Steam Power Plant Overview: Components, Application and Design

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***Abstract*— The world utilizes energy from various sources of energy such as fossil fuels, wind, solar, wind hydroelectric and tidal energy. The market demand of energy and high competitiveness of energy producers requires strategic power plants and systems which are efficient. Steam power plant is a low-cost power plant which generates power continuously and respond rapidly to changing loads whilst meeting high energy demands. The location and design of a steam power plant requires minimum space and can be located near the load center whilst reducing transmission losses. The steam power plant contains multivariable and interactive process and boiler technology is one of the processes which requires a well-designed system. The boiler working fluid absorbs the heat of combustion from the burning of coal and converts the water into steam. This article provides an overview of steam power plant which is a fossil-fuel power plant whilst focusing on application design and configuration of steam power plant**

Keywords*— steam power plant, energy, boiler, coal, electrical generator

I. Introduction

A thermal power station or a steam power plant is a power plant in which the prime mover is steam driven [1]. It consists of a fuel source, boiler, steam turbine, generator and other auxiliaries. Water is heated at high temperatures by the heat generated by the boiler thus turns into steam and spins a steam turbine which convert steam into mechanical energy. The generator then converts mechanical energy to electrical power, forming a cycle known as the Rankine cycle. The Rankine cycle consists of the generation of high-pressure steam, turbine, condenser and finally a pump. A Rankine cycle is the ideal cycle for vapour plants thus it includes four reversible processes known as isentropic compression, cost P heat addition, isentropic expansion and cost P heat rejection [2]. The greatest variation in the design of thermal power stations is due to the different fuel sources. Some prefer to use the term energy center because such facilities convert forms of heat energy into electricity. Some thermal power plants also deliver heat energy for industrial purposes, for district heating, or for desalination of water as well as delivering electrical power. According to Stappato and co-workers there is need to have strategic steam power operations which can evaluate costs, electric power market , creep, thermo-mechanical fatigue and corrosion[3]. According to Stevanoic and co-workers plant flexibility can be upgraded by steam accumulator storage which provides primary and secondary power control[4]. The functionality and layout of the steam will be discussed in detail in this paper.

II. STEAM POWER PLANT FUNCTIONALITY

Steam power plants are normally utilized in to generate electricity using the fuel generated from coal. The fact that it produces steam it is also used in the industries which require sterilization, heating, repulsion, atomization, humidification and moisturization. The functionalities of a steam power plant are boiler, steam turbine, electrical generator and condenser shown by Figure I.

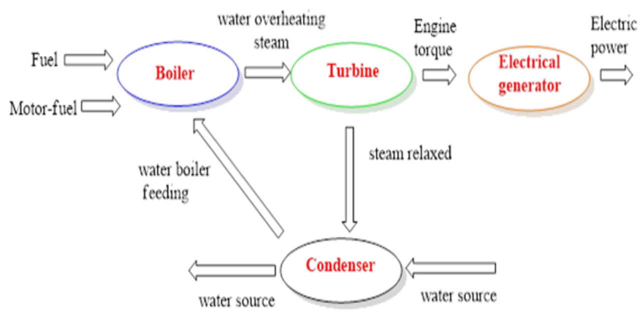

Figure I: General layout of the composition of a steam power plant.

A. Boiler

A boiler is an important part of a steam power plant and it can be divided into three systems namely the feed water system, steam system and fuel system[5], [6]. The fuel system serves the combustion fuel and require high safety measures to avoid explosion and fire. The various parts of the boiler should be accessible for repair and maintenance with capacity to supply steam according to the required requirements. To permit efficient operation, the boiler absorbs maximum amount of heat produced due to burning of fuel in the furnace. The important components of a boiler are discussed below:

Steam separating drum – The feed water from the hot well is stored in the drum. The steam is separated from water in the drum and the steam is usually collected at the top of the drum.

Circulating pump – Water from the steam separating drum is drawn by a circulating pump and it circulates water through the evaporator tubes. Pump circulates water at a rate of 8-10 times the mass of steam evaporated. Forced circulation is necessary to prevent the overheating of tubes.

Distribution header – The distribution header distributes the water through the nozzle into the evaporator.

Radiant evaporator – Water from the drum first enters the radiant evaporator through the pump and header. The water is heated by the radiation heat from the combustion chamber. In radiant evaporator, the hot flue gases do not pass over the water tubes.

Convective evaporator – The mixture of water and steam coming out from the radiant evaporator enters the convective evaporator tubes. The hot flue gases passing over the evaporator tubes transfer a large portion of heat to the water by convection. Thus, water becomes steam, and the steam enters to the steam separating drum.

Superheater – The steam from the steam separating drum enters the superheater tubes where it is superheated by the hot flue gases passing over them. The superheated steam then enters the steam turbine to develop power.

Economizer – The waste hot flue gases pass through the economizer where feed water is pre-heated. By pre-heating the feed water, the amount of fuel required to convert water into steam is reduced.

Air pre-heater – The hot flue gases then passes through the air pre-heater where the air required for combustion is pre-heated.

Boiler efficiency is calculated by dividing boiler output by boiler inputs and multiplying by 100. The inputs and outputs are determined by instruments and the resulting data is used for determination of fuel-to-steam efficiency. The boiler efficiency can be improved by preheating combustion air, installing an economizer, cleaning the boiler and lowering the stack temperature [7], [8].

B. Steam turbines and Condenser

The steam from the boiler super-heated and fed to the steam turbine through the main valve. The heat energy from the steam is converted to mechanical energy which is responsible for driving the turbine [8]. After the heat energy is converted to mechanical energy, the steam is exhausted to the condenser which cools the exhaust gases by means of cold-water circulation. Steam turbine efficiency is calculated by using the ratio of heat equivalent of mechanical energy transferred to turbine shaft to the heat of combustion of coal. The higher the steam turbine efficiency the lower the consumption of coal hence the reduction of production cost of electrical energy.

C. Electrical generator

The generator is connected on the same axis to the steam turbine thus it is responsible for the conversion of mechanical energy of the turbine into electrical energy. The generated electrical energy is delivered bus-bars through transformers, isolators and circuit breakers. The electricity generation by means of steam turbine power plants is projected to grow due to increase in industrial, commercial and residential consumption. The frequency of black-outs, load shedding and power cuts have significantly contributed to the increase in demand of electricity generated from steam turbines..

III. CONCLUSION AND FUTURE PERSPECIVE

The generation of electricity from steam power plant is dependent on the performance and efficiency of the plant. The performance parameters measure how the electricity is being produced and suggests ways to improve the system. Though steam power plant has proven to be an efficient way to generate electricity, there are challenges associated with thermodynamic efficiency. There is need to find way to improve heat rate of a steam power plant.

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