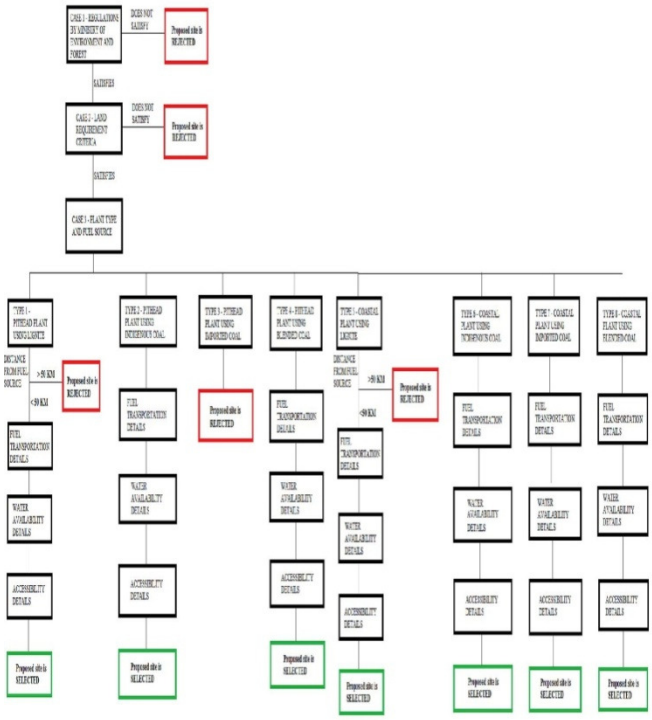

Fig. 1. Decision Tree for assessing site suitability

A. Decision Tree

A decision tree is a way of relating a series of inputs to an output using a series of rules arranged in a tree structure. Fig.1 shows the decision tree for assessing site suitability. A location might be ruled out as completely unsuitable or suitable with some general suggestions. In some cases site can be rejected without performing all the tests. If the proposed site passes through all phases of site selection criteria, it will be selected. The suggestions regarding the latest technologies to be used for the optimal utilization of resources and better efficiency are included at the end of accessibility details. The details regarding the clearances to be obtained are also included at the end.

6. RESULTS AND DISCUSSION

The details about the location being considered will be taken from the user and will be stored in the working memory. Then the inference engine matches the data with the condition part of the rules and the corresponding rules will be fired. The system will ask the questions only which are necessary for decision making. Finally, it will give the corresponding output, whether the site is selected or not. If the site is selected, it will give details regarding the clearances necessary to setup the plant including suggestions to the user on the latest technologies for optimal utilization of the resources and also to improve overall plant efficiency. Otherwise, it will give the reasons to the user for rejection. The sample output window after passing through all the phases of selection is shown in the above Fig. 2.

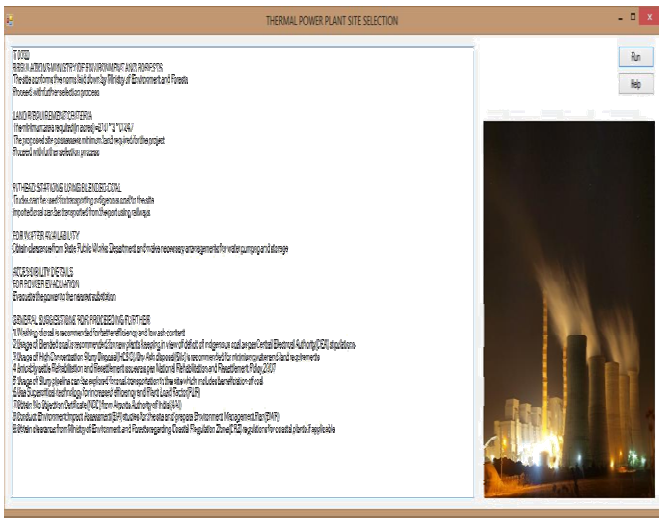

Fig. 2. Graphical User Interface

7. CONCLUSION

Expert System for site selection of thermal power plants using Flex expert system shell has been developed. Knowledge acquired from various sources of books, journals, websites regarding regulations for setting up power plant, minimum land criteria, type of fuel sources, and unit capacities which the power plants follow in the current industrial scenario, accessibility details to the plant, and recommendations of advanced technologies to build a comprehensive knowledge base. Acquired knowledge is organized into modules for easing faster access of the knowledge by the control procedure to give solutions. Knowledge is represented in the form of production rules and is compared with facts given by the user to arrive to a solution using forward chaining inference technique. Flex has proved to be a useful tool in developing an expert system for complex problems. The System has been tested and validated for all possible combinations of the facts given by the user.

8. FUTURE WORK

Expert System developed for site selection of thermal power plants using Flex Expert System Shell represents some point of uncertainty at various stages of site selection process. Issue of uncertainty was not able to be solved by expert system due to its inherent inability in handling uncertain information used in developing the system. The work can be extended with

fuzzy logic which solves the problem of uncertainty, amicably. The project can be extended further to suggest the complete design of the power plant by including the knowledge of the design criteria followed for the commissioning of the power plant into the knowledge base of the system.

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