Site Selection for a Power Plant Using Graph Theory and Matrix Method

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With ever increasing energy demand no site for setting up power plant can be left un-harnessed. Therefore, in the present work a methodology based upon the combination of graph theory and matrix method is developed so that an site may be evaluated in terms of best suitability for setting up a power plant. Factor responsible for best operational performance of a power plant are identified and evaluated in accordance to the site available. The result is represented in the form of index called as site suitability index. High value of suitability index for a plant favors that plant.

1. Introduction

Distributed Generation (DG) unit can be sited near to the power (or heat) demand hub. Due to which energy losses associated with electricity transmission are minimized. Factors related to the DG unit's performance are ownership, module size, interconnection to the power grid, grid interconnection voltage, grid interconnection level (transmission, distribution, customer side of the meter). Distributed generation provides benefits for both the user and the utility provider. The benefits to the user are improved power reliability and quality, reduced total energy cost, barrier against price volatility and reduced environmental impact. In comparison to the other methods of electricity generation, DG unit is more reliable. Therefore, in future it will be more popular than large scale power plants.

While formulating the energy policies for any country the four factors which need to be addressed are: supply security, economic cost, low-carbon emission, and public acceptance. Natural gas has an advantage in which it generates the least amount of atmospheric pollutants such as SO_x, NO_x, and CO_2 among fossil energy sources. Gas-fired power has a better load-following capability compared with other power sources, it can play an important role as a backup power for renewable energies such as wind power or solar power with intermittent characteristics. Additionally, since natural gas is the most suitable feedstock among fossil energy sources for hydrogen manufacturing process, its use is expanding in high efficiency, onsite energy systems based on fuel cells. The principal drawback of natural gas is its high transportation cost in comparison with oil.

Plant erection (civil work), energy conversion efficiency, fuel supply, fuel cost, waste disposal, plant size and maintenance aspects have to be analyzed before hand. Although CCPP or cogeneration is one of the best economical schemes for generating heat and power together still its performance is deteriorated by environmental factors e.g. very low ambient temperature and large fluctuation in temperature. Nuclear power plant is also one of the best alternatives. But its cold start time is more than one week which makes it suitable for base load operations.

Coal based power plants are one of the best source of large scale power generation. As transportation cost for the coal is very high therefore coal based power plant are most efficient near to the coal mines. On the other hand, the largest handicaps for coal are that it generates large amounts of pollutants such as SOx, NOx, soot and dust, or CO_2, and that it creates heavy environmental burdens such as bulky amounts of fly ash and bottom ash after combustion. For this reason, environmental protection measures such as flue gas de-sulfurization and de-nitration facilities or electrostatic precipitator equipment are required.

Large-scale hydropower stations with generation capacities in excess of 1 GW have advantages in economic efficiency; they also have drawbacks including concerns that they could disrupt the native ecosystems and otherwise affect the environment. For this reason, the key issue in the future is to develop and expand the use of "run-of-river" type small scale hydropower installations with capacities up to about 50MWand having a low environmental impact as well as the least amount of CO_2 emissions.

Therefore, it is justified to say that every nature of power plant is not suitable for different locations. For decision making it is a widespread practice all over the world, to employ economic feasibility study before deciding substantial investments on electricity generation projects. The quality of electricity generation plant is associated with voltage and frequency of the generated electricity in comparison with the required standards. The distributed generation is to be considered as an alternative to traditional energy production to prevent power failure and quality improvement. For this alternative, applicability of setting a new power plant and the associated benefits need to be evaluated on a site-specific basis before design stage. Power plant type and quality have a major impact on power plant heat rate, capital cost, generating efficiency, and emissions performance, as well as on the Cost of Electricity (COE).

Electricity generation is series of energy conversion processes and final outcome depends upon the technique followed for the conversion. Among all the useful form of energy electricity is the most abundantly used form of energy with highest availability. In modern era numerous techniques are available for diverse energy sources. The selection of energy conversion process is dependent on many design and operating parameters. Study of these parameters alone is not sufficient for the final selection of the process. It is nature of large scale electricity generation units that their installation at any location is possible only after complete analysis of site, fuel availability, land cost and its type, skills of the labour etc. Although generation capacity for different power plants is different, still their use is made efficiently by transmitting the electric power at the place of utility with the help of grids.

The combination of world-class gas and steam turbine and generator technologies with trend setting power plant system integration results in a highly efficient plant that provides reliable low-cost electricity.

The present work is carried out with a view that a power plant suitable under different set of given conditions has to be finalized so that investors are benefited highest. The decision regarding the energy conversion systems is inefficient without studying all the factors related with cost, maintenance, reliability, availability, efficiency etc. For these factors with a particular site condition it is required to find out best option.

Higher pollution emitting power plants are not suitable in high population density area. Higher fluctuation in temperature leads to decrease in efficiency of gas turbine based power plants. Availability of gas pipe line for Combined Cycle Power Plant (CCPP) and railway line for coal based plant is required for saving transportation cost. Land cost cannot be neglected for the solar plants. Fluctuation in demand can be met more efficiently with power plants of lower capacity. Combined Heat and Power (CHP) is highly efficient if town is near by to supply steam for heating purpose.

Parameters identification, quantification and evaluation are required for the analysis. Maximum outcome of a project, organisation or power plant is possible if best suitability is judged before installation. Further it may be enhanced by considering or analyzing all the factors responsible for performance parameter (e.g. efficiency, reliability, maintainability etc.) at design stage.

2. Graph Theory and Matrix Method

Graph theoretic approach (GTA) is a systematic methodology for conversion of qualitative factors to quantitative values and mathematical modelling gives an edge to the proposed technique over conventional methods like cause-effect diagrams, flow charts etc. Graph theory serves as a mathematical model of any system that includes multi-relations among its constituent elements because of its diagrammatic representations and aesthetic aspects. Graph theory is a logical and systematic approach useful for modeling and analyzing various kinds of systems and problems in numerous fields of science and technology. It is a three stage unified systems approach.

- Modeling of system and subsystem in terms of nodes and edges gives a structural representation in the form of directed graph. This representation is suitable for visual analysis and gives a better understanding of interrelationships among system and subsystems.
- For further analysis, digraph representation is converted to matrix form, which makes it suitable for computational analysis. In the matrix value of each element assigned is based on the inheritance of element itself and its impact on the other performance parameters. However the matrix representation is not unique as changing the labeling of nodes can change it.
- Matrix model is modified according to the suitability of graph theory and results in permanent function model, which is in the expression form. Simplified permanent function expression is represented in terms of a single numerical index which is the indication of system performance.

2.1 Digraph Representation

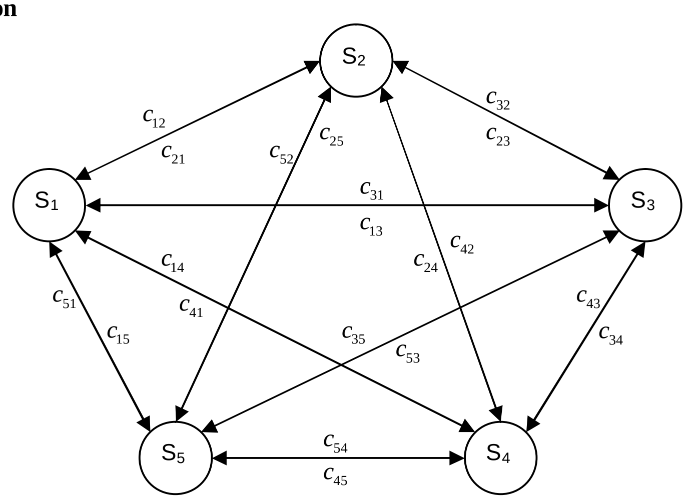

Figure 2.1 *Digraph Representing the five attributes of site Selection and their Interdependencies in the System (attributes: Fuel system (S_1), Cost and Tariff system (S_2), Technical system (S_3), Labour system (S_4) and Land system (S_4))*

A digraph is prepared to represent the different attributes of site selection with interaction amongst them. The digraph consists of a set of nodes $S = \{S_i\}$ with $i=1, 2,\ldots, N$ and a set of directed edges $E = \{c_{ij}\}$. A node S_i represents i^{th} parameter and edges represent the interdependence between parameters. The total of nodes, N, is equal to the number of parameters considered for the attribute. If a node i has relative importance over another node j, then a directed edge or arrow is drawn from node i to node j (c_{ij}). If a node j is having relative importance over i, then a directed edge or arrow is drawn from node j to node i (c_{ji}). In particular five attributes are identified responsible for site selection. If the entire five attribute are affecting each other then it is represented with the help of Figure 2.1. Graph theoretic representation permits the incorporation or deletion of any interconnection or system in order to make it closer to a real life cogeneration cycle power plant based on different design and principles in any given situation. This presentation is very suitable for visual analysis but is not very suitable for computer processing.

2.2 Matrix Representation

A digraph is a visual representation so it helps in analyzing the system to a limited extent only. Because the increase of nodes and edges make the digraph more complex and the visual analysis becomes more difficult. This complicated visualization process is made easy by the matrix representation. Matrix representation of a digraph gives one-to-one representation.
For a general case with n systems, in that case it will be represented as:

$$E = \begin{array}{c} \begin{matrix} i & j & k & -- & m & n & \text{Systems} \end{matrix} \\ \left[\begin{matrix} S_i & c_{ij} & c_{ik} & -- & c_{im} & c_{in} \\ c_{ji} & S_j & c_{jk} & -- & c_{jm} & c_{jn} \\ c_{ki} & c_{kj} & S_k & -- & c_{km} & c_{kn} \\ -- & -- & -- & -- & -- & -- \\ c_{mi} & c_{mj} & c_{mk} & -- & S_m & c_{mn} \\ c_{ni} & c_{nj} & c_{nk} & -- & c_{nm} & S_n \end{matrix}\right] \begin{matrix} i \\ j \\ k \\ -- \\ m \\ n \end{matrix} \end{array} \quad (1)$$

The diagonal elements represent the contribution of attributes in power plant site selection and the off diagonal elements represent interdependencies of each attribute in the matrix. This form of matrix is also known as variable permanent matrix (VPM). This representation is to be developed as permanent function in order to process with computer programming tools.

2.3 Permanent Representation

Both digraph and matrix representations are not unique in nature because they are altered by changing the labels of their nodes. Hence, to develop a unique representation that is independent of labeling, a permanent function of the site selection attribute matrix is proposed here. The permanent is a standard matrix function and is used in combinatorial mathematics (Deo, 2007; Dev et al, 2013 and 2014; Jurkat and Ryser, 1966). The permanent function is obtained in a similar manner as the determinant but unlike in a determinant where a negative sign appears in the calculation, in a variable permanent function positive signs replace these negative signs.

Permanent Function for a general case with n attributes (for matrix expression (1)) is written as per Jurkat and Ryser (1966) formula as:

$$\begin{aligned} Per(E) = {} & \prod S_i + \sum_i \sum_j \sum_k \ldots \sum_m \sum_n c_{ij}^2 S_k S_l S_m S_n \ldots + 2\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right) S_l S_m S_n \ldots \\ & + 2\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{li}\right) S_m S_n \ldots + \sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c^2{}_{ij} c^2{}_{ij}\right) S_m S_n \ldots \\ & + 2\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{lm} c_{mi}\right) S_n \ldots + 2\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right) c_{lm}^2 S_n \ldots \\ & + \sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c^2{}_{ij}\right)\left(c^2{}_{kl}\right)\left(c^2{}_{mn}\right) \ldots + 4\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right)\left(c_{lm} c_{mn} c_{ln}\right) \ldots \\ & + 2\sum_i \sum_j \sum_k \ldots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{li}\right)\left(c^2{}_{mn}\right) \ldots \end{aligned} \quad (2)$$

The permanent of matrix (i.e. equation 1) is a mathematical expression in symbolic form. Equation (2) contains n! terms. The equation (2) contains terms arranged in N+ 1 groups, where N is number of elements. The physical significance of various grouping is explained as under:

- The first grouping represents the effect of all elements.
- The second grouping is absent in absence of self-loops in the digraph.
- The third grouping contains the effect of two-element relative importance loops and the effect of (N − 2) elements.
- The fourth grouping represents the effect of a set of three element relative importance loops or its pairs and effect of (N − 3) elements.

- The fifth grouping contains two sub-groupings. The terms of the first sub-grouping represents the effect of a set of two two-element relative importance loops and the effect of (N − 4) elements. Each term of the second sub-grouping represents the effect of set of four element relative importance loops or its pairs and the effect of (N − 4) elements.
- The sixth groupings contain two sub-groupings. The terms of the first sub-grouping represent the effect of a set of two-element relative importance loops and the effect of three-element relative importance loops or its pairs and effect of (N − 5) elements. The term of the second sub-grouping represents the effect of a five-element relative importance loop or its pairs and the effect of (N − 5) elements.
- Similarly, other terms of the expression are defined.

To calculate this index, the values of S_i and c_{ij} are required. The values of these factors and their interdependence are found on the basis of the production system data available in the organisation and the experience of production personnel. If a quantitative value is not available, then a ranked value judgement on a scale (*e.g.*, from 1 to 10) is adopted. Table 2.1 is suggested for this purpose (Uppadhyay and Aggarwal, 2007; Dev et al 2013a and 2014a). To assign numerical values to the interdependence of parameters c_{ij} the opinions of production experts can be recorded. But this interdependence of parameters cannot be measured directly and, hence, qualitative values may be adopted. These qualitative values of the interdependence of parameters are also assigned on a scale (*e.g.*, 1 to 5), as suggested in Table 2.2.

Table 2.1 *Quantification of Factors Affecting Cogeneration Cycle Power Plant Performance*

S. No.	Qualitative measure of factors	Assigned value of factors S_i
1	Exceptionally low	1
2	Very Low	2
3	Low	3
4	Below average	4
5	Average	5
6	Above Average	6
7	High	7
8	Very High	8
9	Exceptionally High	9

Table 2.2 *Quantification of Interdependencies*

S. No.	Qualitative measure of interdependencies	c_{ij}
1	Very Strong	5
2	Strong	4
3	Medium	3
4	Weak	2
5	Very weak	1

3. Site Selection Factors

Factors affecting the selection of power are very large in number. Therefore, it becomes difficult to study them as a whole. To solve the problem the broad category of factors is divided into following five categories and discussed in detail afterwards:

a) Fuel
b) Cost and tariffs
c) Technical
d) Labour
e) Land

Fuel

The driving vigour for a power plant is the switch of fuel chemical energy into mechanical energy and finally outcome is in the form of electrical energy. Fuel cost is least in the case of hydroelectric power plants. Fuel cost is further dependent upon two factors (1) Fuel availability (2) Calorific Value. Nuclear fuel is very expensive and very small amount of fuel is needed to operate a large power plant. But safety issues are associated with Nuclear power plants. Besides, the developing countries like India are not technically smart enough to develop technology for Uranium separation, operation and maintenance of power plant and finally disposal of radioactive waste. Availability of Geothermal steam is also one of the fortunes because fuel cost and pollution emission is lesser. In India coal is the most abundant fuel. But coal is not a clean fuel. Transportation of coal from mines to the power plant is costly. These problems may be overcome by using coal gasification. Further coal gasification is associated with contamination of ground water. If abundant resources of gas and petroleum are available then CCPP is best option with economical interesting propositions. CCPP is useful if the power generation is in Mega Watts

(MWs). For small capacity requirement of electricity gas turbine, wind mill and solar thermal cell are more useful. In the desert and snow laden area solar cell are the best option. In the sea shore area wind mills are useful if high velocity winds are available. Every parameter is dependent on sub-parameters. Therefore, it becomes difficult for the analysis of impact of different parameters and sub-parameters.

Fuel characteristics affect combined-cycle performance in a variety of ways. High hydrogen content in fuels results into high water content in the combustion products. Water has higher heat content than air or other combustion products, so fuels with high hydrogen content increase output and efficiency. Ash bearing fuels foul the gas turbine and HRSG; therefore, equipment and system design considerations that accept fouling reduce plant output and efficiency. Sulfur content in the fuel may require adjustment in the temperature of the stack gas and the water entering the HRSG economizer to prevent condensation of corrosive sulfuric acid. The increased stack gas temperature required by higher sulfur content decreases output and efficiency. The carbon, moisture, ash, sulfur and energy contents, and the ash characteristics are all important in determining the value of the coal, its use in power generation, the choice of the technology employed, and its transportation and geographical extent of use. Heating value and mine-mouth cost typically vary directly with carbon content, whereas sulfur and ash content vary widely and depend primarily on site-specific geologic conditions. Moisture content normally increases from bituminous coal to lignite. Generating plants designed for high carbon content fuels have a higher generating efficiency and lower capital cost, and could be more effectively designed for CO_2 capture. Coal ash content and properties affect boiler design and operation. High-ash coals causes increased erosion and reduce efficiency, and may be more effectively handled in circulating fluid-bed boilers.

Cost

The price of a power plant mainly comprises the costs of capital construction, operation (repairs and labor compensation), and fuel. In the case of nuclear power plants, we should add the cost of disposing waste and the plant itself. Let us consider construction costs. They include the land price; the costs of territory preparation and premises construction; the cost of equipment of all types, including heat and electricity processing during generation and transmission; the cost of water and air treatment; discharge; design work; and initial costs.

Technology is changing day by day and new and tested technology is needed for the best utilization of resources. Adoption of new technology is associated with investment in terms of man, machine and money. Selection of a single- or multiple-pressure steam cycle for a specific application is determined by economic evaluation, which considers plant-installed cost, fuel cost and quality, plant-duty cycle, and operating and maintenance cost. For energy conversion system, installation and operation cost are both very high. With the awakening about environmental issues, waste disposal cost is also increased. Oil fired combustion engines and gas turbine power plants are associated with lowest cost of installation. But their energy conversion efficiency is also low. An increase in efficiency is achieved due to conversion of these power plants into CCPP.

The price level of power plant construction has risen remarkably during the recent years. The price increase has been caused by the growth of construction costs, the prices of metals (steel, copper and aluminum) and power plant components as well as the unbalance between demand and supply in the field of power plant construction. In addition, the fuel prices have rise rather strongly during the recent years. The general cost growth increases the operation and maintenance costs.

The combined cycle gas turbine plant is assumed to locate near the existing natural gas network so that the connection fee to the existing gas network does not contribute much to the investment cost. The combined cycle gas turbine plant consists of a gas turbine, a waste heat boiler and a steam turbine. The output capacity of the plants is 400 MW and its efficiency 58 %. The investment cost of the combined cycle gas turbine plant is 280 million euro (700 €/kW). The coal-fired power plant is based on pulverised coal combustion and the size of the plant is 500 MW. The coal plant would be located on the sea coast. The plant is equipped with SOx and NOx removal units. The efficiency of the coal power plant equals to 42 %. The investment cost is 650 million euro (1300 €/kW).

For wind power plants, the investment cost level depends on the market volume, competition situation, the project size and the local conditions of the site. The increased demand and the price increase of materials (steel and Aluminium) and components have clearly raised the prices recently. The investment cost of wind mills located on the coast is estimated at 1300 €/kW. Off-shore wind power plants at sea would cost 2000 €/kW. In this study the investment cost of a 3MW coastal wind power plant is assumed to be 3.9 million euro (1300 €/kW). The following fuel prices have been used in this study: nuclear fuel 1,85 €/MWh, natural gas 23,2 €/MWh, coal 11,0 €/MWh, peat 8,90 €/MWh and wood chips 13,4 €/MWh.

The output levels of generators are to be scheduled in a power system to meet demand over a certain period while minimizing the total generation costs. These costs take into account the fuel cost, CO_2-emissions cost and start-up cost and the scheduling of the generators is constrained by their maximum and minimum output levels, ramp rate and minimum up and down times.

Rapid Start, fast ramp rate, improved turndown and fuel flexibility are some of the desired features of a CCPP.

Fuel cost and CO_2-emission cost, together results in the marginal costs of the generators. These marginal costs vary between 100 and 250 €/MWh depending on the generator's efficiency. Start-up costs vary between 1000 and 20,000 € per start-up and are proportional to the size of the generator.

Technical Factors

Operating experience and industrial research show that the operational efficiency and reliability of furnace systems, the explosion safety and operational reliability of dust preparation, the reliability and operating lifetime of heating surfaces, and the amount of nitrogen oxide emissions depend on the degree of uniformity of the distribution of fuel and air over the burners in a furnace. Failure to meet the required fuel-air ratio in the burners leads to a deterioration in ignition stability, reduced fuel burn-up, and increased yield of toxic combustion products. Elevated concentrations of dust in the dust ducts can lead to dust deposits in the ducts or even to blockage of individual lines, which increases the explosion hazard for the system and reduces the productivity of the dust system.

In order to increase their operational reliability, some designs for reinforced concrete smokestacks have an annular air ventilation channel rather than thermal insulation between the reinforced concrete body of the smokestack and the refractory lining, In order to avoid cracking of the lining, the air introduced into the air channel is heated in an air heater to temperatures such that the temperature drop across the lining structure is acceptable.

The criteria for selection of the existing gas turbines included number of factors, main among them included the following: one or more of the required design features already existing, easy analysis procedures for modified gas turbines, advanced technology features such as high firing temperature or newly developed blade aerodynamic design features and wide range of parameters such as overall pressure ratio, turbine inlet temperature and power output.

The power-generating equipment of thermal power plants (TPP) generates noise that may exceed the permissible levels for TPP site and surrounding areas. The characteristics of TPP's noise that distinguish it from other sources are its persistence due to the round-the-clock operation of power plants and the presence of tonal components in the emission spectrum of power-generating equipment of certain types. The operation of combined-cycle and gas-turbine plants, as well as equipment of higher technical specifications increases the sound pressure in the surrounding area. The noise from power-generating equipment is most frequently reduced with silencers and barriers. Silencer designs for power-generating equipment can differ significantly, depending on the type of noise source, noise level, and operating conditions. For example, steam exhausts and gas-turbine air path are characterized by high-frequency noise, while hot-water boilers by low- and mid-frequency noise. When designing a silencer, it is important to consider the presence of tonal components in the noise source. The silencer must possess not only high acoustic efficiency, but also minimum drag. It would be reasonable to design minimum-drag silencers based on numerical modeling of three-dimensional gas flow. The materials used to manufacture silencers should ensure their reliable operation. For example, silencers in gas paths are exposed to low-temperature corrosion, while steam silencers are subject to considerable pressure and temperature differentials.

The noise from the gas-air ducts of hot-water boilers is much weaker than from gas-turbine units and draft fans, its environmental impact is noticeable because of the proximity and great number of residential areas.

Wind installations, in addition to electricity accumulation means, require constant wind speeds of at least 4 m/s. Tidal hydroelectric plants are also strictly local and expensive energy sources.

Grid Disturbance is caused by specific devices of the grid, such as serial capacitor, thyristor-controlled series capacitors (TCSC), and high-voltage direct current (HVDC) system, and the disturbance is interacted between the grid and the generator, which will be significantly amplified under the complementary situation that the sum of the frequency of the grid disturbance and the natural torsional frequency of turbine generator shafts equals (is very close to) the power frequency.

Labour

The primary objective of the present work is to develop a methodology for the power plant design selection that offer high customer benefit through low life-cycle costs.

CCPP exhaust emissions are minimized by the dry low NOx Hybrid Burner Ring (HBR) combustion system.

All three main components (Gas Turbine, Steam Turbine and Turbo- Generator) are arranged on a single shaft. A Synchronous Self-Shifting (SSS) clutch is installed between the generator and steam turbine. This provides high operating flexibility and reliability.

The requirements for power plants are changed highly with the advent of deregulated and liberalized markets. Economic factors, such as life-cycle costs, Net Present Value (NPV) and Internal Rate of Return (IRR) became the customer's focus. During the development of a power plant, according to customer need, modern design methods including Quality Function Deployment, FMEA and Six Sigma are used to achieve customer's satisfaction in terms of investment cost, reliability, availability, lead time and quality. Site specific requirements, such as water supply systems mainly influence the scope outside the Power Block and can easily be adapted. Economic modeling of design variants inside the Power Block, such as redundancy of feedwater and condensate pumps result in a base design that is optimized from the customer's point of view. By optimizing the core of the plant, i.e. the Power Block, only a limited number of variants and options are required. This results in a large number of plants with an identical design of the Power Block.

Application of a steam turbine in conjunction with gas turbine depends on specific cooling conditions, economic evaluation of efficiency and power output. For example, The SST5-3000 incorporates a single flow axial exhaust low-pressure steam turbine providing best economical benefit at medium to high condenser back pressure. The typical application for the SST5-3000 is in combination with a wet cooling tower at ambient temperatures above 12°C or with an air-cooled condenser. While the SST5-5000 incorporates a two-flow low-pressure steam turbine with increased exhaust area, which makes it the choice for low condenser back pressure. The typical application for the SST5-5000 is in combination with once-through cooling or a wet cell cooling tower at ambient temperatures below 12°C.

A combined cycle power plant of 400 MW needs a space of 250m X 200m including fuel tank.

The main building is a compact structural steel building of rectangular design and houses the gas turbine, generator and steam turbine along with their associated components. The main gas turbine auxiliaries are arranged on a steel platform along side the gas turbine. The common lube oil system for gas turbine, generator and steam turbine is arranged at ground floor level. All generator auxiliaries are directly arranged next to the generator either on the main steel platform or on the ground floor. The auxiliary components for the water/steam cycle and the closed cooling water system are located in an annex to the turbine building. The air-intake filter house is located above the annex at the side of the main bay of the turbine building. The filtered air is led straight into the gas turbine compressor by way of an aerodynamically optimized oblique steel-fabricated duct, in which a silencer is installed. Access to the building is provided via the entrance bay next to the turbine-generator set. Adequate access for inspection and maintenance is provided for all main and auxiliary equipment. An overhead traveling crane runs the full length of the turbine building and is capable to lift all the heavy equipment in the building including the generator. Special attention is to be given to provide short moving distances and adequate dismantling and laydown areas for major maintenance operations, as well as good accessibility to buildings and components for maintenance.

The HRSG as well as the annexed feedwater pumps are designed for outdoor installation. The pre-fabricated and pre-tested Power Control Centers (PCCs) for electrical and I&C equipment are located outdoors close to the turbine buildings to ensure short connection runs. The central control room and administration building are arranged close to the turbine building. Layout provisions are made in the plant for a workshop and storage building. A forced-draft cooling tower is arranged behind the turbine building with the circulating water pump also in outdoor installation. In case of once-through cooling, the water intake and outfall structure is designed according to site requirements.

Further it is to be ensured that sufficient water supply is available, effluents may be discharged properly and electrical termination at high-voltage bushing of the generator step-up transformer is available.

The gas turbine, generator and steam turbine can be arranged on a single-shaft basis. The steam turbine is coupled with a SSS clutch to the generator. A Synchronous Self-Shifting (SSS) clutch is located between the generator and the steam turbine. This allows individual gas turbine start-up without the need for cooling the steam turbine. Once the steam parameters match the requirements of the turbine, the steam turbine turns and synchronizes automatically with the generator. The clutch, along with independent gas turbine and steam turbine turning gears, enables the shortest possible time from plant shutdown to gas turbine inspection and maintenance. This design is more beneficial over multi-shaft arrangement in terms of smaller footprint due to a more compact arrangement, higher efficiency (hydrogen cooled generator instead of two air-cooled generators), and higher availability due to fewer components. Performance improvement of a gas turbine is improved by selecting four-stage turbine for moderate stage loading, disk-type rotor with Hirth serrations and central tie bolt for rotor stability, low NOx Hybrid Burner Ring (HBR) combustion system for reduced environmental impacts, dual fuel capability (on-line transfer), variable inlet guide vanes for improved part-load efficiency and all blades removable with rotor in place for easy maintenance and shorter outages.

4. Steps of the Methodology Developed

Following steps are involved in the proposed methodology. By following the proposed methodology site suitability index can be evaluated.

1. Identify the various factors affecting the selection of power plant site. Factors may differ from organisation to organisation depending on the size of organisation, prevailing culture and environmental factors.
2. Group the identified attributes into categories.
3. Develop digraph between the major attribute categories (at system level) depending on their interdependencies. This is the digraph at the system level.
4. Develop digraph for the individual attribute category between the attributes in each category as done in step (3). This is the digraph at the sub-system level.
5. Develop sub-attribute matrix for each category of attribute. This will be of size M × M, with diagonal elements representing attributes and the off-diagonal elements representing interactions among them. Substitute the value of inheritance and interdependency in sub-attribute matrix of each attribute category. The value of inheritance (diagonal element) of attribute is to be decided on the basis of scale 1–9 and value of interdependency is decided by the experts (academia and industries) on the basis of scale 1–5.
6. Compute the value of permanent function for each category of attribute.
7. Develop power plant selection attribute matrix at the system level.
8. Put the value of inheritance and interdependency in attribute matrix of system level. At the system level,
9. The permanent value of each sub-attribute matrix provides inheritance of attribute in power plant selection and quantitative value of interactions among attributes is decided on the basis of scale (1–5) through proper interpretation by experts.
10. Find the value of permanent function for the system. This value of permanent function will provide the intensity of attribute. This is the value of BI_{WCM} which mathematically characterizes the inhibiting strength of various attributes in a particular organisation based on the presence of different attributes and their interdependence.
11. Record the results of study and document them for future analysis.

5. Limitations of Present Study

The present study finds various factors affecting the selection of power plant site are identified and categorized in context to Indian industries. It is well known that no work can be faultless. In this study identification of factors is done through extreme literature review and verified by a questionnaire based survey. The information collected from questionnaire may be erratic. Therefore quality of work depends upon the information collected.

6. Scope for Future Work

The gap in the existing work always creates an opportunity for further work. Further more in future new attributes may arise and present attributes may not behave as attributes. The result of the present study is qualitative in nature; therefore in future a mathematical model may be developed to get quantitative results. For the quantification of factors fuzzy modelling may also be applied.

7. Conclusion

In the present work factors affecting the power plant site selection are identified and categorized into five classes. These five classes are also incorporating some sub-factors which are affecting these factors. For the analysis a methodology based upon Graph Theory and Matrix Method (GTMM) is proposed. This methodology is considering the inheritance and interdependencies in-between the factors. Therefore, the solution is veered to real life situation.

8. References

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