This chapter deals with the step-wise procedure of the total system design (TSD) methodology for a thermal power plant. The total system design model consisting of seven phases is proposed and the details of the model are explained. This TSD procedure provides commercially viable design information i.e. compatible with the available manufacturing facility as an output starting from an initial concept. It is shown that a system tool is necessary to consider systems / subsystems / components and interactions among them in various stages and the steps of the design process. An illustrative example to understand the TSD is carried out for the boiler subsystem of the thermal power plant. The conventional design process is compared with the TSD process to highlight the various advantages of the Total System Design.

4.1 INTRODUCTION

The design of a power plant system is one of the important functions for Design Engineers. The approach for the system design affects the initial and operating costs as well as the system reliability. The methodology of arriving at an optimal power plant design is complex, not only because of the arithmetic involved, but also because of many qualitative judgments that have to be considered. Thus the entire design project must be broken down into several sub problems which are then treated independently. Each of the sub-system can be considered as a problem of optimum design, Arora [1989].

The quality of final design is not just conformance to specifications and avoidance of errors, but includes the customer satisfaction. Dubensky [1993] underlined the various aspects of simultaneous engineering of the automotive design process. Nordeen [1993] explained that total quality has evolved into Total Quality Management (TQM) by placing more importance on prevention of pre-production processes, designed-in quality and quality in every activity of an organization. Shilke and Rohde [1989] proposed a systems approach which integrates all aspects of production definition, design, manufacturing and use. This approach is required to
engineer complex systems using today’s computer-aided tools and rapidly-advancing analytical techniques. Oakland [1993] developed a Total Quality Management (TQM) model for an organization.

The available literature reveals that in the present environment, the total quality management (TQM), concurrent engineering and system approach are to be considered in design context in order to achieve high quality and low cost with less lead-time. Therefore, in this chapter, an extensive study is carried out to evolve a design methodology for a thermal power plant using the system and quality approach.

4.2 ROLES OF INTERDISCIPLINES IN POWER GENERATION

Engineers are responsible for the design, construction, and operation of power plants. The engineering staff of a utility company takes the lead in developing the load forecasts for the future. They may employ specialists in the field to develop the forecast. An electrical system load study may be prepared to determine the most feasible additions to transmission facilities and generation facilities. The final report leads to the selection of general area location, size, and scheduling of generation installations. These forecasts are generally long range and are updated periodically.

Engineering feasibility studies must be made to determine the type of generation to be installed. This usually involves the examination of drawings of conceptual plant arrangement showing fuel supply access, condensing water arrangements, transmission line access, construction cost estimates, construction schedules, cash flow, and estimates of fuel costs and operating costs of various alternatives. An architect-engineering firm is usually selected to perform the preceding site and feasibility studies. The construction cost estimates at this stage are ‘preliminary’ and new revised estimates must be made from time to time. After the site has been selected, and the necessary permits and finances have been obtained by the utility company, the actual plant design begins. Again, an architect-engineer (A-E) firm is selected to perform this design service. The design of a steam thermal power plant requires the services of a large number of engineers of many different disciplines. The actual number varies with the type and complexity of the plant. A nuclear plant design would require hundreds of engineers by the architect – engineer firm alone.
Table - 4.1 shows different engineering disciplines involved in the design of a coal fired steam power plant.

The architect-engineers staff serves as application engineers, fitting together and shaping the many different components into a working system. The suppliers and manufacturers of the individual components have an engineering staff separately to design their respective equipments.

Since time is of the paramount importance in the power plant design and its construction, the design function must take several courses simultaneously. One major engineering function that must commence in the early stages of the design process is the preparation of purchase specifications for the principal equipments. Time must be allowed to give a feedback to design engineers if some clarification or any modification in the manufacturing of a component is felt so that they could complete their job.

Manufacturer lead time is a major element in the scheduling process, and forms a part of the "critical path" of engineering and construction schedule. The order of priority and the assigned engineering discipline for the preparation of the principal specifications is usually as follows:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Engineering Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine-generator</td>
<td>Mechanical and electrical</td>
</tr>
<tr>
<td>Steam-generator</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Condenser and auxiliaries</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Feed-water heaters</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Boiler feed pumps and drivers</td>
<td>Mechanical and electrical</td>
</tr>
<tr>
<td>Main transformers</td>
<td>Electrical</td>
</tr>
<tr>
<td>Electrical switchgear</td>
<td>Electrical</td>
</tr>
</tbody>
</table>

These purchase specifications may require revisions before final purchase orders are placed to accommodate adjustments required by system design studies or other developments. These studies probably would include:

Feed-water cycle arrangements, including number of heaters
## TABLE – 4.1

### ENGINEERING INVOLVEMENT IN THERMAL POWER PLANT DESIGN

<table>
<thead>
<tr>
<th>PRINCIPALS</th>
<th>APPLICABLE ENGINEERING DISCIPLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
</tr>
<tr>
<td>Utility company</td>
<td>Y</td>
</tr>
<tr>
<td>Regulatory commissions</td>
<td>Y</td>
</tr>
<tr>
<td>Architect – engineer</td>
<td>Y</td>
</tr>
<tr>
<td>Steam generator manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Turbine generator manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Coal handling equipment</td>
<td>Y</td>
</tr>
<tr>
<td>Condenser manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Ash-handling equipments</td>
<td>Y</td>
</tr>
<tr>
<td>Pump manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Water treatment manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Waste treatment manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Fan manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Pollution control manufacturer</td>
<td></td>
</tr>
<tr>
<td>Feed water heater manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Piping valve manufacturer</td>
<td>Y</td>
</tr>
<tr>
<td>Switchgear manufacturer</td>
<td></td>
</tr>
<tr>
<td>Instrumentation and control</td>
<td>Y</td>
</tr>
<tr>
<td>Electric motor manufacturer</td>
<td>Y</td>
</tr>
</tbody>
</table>

### Abbreviations Used:

- **CON** - Consultant
- **MECH** - Mechanical
- **AR** - Architect
- **CHD** - Civil - Hydraulic
- **CCC** - Civil - Concrete
- **CST** - Civil - Structural
- **EE** - Electrical
- **EL** - Electronics
- **CHE** - Chemical
- **ENV** - Environmental
- **I&C** - Instrumentation and Control
- **Y** - Yes

56
Condenser and cooling tower optimization
Boiler feed pumps: number, sizing, and method of driving
Deaerating heater
Feed-water heater terminal differences, and drain cooler approaches
Boiler forced and induced draft fan drives
Major pipe sizing

The preparation of purchase specifications and system design studies require engineering input from engineers employed by various manufacturers. The analysis of proposals received in response to the issuance of the purchase specifications for equipment for the plant is also a major function of the architect - engineer staff. This culminates in the preparation of purchase orders, and revising the initial specifications as required, after the analysis of proposals.

The Architect - Engineer Company begins with the drawings for the plant layout, showing equipments locations and specifying outlines as soon as preliminary equipment drawings are available from the principal manufacturers. Then, a “Plot Plan” drawing is made for the orientation of the plant on the site. Also locations are developed for soil test borings for foundations by the civil-concrete engineers. The civil-structural engineers prepare their steel framing drawings, while the Architects prepare plan for various buildings, offices and other services. Mechanical engineers prepare piping diagrams. Electrical engineers prepare the details of auxiliary power supply system. To finalize the above tasks frequent conferences are held with the utility company staff engineers and the various manufacturers. Preparation of drawings for construction purposes constitutes the most time consuming design effort by all engineering disciplines. Computerized design and drafting have been developed in recent years in order to save time, improve accuracy, and coordinate the efforts of those who are preparing construction drawings in the same general physical area.

The engineering and design of a coal-fired power plant unit of large capacity (500 to 800 MW) may require as many as 800,000 hours time of the Architect - Engineer staff, which includes engineers, clerical, purchasing, expediting, and shop inspection staff. Also considerable man-hours are expended by utility company engineering staff and by many manufacturers' engineering staff.
A quality assurance program must be established at the beginning of the design process and extended through construction to plant operation. During construction, engineers of the various disciplines serve as liaison between the architect-engineer design staff and the construction staff. Engineers must check the accuracy of installation and perform quality control.

4.3 SYSTEM DESIGN APPROACH

As discussed above, the design of a thermal power plant requires the services of a large number of engineers from the different engineering disciplines. The design function must take several courses simultaneously. The quality of system design affects the initial and operating cost as well as the system reliability. A general system design flow chart can be represented as shown in Fig. - 4.1.

System simulation is the calculation of operating variables for the system under various conditions. System simulation assumes the pre-knowledge of the performance characteristics of all components. Simulation is used when it is not possible or not economical to observe the real system. To search for the optimal design, system simulation must be exercised. In the power plant system design, optimization generally means a search process for a system design that will have an optimal performance. More specifically, the optimal system is a system that will result directly or indirectly in low production cost and improved performance. Also, at the same time the optimal design will have an acceptable impact on plant environment.

The inputs to the system design include, along-with the problem statement or specification, the component design information and constraints. The problem statement may specify a general goal of the system under consideration. Since the system consists of many components, the component information must be known and available as input. The system design procedure will generate feasible solutions. In the next step, scheme must be developed to search for the optimum solution.

4.4 TOTAL SYSTEM DESIGN AND QUALITY

Quality is regarded as one of the major factors for competitiveness. Actually quality should be an attitude. The exercise of this attitude with in the whole collection
A GENERAL SYSTEM DESIGN FLOW CHART

FIGURE – 4.1
of activities of an organization is known as TQ Control that requires the existence of a quality system for the implementation of quality management which is responsible for coordinating the actions towards quality in all departments in order to attain the desired quality in the final product. Design plays a key role in quality function. In fact the quality and design have identical objectives.

Designing for quality requires, first of all, a comprehensive understanding and evaluation of the needs from which the specifications for the product design are formulated. Ability is one of the elements of product specifications. This has been pointed out by Pugh [1989] who stresses in his work the importance of the specifications for the design activity. In a further work he discussed the specific aspect of quality in the design process.

In the design stage, the consideration of quality aspects was initially done with the inclusion of the quality characteristics into the specifications. The incorporation of quality characteristics into product design specifications is part of the quality function deployment used by some companies. Kogure and Akao [1983] discussed some of the features of the quality function deployment. One of the obstacles that may be encountered is the difficulty to quantify some of these features. Recent developments in the fields of reliability, tolerances and process capability make possible to define, by means of measurable specifications, several characteristics that could not be quantified before.

Quality is also introduced at the design phase. Techniques like Failure Mode and Effect analysis (FMEA) and Fault Tree Analysis (FTA) provide designers the means to predict consequences of faults or failures in the design as well as operating stage. Simulation, a prediction tool, can be applied throughout whole design process.

In recent years, Taguchi methods have drawn attentions of the researchers. These methods apply statistics to evaluate the combined effect of design parameters in order to minimize the variation of performance characteristics around the target values. The variation is considered to be directly proportional to the quality losses caused by the product. The main features of Taguchi methods are the philosophy of off-line control and the use of statistics for planning experiments and analyzing data. These methods are applied after the conceptual stage is over in the design process.
Other means of quality assurance during the design phase are, for instance, inhouse or field tests with models and prototypes. The current importance given to the quality leads to the impression that in order to achieve quality, design has to be done in a different way but it is not so. If design is done properly in the first place, good quality will be a consequence and thus it require a total and integrated approach which leads to the need for Total System Design.

A step by step procedure is developed to carry out the plant design. The design process needs to be evaluated at each and every phase of design which is important due to fast growing technical advancements, new manufacturing techniques and increasing demands for power. The Total System Design model is developed and is shown in Fig. – 4.2. Here each and every phase is evaluated and if necessary the previous phase is repeated with some modifications. This is also important to consider new environmental and regulatory constraints, if any. The different phases considered in this proposed model are:

1. Concept
2. Problem Formulation
3. Functional Specifications Representation
4. Conceptual Design
5. System Design
6. Synthesis and Optimization
7. Design Presentation

4.4.1 Concept

The concept is the basic idea coming in the designer's mind. For any design activity, the concept is the basis that can be developed, modified and tested and to achieve the goal.

4.4.2 Problem Formulation

The phase begins with the market research. In market research, the feasibility of the concept has to be justified. The design teams are likely to lack an awareness of essential search areas and knowledge of market information processing procedures.
A TOTAL SYSTEM DESIGN MODEL

FIGURE – 4.2
A structured approach is developed for thorough processing of market information in order to establish a definitive design specification. This approach comprises a number of steps with the emphasis on obtaining the full spectrum of information, establishment of a comprehensive information base and its subsequent synthesis and analysis.

4.4.2.1 Information Processing

Information may be regarded as the 'life – blood' of a design. Therefore, it must be considered as a major activity which must be planned, organized and controlled. A profile approximately to the dotted line, shown in Fig. – 4.3, results, if the information input is considered in relation with the core phases of design. However, whereas greater importance is attached to the first two phases of the design there is a fundamental significant change in the profile and it takes the shape similar to the solid line.

Information processing is regarded as commencing with the realization of a need and is not complete until either the required information is in a form which forwards the project or else is not obtainable. The main steps in market information processing are defined as:

a. Clarify objective
b. Search, locate and obtain
c. Synthesis and analysis

Clarifying the objective is often overlooked with the subsequent waste of time and effort resulting in vague and incomplete activity. In contrast, clear objective helps the subsequent process by providing additional viewpoints and keywords so vital to effective information gathering.

4.4.2.2 Search, Locate and Obtain

Factors which influence the plant environment are many, varied and interactive. They include technology, market strategies, human factors, statutory requirements, corporate goals and social/political/economic factors etc. In order to
VARIATION IN INFORMATION INPUT DURING THE DESIGN ACTIVITY

FIGURE – 4.3
accommodate these factors and to assess their influence on the project, it is essential
to obtain information in the following areas.

1. Business and Statistical
2. Competitive and Analogous Plants
3. Standards, Codes, Regulations and Legislation
4. Books, Papers and Reports
5. Manufacturing Facilities
6. Specialists
7. Buyers and Users

1 Business and Statistical

This category includes collection of information on the availability of market sectors and sizes, competitors and their activities. Such information is required in order to identify the market trends and to relate the competitors' performances.

2 Competitive and Analogous Plants

Competitive and analogous plants are existing plants which either compete with the proposed design or provide a comparable function. Acquisition of knowledge of competitive plants and/or other conventional and non-conventional sources of energy generation is vital in the design of a plant.

3 Standards, Codes, Regulations and Legislation

Standards, codes of practice, regulations and legislation are collectively the various technical and legal requirements and are to be met. Their significance is usually self evident and design teams need to consider the various levels such as local, national and international requirements.

4 Books, Papers and Reports

Books, papers and reports are the published works from experts, academicians, researchers and others providing a wide variety of material
including background, plant surveys and latest developments, etc. for design team, a variety of useful information can be gleaned from the enormous amount of published literature.

5 Manufacturing Facilities

Manufacturing facilities are the available processes and materials required for commissioning of a plant. Design teams need to be aware of the scope of facilities available and also the constraints in order to execute the design for compatibility with proposed manufacturing facilities.

6 Specialists

Specialists are individuals and organizations which have gained an expertise on plants. The design team needs social as well as technical skills to gather information from specialists.

7 Buyers and Users

Buyers and users are the people most concerned with the different uses of power like residential, industrial or commercial. Their views are one among the most vital sources of information.

4.4.2.3 Synthesis and Analysis

It is the crucial stage in information processing and is used to identify patterns and trends which will lead to compilation of the design specifications. It is essential to employ systematic methods and techniques as an aid to the synthesis and analysis of information in order to ensure that the maximum benefit is being obtained and deductions made with an acceptable level of confidence. The systematic synthesis and analysis of information is very important in the current environment with the rapid growth in the information available to design teams. The main steps to be taken in information synthesis and analysis are Organization, Categorization, Structuring and Deduction and are realized as being interactive and iterative.
4.4.2.4 Planning Programme

Before going to the actual design stage, the designers have to formulate the objectives and other planning programs. The objectives of the plant design process are formulated based upon design variables, cost, performance functions and constraints etc.. The corresponding plant objectives are created by clarifying design objectives, sub objectives and the relationships between them. Then, the review and impact analysis are carried out to finalize the final objectives of the plant design. Next step is to provide plant design practice codes and procedures. The structure and control of the system for managing the plant design is fully described and documented. This includes control of specifications. The different design activities of the plant design are assigned to systems, teams and tools.

4.4.2.5 Design Review Procedure

The work of designers needs to be controlled where it affects the work of others, including subsystems/components design activities. Hence, the organization and technical interfaces are identified for controlling them. Then, the plant design review procedures are established to ensure that the design meets the specified requirements and that progress is being made towards the objectives. This will require a system for the timely identification of problem areas.

This problem formulation phase is represented by a flow chart and is given in Fig. – 4.4.

4.4.3 Functional Specifications Representation

Functional specifications contain all the facts relating to the final outcomes of the system. It should try to avoid ‘leading’ the design and predicting this outcome, but nevertheless it should also contain the realistic constraints to be imposed upon the design by either the company or the market. The design functional specifications are the fundamental control mechanism which helps success to be achieved. To be successful, one has to be systematic and thorough, paying meticulous attention to detail from the beginning to the end of the total design activity. This phase is represented in Fig. – 4.5.
CONCEPTS AND PROBLEM FORMULATION PHASE

FIGURE - 4.4
FUNCTIONAL SPECIFICATIONS REPRESENTATION PHASE

FIGURE - 4.5
The main aim of this phase is to establish the required functions and the system boundary of a new plant design. Firstly, the input and output requirements of the plant design are identified in terms of performance, cost, use, aesthetics, quality, technical details and the reliability etc. Similarly, the output requirements of the plant design are identified and defined. The plant requirement specification is created from these input and output requirements of the plant design. These specifications are further used to identify the various functions of the plant system and/or its subsystems/components and the final objectives obtained in the previous phase are allocated to each. The next step is to establish technological principles, sequence of operations and technical processes for each of the functions subject to the constraints imposed because of their interactions by identifying critical functional interactions. Further, these functional interactions are optimized. Now the generic subsystems are identified and the functional requirements are allocated to these subsystems. This procedure has to be extended up to the component level. The functional structure, thus prepared, is tested to find out whether generic subsystems satisfy all the functional requirements or not. If further optimization is not possible, then, next step namely creation of functional specifications is done that will give all functions required for the plant with the corresponding generic subsystems after considering all the factors including interactions.

4.4.4 Conceptual Design Phase

Once the functional requirements are specified, various kinds of knowledge are processed to generate design concepts. The conceptual design phase is given in Fig. – 4.6.

4.4.4.1 Candidate Conceptual Design

Pham and Yong [1993] represented the design concepts symbolically in terms of five components: sub-systems, spatial relationships, connectivity, functionality and processes. Interactions are the ways in which various sub-systems of a plant affect one another. A description of these interactions which highlights qualitative differences regarding how alternative plants work is known as interaction topology / structural relationships of the sub-systems. Such a topology describes a network of sub-systems, the connections implemented and the interactions and behaviors produced.
CONCEPTUAL DESIGN PHASE

FIGURE - 4.6
A candidate topology is then proposed by tracing paths through the existing topology and relating the desired variables. The proposed candidate plant is subjected to a verification process which will determine whether or not the combined behavior of the interactions in the candidate plant, produces the desired interactions.

4.4.4.2 Design Specification and Alternative Solutions (D Spec.)

As soon as the topology is finalized the results of the previous step are summarized in a set of specifications of desired output which the system must be capable of producing in order to satisfy the requirements. These design specifications are created, identifying the required performance attributes and stating precise performance requirement for each attribute.

The next phase of the conceptual design deals with the generation of different alternative design solutions satisfying the prescribed design specifications. Potentially suitable alternative solutions are evaluated for the feasibility of the design.

4.4.4.3 Design Reviews

All feasible plant design solutions are reviewed by a design team. The aim of design reviews is to establish that:

1. The design of the plant will meet all specified plant performance criterion.
2. All possible alternatives have been considered.
3. All statutory requirements will be met.
4. There is adequate documentation to define the design and how the plant is to be operated and maintained.

4.4.5 System Design

In system design phase as explained in Fig. – 4.7, the system approach is applied to analyze the alternative plant design solutions. Various mathematical techniques are used for evaluation, comparison and selection of an optimal design solution analyzing each and every alternate design solution considering various subsystems, components and their interdependencies.
System Design

Structural Analysis of Alternative Solutions

Perform Reliability Analysis

Perform Quality Analysis

Evaluate Design Solutions and Select One

Analyze Evaluated Design Solutions for Further Improvement

Likely?

Yes

No

Design Reviews

OK?

No

Yes

Synthesis and Optimization

SYSTEM DESIGN PHASE

FIGURE - 4.7
In the beginning, various analyses such as structural analysis, reliability analysis and quality analysis etc. are carried out for alternative design solutions. Then, the developed methodologies namely Graph Theoretical Methodology and Multiple Attribute Decision Making Methodology are applied for evaluation and selection process. The selected plant design solution is then analyzed for any further improvement.

4.4.6 Synthesis and Optimization

The researches are going on the design process usually from an engineering design point of view. Since this research is mainly into existing practice, thus has resulted in erudite papers and books which add to diagnostics talk but give little guidance on curing the disease. Keeping in consideration of this fact the strategy of total system design has been developed which is defined as the systematic activity necessary from the identification of the market of user need to the selling of the success product to satisfy the need of the customer. The main aim of this is to convert the selected optimum design solution into commercial viable design solution which is competent enough to satisfy the customers' need producing desired product based on several factors such as aesthetics, imitation, value analysis, maintainability, reliability, environmental considerations, performance and technical processes etc.. This phase is shown in Fig. – 4.8.

4.4.6.1 Design Models

The design models are developed on computer for synthesis and optimization. Using this model, the performance of the individual subsystems and components are optimized with consideration of their interactions and other statutory constraints of environment, aesthetics, government policies, generation, safety and ergonomics etc.

4.4.6.2 Technical Process and Material Selection

The materials which are able to perform the required operations under appropriate conditions such as physical, thermal, chemical etc. are evaluated using various techniques like MADM and GTM. The selection of materials is carried out separately for individual components. Then, the technical processes are investigated
SYNTHESIS AND OPTIMIZATION PHASE

FIGURE - 4.8
for safety, aesthetics and environmental implications etc. and are selected for each and every operation that has to be performed.

4.4.63 Test and Validation

Now the plant design testing and evaluation is to be done. All the testing and validation are carried out using expert systems and GTM, by real time simulation. The expert system acts as an engineer, by creating the plant with corresponding process designs in the computer and simulates the actual condition. The whole test and validation is done on the computer screen using the expert system. Hence, the tedious, time consuming and expensive test and validation procedures are eliminated.

4.4.7 Design Presentation Phase

Finally, in this phase, the plant design is presented in a convenient manner. The detailed drawing of the plant design are prepared using computer software like AutoCAD, Catia etc. and are transmitted in the desired form (preferably digital) to manufacture various subsystems and components using CAD/CAM integration. In the last, the design quality manual is prepared which is a document in which the complete procedures of total system design methodology of the plant i.e. how the system operates to achieve the general goals are detailed. This design quality manual may be used as a reference to carry out the design process in order to achieve the high quality plant design at every time; a new design is developed for a plant using this procedure.

4.5 CASE STUDY (BOILER)

The boiler is a main component in the power plant. Although the boiler is usually designed to provide steam at the desired temperature and pressure to the turbine yet there are certain other predominant factors like efficiency, availability and total cost that must be considered if a satisfactory design of the boiler is to be carried out. The factors are inter related and can be explained as under.

i. The steam conditions at the turbine throttle are well defined for each generating system. The increase / decrease in the steam temperature from the design value will adversely affect the boiler and turbine materials and efficiencies.
ii. As in the main steam pipe, pressure drop in the reheater and its piping must be appropriately balanced against the initial cost.

iii. The firing equipments should be so chosen that there will be a minimum amount of unburned carbon in the ash and virtually complete combustion in the furnace. Air infiltration to the boiler should be minimum, because it results in additional loss to the chimney and, thus, to the steam generating system.

iv. Furnace size and shape should be so designed that the mixture of fuel and air will have sufficient residence time for complete combustion. Too much energy results in high chimney temperature and, thus, reduces boiler efficiency. On the other hand, if the furnace exit temperature is too low, there will be more heat transfer surface requirement and some corrosion of the metal in the air heater.

v. Fuel selection is usually determined on the basis of its availability and cost. The characteristics of the fuel have important influences in the boiler design.

vi. The temperature of the flue gases entering the superheater and reheater should be lower than the ash fusion point to avoid undesirable slag ash deposits.

vii. The boiler should have its availability as such that it would not lower the availability of the entire plant. Poor availability leads to choking of flue gas in tube banks, ash deposits and even failure of pressure parts.

viii. Like other major subsystems in the power plant system, the boiler should be efficient and reliable. In addition, the boiler must be compatible with other components in such a manner that it would result in a lowest production cost.

To illustrate total system design (TSD) methodology to achieve total design quality, a subsystem of the thermal power plant, boiler, is taken as an example to explain its different steps. There are three main inputs i.e. fuel, air and water. Only fuel and air interact directly before combustion; water interacts indirectly with the products of combustion.
4.5.1 Conventional Design Procedure

In the conventional design procedure, the various steps of the design procedure are carried out in a sequential manner.

1. The task of the design process is decided by the market research activity. This includes the specifications.

2. The management will decide the project proposal with the budget for different activities.

3. Conceptual Design:
   i. The problem formulation is the first step in this stage. Here, the overall characteristics of the boiler house are decided.
   ii. The various functions of sub-systems of the boiler house are identified.
   iii. The different alternative solutions for each sub-system are generated.

4. Detailed Design:
   i. Evaluation and selection of best alternative design solution.
   ii. To carry out the detailed design procedure for different subsystems by different organizations.

5. The sub-system design is tested and validated for specified requirements of the particular design.

6. From steps 1 to 5, only the product design of the boiler is carried out, not the corresponding process design. The corresponding process design is done separately for the various components of the sub-systems. This will increase the lead-time in design process.

4.5.2 Total System Design Procedure

In the total system design procedure, the various steps of the design procedure are carried out in a simultaneous manner and are:
First the concept i.e., to develop an organization to design the complete boiler subsystem of the plant is inspired by an individual or group of people.

The viability/market availability for the particular type of boiler subsystem is identified by the market research team based on:

a. Interaction with various manufacturers to assess their requirements.

b. Identification of the prospective customers to assess their expectations and need.

c. Identification of the strong and weak points of the available boiler subsystems.

d. Incorporation of new technology and advancements.

The complete boiler design and development planning program is developed by considering the design variables: cost function, constraints, business and corporative objectives, design codes and practices etc.

The requirements according to IBR regulations are created by identifying the design input and output requirements.

Now the various functions of the sub-systems of the boiler subsystem are identified for example the required temperature and pressures etc.

The functional (requirements) specifications for these sub-systems are to be tabulated and documented properly for reference throughout the design procedure.

The different candidate conceptual designs for the boiler subsystem are proposed and the specification required for various sub-systems are decided and documented as design specifications.

For design specifications, various alternative design solutions are generated and evaluated to find the feasible solutions. These design solutions are reviewed for any further improvements.
The reliability and quality analyses of all the alternative design solutions are carried out using system concept from system to component level to select the best one among them.

The complete design procedure of the boiler subsystem is reviewed for any further improvements, if possible.

The real time design analyses are carried using detailed design and control models of boiler subsystems. Here, the performance of individual sub-systems and components are optimized considering their interactions. The available new materials are evaluated for each and every component under appropriate conditions and the best material is selected.

Depending upon the components and their materials, their corresponding production processes are evaluated and selected. The individual design is carried out to optimize the aesthetic, ergonomic and safety aspects.

The final optimization of the complete design process is carried out. The test and validation is done for each component & for boiler subsystem as a whole.

Finally, the boiler subsystem design output is presented in an appropriate form using CAD soft wares, i.e., 2D/3D models, etc.

In general, the comparison between the conventional design process and total system design process are carried out and tabulated in Table - 4.2.

4.6 CONCLUSIONS

The following conclusions can be drawn from this chapter:

1. The Total System design model provides a comprehensive view of the total design process of the thermal power plant.
2. It is found useful to identify various design teams, support systems and tools to carry out the total system design of the plant.
3. The quality of system design affects the initial and operating costs as well as system reliability and quality.

4. The procedure for total system design provides commercially viable design information as an output starting from the initial concept of the plant. It has been established that a system tool is necessary to consider system/subsystems/components and their interactions in various phases of the design process.

5. It is found from the comparison of the conventional design and total system design procedure for the boiler subsystem that the TSD methodology provides the completeness of the design process.
## TABLE – 4.2

### CONVENTIONAL DESIGN AND TOTAL SYSTEM DESIGN – A COMPARISON

<table>
<thead>
<tr>
<th>S. No.</th>
<th>CONVENTIONAL DESIGN</th>
<th>TOTAL SYSTEM DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carried out in sequential manner.</td>
<td>Carried out in simultaneous manner.</td>
</tr>
<tr>
<td>2</td>
<td>The influence of the management of the organization is not taken into account.</td>
<td>Every aspect of the management of the organization is considered.</td>
</tr>
<tr>
<td>3</td>
<td>The various teams, systems and tools are not specified.</td>
<td>The various teams, systems and tools are specified.</td>
</tr>
<tr>
<td>4</td>
<td>The product design and process design are done independently.</td>
<td>Both product and process designs are designed simultaneously.</td>
</tr>
<tr>
<td>5</td>
<td>There is no interaction between various design groups/organizations designing various components.</td>
<td>The design activities of various design groups/organizations are properly coordinated.</td>
</tr>
<tr>
<td>6</td>
<td>The real time testing is carried out after the production of the sub-system. Hence any modification will cost more.</td>
<td>The various system analyses to find out system characteristics are carried out using real time simulation techniques, so that the product need not be tested after production.</td>
</tr>
<tr>
<td>7</td>
<td>Even though the aim is to achieve a high quality design output, the quality awareness is not there in the design processes, teams, etc.</td>
<td>High quality design output is the main object of the design process. The quality is achieved at each and every design steps.</td>
</tr>
<tr>
<td>8</td>
<td>The design process, the management concerns, production processes, marketing, etc. are taken as different works of the organization.</td>
<td>The design process includes each and every works of the design organization.</td>
</tr>
</tbody>
</table>