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Operation and Maintenance Schedule of a Steam Turbine Plant

(A Case Study of Egbin Thermal Power Station)

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ABSTRACT

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Thermal electrical power generation is one of the major methods used in Egbin thermal station. Due to inconsistency and failure in the power supply in Nigeria, there is a need for a proper operation and maintenance schedule strategy of the various kinds of power plants accessories so as to facilitate their efficiencies and functionality.

Egbin thermal station, which is one of the major power generating stations in Nigeria was used as a case study. The station has an installed capacity of 1320 MW consisting of 6 units of 220MW each. It is in the generating sector of the Power Holding Company of Nigeria (PHCN) which is the state owned Electric Power company. Egbin thermal station was commissioned on 11th May, 1985.
Thermal electrical power generation is one of the major methods, used in Egbin thermal station. The major components of Egbin thermal station are boiler, steam turbine, condenser and the feed pumps.

The objective of this research was to study and enumerate profound solutions in order to minimize the risk of failure and effectively manage the reliability of the substation equipment, stemming from a proper maintenance strategy.

The operation and maintenance of Egbin Thermal station was examined and the conclusion was that it was challenged with insufficient Gas supply and restrictions, poor water quality and breakdown of two units due to boiler explosion in 2007, causing power generating plant to be shut down creating a 880 Mega Watts drop in power generation in the whole country. This occurrence has had a massive setback on the power plant, hence a proper maintenance strategy needs to be designed to curb the effect and develop a long lasting solution to prevent further potential disaster.

Keywords: Power supply in Nigeria, steam turbine, thermal station, operation and maintenance Schedule of thermal station

CONTENTS

1. INTRODUCTION

This chapter gives a short introduction to the research subject and describes the classification of the power plant, existing power plants, location and their generated power in Nigeria. A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After which it passes through the turbine, the steam is condensed in a condenser; this is known as the Rankine cycle.

Steam turbines are devices used to convert the pressure energy of high pressure steam to kinetic and hence electrical energy in power plants and certain types of engines. While steam turbines might be one of the more revolutionary inventions in the power generation and conversion industry. High performance steam turbines of today are specialized in their design and incorporate many efficiency increasing technologies.

Steam turbine maintenance is of high importance to keep the steam turbines efficiency high and to conform to safety standards to avoid any unforeseen dangers. The steam turbine operates under high steam pressures, and has a number of moving parts that move at extremely high velocities. The nozzles and turbine blades are designed via careful analysis and the parts are manufactured to a high degree of finish and accuracy.

A steam power plant continuously converts the energy stored in fossil fuels i.e. coal, oil, etc. or fossil fuels e.g. uranium, thorium into shaft work and ultimately into electricity. The working fluid is "water" which is sometimes in the liquid phase and sometimes in the vapor phase during its cycle of operations.

A fossil fuelled power plant is an example of bulk energy converter from fuel to electricity using "water" as the working medium. The energy released by the burning fuel is transferred to water in the boiler to generate steam at high temperature, which then expands in the steam at high temperature, which then expands in the steam turbine to a low pressure to produce shaft work. The steam leaving the turbine is condensed into water in the "condenser" where cooling water from a river or sea circulates, carrying away the heat released during condensation. The water (condensate) is then feedback to the boiler by the pump and the cycle goes on repeating itself.

Steam turbine power plants operate on "Rankine cycle" for the production of electric power. If the steam from the waste heat boiler is used for process or space heating, the term "cogeneration" is the more correct terminology (simultaneous production of electric and heat energy).

Steam turbine plants generally have a history of achieving up to 95% availability and can operate for more than a year between shutdowns for maintenance and inspections. Their unplanned or forced outage rates are typically less than 2% or less than one week per year. Modern large steam turbine plants (over 500MW) have efficiencies of about 40-45%. These plants have installed cost between $800 (441 euros) and $2000/KW (1500 euros), depending on environmental permitting requirements.

This paper presents an assessment of the state of the thermal plants in Nigeria, with a view to suggesting solutions to remedy the deteriorating states of the plants, in order to improve the power supply system in the country.

1.1 The major components of a steam power plant

- Turbine (High, Intermediate and Low pressure).
- Boiler (Economizer, Evaporator, Drum and Super heater).
- Generator
- Condenser
- Feed pumps

1.1.1 Steam turbine

Steam turbines are machines that are used to generate mechanical (rotational motion) power from the pressure energy of steam. Steam turbines are the most popular power generating devices used in the power plant industry primarily because of the high availability of water, moderate boiling point, cheap nature and mild reacting properties. The most widely used and powerful turbines of today are those that run on steam. From nuclear reactors to thermal power plants, the role of the steam turbine is both pivotal and result determining.

A steam turbine is basically an assemblage of nozzles and blades. Steam turbines are not only employed to operate electric generators in thermal and nuclear power plants to produce electricity, but they are also used (a) to propel large ships, submarines and so on, and (b) to drive power absorbing machines like large compressors, blowers, fans and pumps.

Turbines can be condensing or non-condensing, depending on whether the back pressure is below or equal to the atmospheric pressure. For small units without reheat, the steam turbine may consist of a single turbine when the steam expanding through the turbine exhausts to a condenser or a process line. For a large unit without reheat, the steam may expand through an initial section and then exhaust to a condenser or to a process. The initial turbine is designated as the high-pressure (HP) turbine and the second turbine the low-pressure (LP) turbine.

For a single reheat cycle, the steam from the boiler flows to the HP turbine where it expands and is exhausted back to the boiler for reheating. The reheat steam coming from the boiler flows to the intermediate-pressure (IP) or reheat turbine where it expands and exhausts into a crossover line that supplies steam to double-flow LP turbine (O. I. Okoro, and T. C. Madueme, Renewable Energy, vol. 29, pp.1599-1610, 2004).

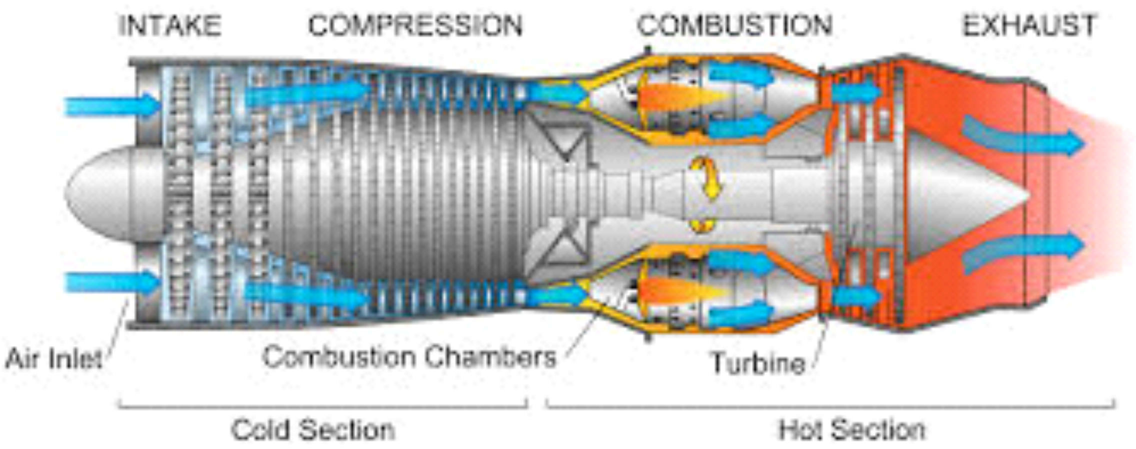

Figure 1a. Steam turbine

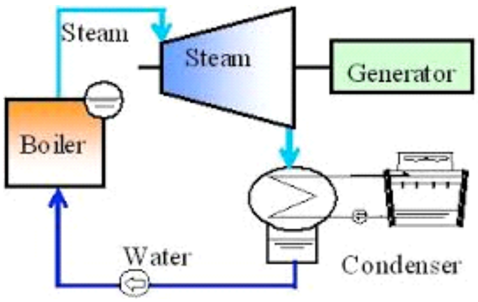

Figure 1b. Condensing steam turbine

1.1.2 Boiler

A boiler generates steam at the desired pressure and temperature by burning fuel in its furnace. Boilers are used in both fossil-fuel and nuclear-fuel electric generating power stations. A boiler is a complex integration of furnace, super heater, reheater, boiler or evaporator, economizer, and air preheater along with various auxiliaries such as pulverizers, burners, fans, stokes, dust collectors and precipitators, ash-handling equipment, and chimney or stack. The boiler is where phase change (or evaporator) occurs from liquid (water) to vapour (steam), essentially at constant pressure and temperature (The Control of Boilers, 2nd Edition, Sam G. Dukelow, 1991).

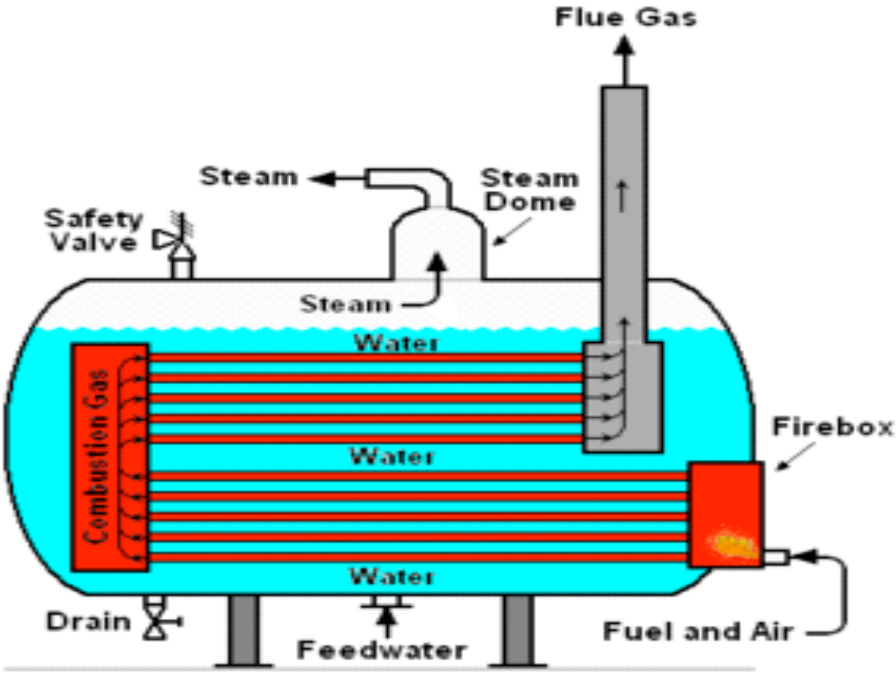

Figure 2. Boiler

The components of a boiler include

- **Economizer**: An economizer is a heat exchanger which raises the temperature of the feed water leaving the highest pressure feed water heater to about the saturation temperature corresponding to the boiler pressure. This is done by hot flue gases exiting the last super heater or reheater at a temperature varying from 370°C to 540°C.

- **Evaporator**: is where phase change occurs from liquid (water) to vapour (steam), essentially at constant pressure and temperature.
- **Drum:** Made from high carbon steel with high tensile strength and its working involves temperatures around 390ºC and pressures well above 350 psi (2.4MPa). The separated steam is drawn out from the top section of the drum and distributed for process. Further heating of the saturated steam will make superheated steam normally used to drive a steam turbine.

Saturated steam is drawn off the top of the drum and re-enters the furnace in through a super heater. The steam and water mixture enters the steam drum through riser tubes, drum internals consisting of demister separate the water droplets from the steam producing dry steam. The saturated water at the bottom of the steam drum flows down through the down comer pipe, normally unheated, to headers and water drum. Its accessories include a safety valve, a water-level indicator and level controller. The feed-water of the boiler is also fed to the steam drum through a feed pipe extending inside the drum, along the length of the steam drum.

A steam drum is used without or in the company of a mud-drum/feed water drum which is located at a lower level. A boiler with both steam drum and mud/water drum is called a bi-drum boiler and a boiler with only a steam drum is called a mono-drum boiler. The bi-drum boiler construction is normally intended for low pressure-rating boiler while the mono-drum is mostly designed for higher pressure-rating(Fundamentals of Engineering Thermodynamics" Moran and Shapiro, Published by Wiley).

- **Super heater:** The super heater is a heat exchanger in which heat is transferred to the saturated steam to increase its temperature. It raises the overall cycle efficiency. In addition it reduces the moisture content in the last stages of the turbine and thus increases the turbine internal efficiency. In modern utility high pressure, more than 40% of the total heat absorbed in the generation of steam takes place in the super heaters. So large surface area is required for superheating of steam (Pearsons, Sir Charles A, “The Steam Turbine” p.20-22).

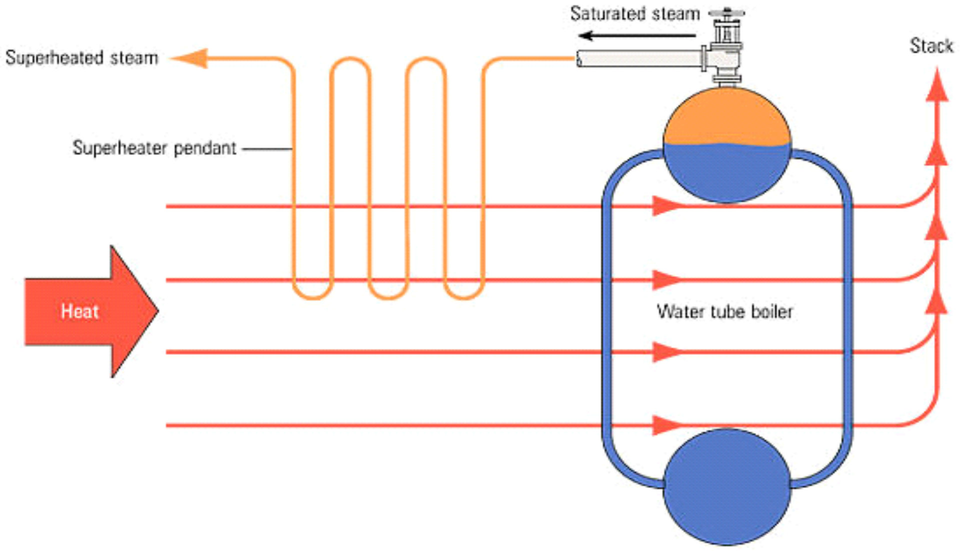

Figure 3. Superheater

1.1.3 Condenser

- **Condenser**: The condenser condenses the steam from the exhaust of the turbine into liquid to allow it to be pumped. If the condenser can be made cooler, the pressure of the exhaust steam is reduced and efficiency of the cycle increases. The surface condenser is a shell and tube heat exchanger in which cooling water is circulated through the tubes. The exhaust steam from the low pressure turbine enters the shell where it is cooled and converted to condensate (water) by flowing over the tubes. Such condensers use steam ejectors or rotary motor-driven exhausters for continuous removal of air and gases from the steam side to maintain vacuum. For best efficiency, the temperature in the condenser must be kept as low as practical in order to achieve the lowest possible pressure in the condensing steam. Since the condenser temperature can almost always be kept significantly below 100 °C where the vapor pressure of water is much less than atmospheric pressure, the condenser generally works under vacuum. Thus leaks of non-condensable air into the closed loop must be prevented. Typically the cooling water causes the steam to condense at a temperature of about 35 °C (95 °F) and that creates an absolute pressure in the condenser of about 2–7 kPa (0.59–2.1 in Hg), i.e. a vacuum of about -95 kPa (−28.1 inHg) relative to atmospheric pressure. The large decrease in volume that occurs when water vapor condenses to liquid creates the low vacuum that helps pull steam through and increase the efficiency of the turbines. The limiting factor is the temperature of the cooling water and that, in turn, is limited by the prevailing average climatic conditions at the power plant's location (it may be possible to lower the temperature beyond the turbine limits during winter, causing excessive condensation in the turbine). Plants operating in hot climates may have to reduce output if their source of condenser cooling water becomes warmer; unfortunately this usually coincides with periods of high electrical demand for air conditioning (Wichtmann, A., Wechsung, M., Rosenkranz, J., Wiesenmüller, W., Tomschi, U., Flexible Load Operation and Frequency Support for Steam Turbine Power Plants, VGB PowerTech 7/2007, pp. 49-55).

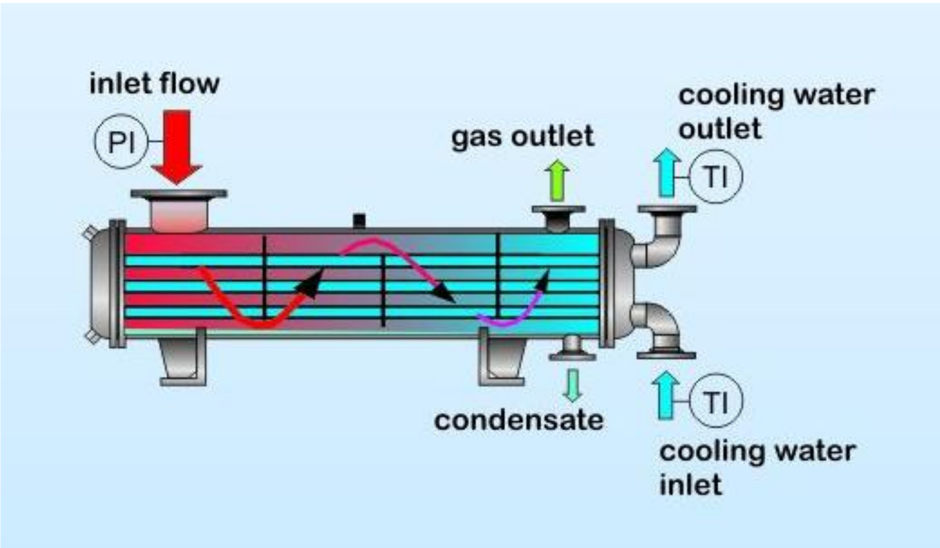

Figure 4. Condenser

The condenser generally uses either circulating cooling water from a cooling tower to reject waste heat to the atmosphere, or once-through water from a river, lake or ocean. The heat absorbed by the circulating cooling water in the condenser tubes must also be removed to maintain the ability of the water to cool as it circulates. This is done by pumping the warm water from the condenser through either natural draft, forced draft or induced draft cooling towers that reduce the temperature of the water by evaporation, by about 11°C to 17 °C (20 to 30 °F)—expelling waste heat to the atmosphere. The circulation flow rate of the cooling water in a 500 MWe unit is about 14.2 m^3/s (225,000 US gal/min) at full load. The condenser tubes are made of brass or stainless steel to resist corrosion from either side. Nevertheless they may become internally fouled during operation by bacteria or algae in the cooling water or by mineral scaling, all of which inhibit heat transfer and reduce thermodynamic efficiency. Many plants include an automatic cleaning system that circulates sponge rubber balls through the tubes to scrub them clean without the need to take the system off-line. The cooling water used to condense the steam in the condenser returns to its source without having been changed other than having been warmed. If the water returns to a local water body (rather than a circulating cooling tower), it is tempered with cool 'raw' water to prevent thermal shock when discharged into that body of water. From the bottom of the condenser, powerful condensate pumps recycle the condensed steam (water) back to the water/steam cycle.

- Feed pumps: These are pumps that conveys treated feed water under pressure to the boiler for its operation of generating steam (Thomas C. Elliott, Kao Chen, Robert Swanekamp (coauthors) (1997). Standard Handbook of Power plant Engineering (2nd edition ed.). McGraw-Hill Professional).

1.2 Classification of power plant

Conventional

Steam Engines

Steam Turbines

Diesel

Gas Turbines

Hydro-Electric

Nuclear

Non conventional

Thermoelectric Generator

Thermionic Generator

Fuel- cells

Photovoltaic Solar Cells

Fusion Reactor

Biogas, Biomass Energy

Geothermal Energy

Wind Energy

Ocean Thermal Energy Conversion

Wave and Tidal Wave

Energy Plantation Scheme

All the above mentioned power plants are classified according to the ways in which steam is being generated. Some of the ways are explained below.

Nuclear Power Plant uses a nuclear reactor's heat to operate a steam turbine generator.

Geothermal Power Plant uses steam extracted from hot underground rocks.

Renewal Energy Plan may be fuelled by waste from sugarcane, municipal solid waste, land fill methane or other forms of biomass.

In Integrated Steel mills, a blast furnace exhaust gas is a low cost although low energy density fuel.

Waste heat from industrial processes is occasionally concentrated enough to use for power generation, usually in steam boiler and turbine.

Solar Thermal: electric plants use sunlight to boil water which turns the generator.

Fossil fuelled power plants may also use a steam turbine generator or in the case of natural gas fired plants many use a combine turbine.

Fossil fuel power plants are designed on a large scale for continuous operation. In many countries, such plants provide most of the electrical energy used.

A fossil power plant always has some kind of rotating machinery to convert the heat energy of combustion into mechanical energy, which then operates an electrical generator. The mover may be a steam turbine, a gas turbine or in small isolated plants, a reciprocating combustion engine.

By- products of power plant operation need to be considered in both the design and operation. Waste heat due to the finite efficiency of the power cycle must be released to the atmosphere, often using a cooling tower, or river or lake water as a cooling medium. The flue gas from combustion of the fossil fuels is discharged to the air; this contains carbon dioxide and water vapour, as well as other substances such as nitrogen, nitrous oxides, sulphur oxides, and (in the case of coal-fired plants)fly ash and mercury. Solid waste ash from coal-fired boilers must also be removed, although some coal ash can be recycled for building materials. Gas burning is much simpler as the fuel is ready for combustion and requires no preparation. The other advantages are:

- Cleanliness
- Ease of control of furnace temperature
- Ability to produce a long slow burning flame with uniform and gradual heat liberation
- Ease of temperature regulation

Natural gas is used for steam generation in gas producing areas or in areas served by gas transmission lines and where coal is costlier. The proportioning, mixing and burning of gas air mixture can be achieved in many ways. Natural gas is often informally referred to as simply "gas", especially when compared to other energy sources such as electricity. Before it can be used as a fuel, it must undergo extensive processing to remove almost all materials other than methane. The by-product of that processing include ethane, propane, butanes, pentanes, and higher molecular weight hydrocarbons, elemental sulphur, and sometimes helium and nitrogen.

Natural gas is the major source of electricity generation through the use of gas turbines and steam turbines. Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. Natural gas burns cleaner than other fossil fuels such as oil and coal and produces less CO per unit energy released. For the equivalent amount of heat, burning natural gas produces about 30% less than carbon-dioxide than burning petroleum and about 45% less than burning coal.

1.3 Existing power stations, location and their generated power in Nigeria

- Egbin thermal station, Lagos: 1320MW
- Afam thermal station, Rivers: 969MW
- Sapele thermal station, Delta: 1020MW
- Ijora thermal station, Lagos: 40MW
- Kainji hydro station, Niger: 760MW
- Jebba hydro station, Niger: 578.4MW
- Shiroro hydro station, Niger: 600MW
- Ajaokuta thermal station: 110MW
- Okpai thermal station : 480MW
- Omotosho thermal station: 335 MW
- Geregu thermal station: 414MW

- Omoku thermal station: 150MW
- Delta thermal station: 954MW
- Olorunshogo thermal station: 335MW
- AES thermal station: 315 MW

Table 1. Summary of generation capabilities of PHCN power stations as operated in the year 2010 (Jan-Dec).

Plant	Operator	Age (Year)	Type	Installed Capacity (MW)	Average Availability (MW)	Availability Factor	No of Units installed	Current No Available
Kainji	PHCN	38 to 40	Hydro	760	438.86	0.58	8	6
Jebba	PHCN	25	Hydro	578.4	529.40	0.92	6	4
Shiroro	PHCN	22	Hydro	600	488.82	0.81	4	4
Egbin	PHCN	23	ST	1320	694.97	0.53	6	5
AES	AES	7	GT	315	233.91	0.77	9	9
Ajaokuta	STS	NA	GT	110	24.88	0.23	2	2
Sapele	PHCN	26 to 30	ST/GT	1020	156.60	0.15	10	1
Okpai	AGIP	3	GT/ST	480	394.56	0.88	3	3
Afam	PHCN	8 to 45	GT	980	82.12	0.09	20	3
Delta	PHCN	18	GT	954	211.67	0.24	18	12
Geregu	PHCN	NA	GT	414	305.14	0.74	3	3
Omoku	RS	3	GT	150	87.27	0.87	6	4
Omotosho	PHCN	1	GT	335	256.58	0.77	8	2
Olorunsogo	PHCN	1	GT	335	271.46	0.81	8	2
Total				8351.4	4176.24	8.39	152	60

- Source: NCC Oshogbo

Egbin thermal station will be used as a case study here. The generating unit in Egbin thermal station is made up of a boiler, a turbine, and its accessories and a generator section. The plant works on 6 units, a unit generates 220MW. Five men run a unit. Egbin thermal station is not a combined cycle power plant; rather it is a steam power plant. Gas is what is used to convert water to steam in the boiler.

2 POWER PLANT

A power station is an industrial facility for the generation of electric power. Power plant is also used to refer to the engine in ships, aircraft and the other large vehicles.

Some prefer to use the energy center because it more accurately describes what the plants do, which is a conversion of other forms of energy. However, power plants is the most common term in the U.S, while elsewhere power station and power plant are both widely used, power station prevailing in many common wealth countries and especially in the U.K.

At the center of nearly all power stations is a generator, a rotating machine that converts mechanical energy into electrical energy by creating relative motion between a magnetic field and a conductor. The energy source harnessed to turn the generator varies widely. It depends chiefly on which fuels are easily available and the types of technology that the power company has access to.

Figure 5. Egbin thermal station.ijede

2.1 HISTORY ON MAJOR TYPES OF POWER PLANT

2.1.1 Steam Power Plant

Steam is referred to as 'vaporized water' in physical chemistry. It is, in its purest form, invisible and gaseous. It is better understood as the condensing 'mist' seen above water at boiling point. The hot vapor or steam is nothing but droplets of water and has the power to move objects and run complex gadgetry. Since the very beginning of recorded history, experiments with steam to understand its properties have been conducted. Probably the first pot of boiling liquid witnessed intrigue setting in. The inherent power of steam to heat and empower movement was used but never defined in a scientific manner.

Steam powered turbines are mentioned in the 1551 Taqi al-Din. Steam power was also harnessed for a number of experiments, like Thomas Savery's water pump in 1698. However, frequent explosions kept the experiments within laboratories, till the advent of the Industrial Revolution in the eighteenth century. In 1712, Thomas Newcomen designed the atmospheric engine using steam power. Steam was additionally used to pump water, drain mines and work water-wheels. In 1800, steam was used to generate high-pressure for transport related applications. The race to create better and smaller manufacturing techniques with the help of steam power never stopped since. The first major revelation and defined recording of steam power came with James Watt's development of the Watt engine since the 18th century. This coal powered engine ran on generated steam. Management of coal made the design relatively cheap to use.

The next step was the designed mechanism to generate a rotary motion. This added value to the make-shift and rudimentary factory machinery. Once steam power was harnessed to address needs further away from a water source, factories were constructed away from rivers. This accelerated the production levels during the Industrial Revolution. Steam power also enabled the strength of condensation to create the 'vacuum'.

However, the main forces of scientists and engineers after the industrial revolution was the use of steam turbines to produce electricity by moving the armature arms of the electrical generator. The very first commercial central electrical generating stations in New York and London, in 1882, also used reciprocating steam engines.

As generator’s sizes increased, eventually turbines took over due to high efficiency and lower cost of construction. By the 1920s any central station larger than a few thousand kilowatts would use a turbine prime mover.

Steam power was successfully used to franchise engines till the advent of electric motors. All through the initial stages of the Industrial Revolution, steam power relieved power generated by animal and employees. Slowly, steam power sanctioned the presence of locomotives, steam ships and heavy duty furnaces. In fact, steam technology was the answer to the smelting requirements of the base metal during the Industrial Revolution - iron. Engine-building fostered favorable ground for engineering partnerships and this in turn fueled the demand for steam technical centers to solve related problems within the machine tool applications.

Steam power plants earned patents and dedicated markets. Radical improvements and improved engine efficiency led to savings that kept manufacturers and clients happy. Steam power added quality to the working of the atmospheric engine, blast furnace, lathe machines and boilers. Today, it is not so difficult to imagine the smallest steam engine, generation of electricity, without adding to pollution levels, clean fuel transportation modes or steam powered thermal energy. These and other 'steam' wonders enable a work environment that is not only quieter and cleaner, but also fuel efficient and easy on space. The modern era has redefined the use of steam. It is no more something that is lost in the kitchen that manifests full potential in an industrial environment. In human practices, Steam saunas for weight loss and the transfer of heat generated by steam power for cooking, fabric cleaning and central heating systems are quality enhancing aspects of our adopted lifestyles.

Thermal power plants have big boilers that burn fuel to make heat. A boiler is like a teapot on a stove. When the water boils, the steam comes through a tiny hole on the top of the spout. The moving steam makes a whistle that tells you the water has boiled. In the power plant, the water is brought to boil inside the boiler and then piped to the turbine through very thick pipes.

In the most boilers, wood, coal, oil or natural gas is burned in a firebox to make heat. Running through the firebox and above that hot fire are a series of tubes with water running through them. The heat energy is conducted into the metal pipes heating the water in the pipes until it boils into steam (Wichtmann, A., Wechsung, M., Rosenkranz, J., Wiesenmüller, W., Tomschi, U., Flexible Load Operation and Frequency Support for Steam Turbine Power Plants, VGB PowerTech 7/2007, pp. 49-55).

2.1.2 Gas Power Plant

Gas turbine, also called a combustion turbine, is a rotary engine that extracts energy from a flow of combustion gas. It has an upstream compressor coupled to a downstream turbine, and a combustion chamber in-between. Gas turbine may also refer to just the turbine component.

Energy is added to the gas stream in the combustor, where fuel is mixed with air and ignited. In the high pressure environment of the combustor, combustion of the fuel increases the temperature. The products of the combustion are forced into the turbine section. There, the high velocity and volume of the gas flow is directed through a nozzle over the turbine's blades, spinning the turbine which powers the compressor and, for some turbines, drives their mechanical output. The energy given up to the turbine comes from the reduction in the temperature of the exhaust gas.

Energy is extracted in the form of shaft power, compressed air and thrust, in any combination, and used to power aircraft, trains, ships, generators, and even tanks (Pearsons, Sir Charles A, “The Steam Turbine” p.26-31).

2.1.3 Hydropower plant

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants. Worldwide, an installed capacity of 777 GWh supplied 2998 TWh of hydroelectricity in 2006. This was approximately 20% of the world's electricity, and accounted for about 88% of electricity from renewable sources.

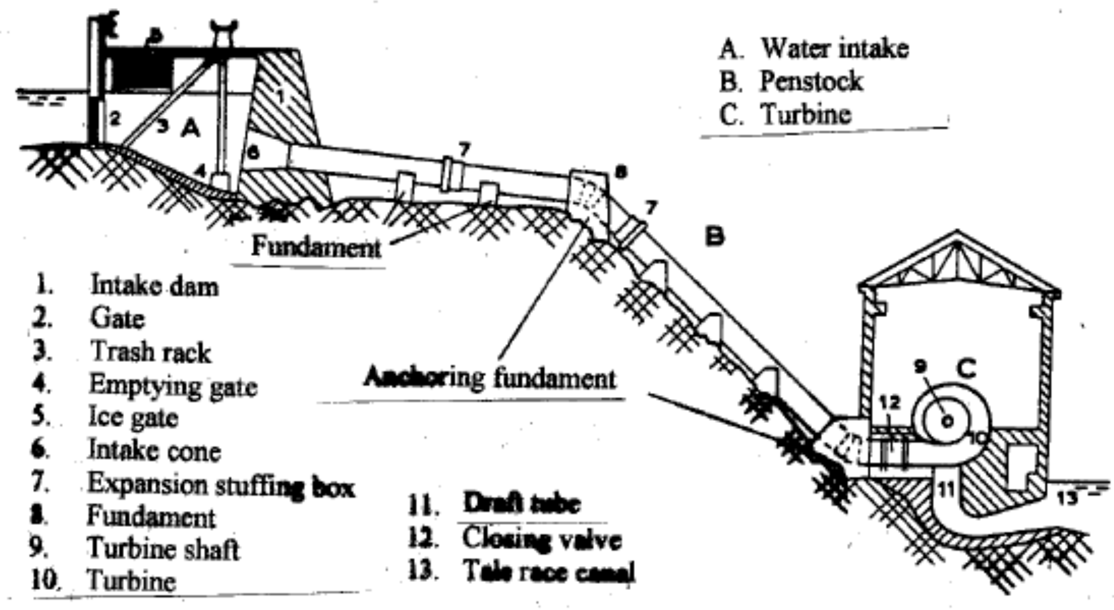

Figure 6. Arrangement of a hydropower plant

Figure 6 shows schematically an example of a plant arrangement with indication of the localization of the details to be mentioned.

Table 2 List of parts from figure 6

No	Name of parts	No	Name of parts	No	Name of parts
1	Intake dam	6	Intake cone	11	Draft turbine
2	Gate	7	Expansion stuffing box	12	Closing valve
3	Trash rack	8	Fundament	13	Tale race canal
4	Emptying gate	9	Turbine shaft		
5	Ice gate	10	Turbine		

The water intake is normally constructed in connection with an accumulation dam, in the river course. The shallow water intake is equipped with a coarse trash rack (3) which prevents trees, branches, debris and stones from entering the conduit system to the turbine.

An intake gate (2) is arranged to shut off the water delivery when the conduit system has to be emptied. In addition a small gate (4) may be arranged for drainage of the leakage through the main gate.

A deep water intake takes the water directly from the reservoir. It has no trash rack. There is a sump below the intake. Its main function is to collect blasting stones from the piercing of the the head race tunnel into the reservoir. It also traps stones sliding into the reservoir close to the intake.

Deep water intakes allow for very strong regulation of the reservoirs. An intake gate is installed with the same function as described for the shallow water intake.

Conduit system:

From the water intake to the turbine there is a conduit system constructed as open canal, tunnel, penstock or pressure shaft or a combination of these. Open canals are usually digged in the ground, blasted in rock or built up as a chute of wood or concrete.

A steel penstock connects the shaft with the valve in the machine hall. Inside the rock the penstock is embedded in a concrete plug. Penstocks are normally welded pipe constructions of steel plates. A flange connects the penstock with the valve. Penstocks above the ground are mounted on foundation concrete blocks where the penstock may slide according to thermal expansion. In certain positions the penstocks are fixed in reinforced concrete anchoring blocks (8) on. Between these anchoring blocks the penstocks are equipped with expansion stuffing boxes (7).

At the upstream end of a penstock an automatic isolating valve is normally installed. This valve closes automatically if a pipe rupture should occur.

Closing valve:

Upstream of the turbine a closing device (12) is installed. Depending on water head and capacity it may be a gate, a butterfly valve,a gate valve or a spherical valve. By submerged turbines a closing device, normally a gate, is installed also at the outlet from the draft tube (Arne Kjølle, Professor Emeritus Norwegian University of Science and Technology)

Hydropower has been used since ancient times to grind flour and perform others tasks. In the mid-1770s, a French engineer Bernard Forest de Bélidor published Architecture Hydraulique which described vertical- and horizontal-axis hydraulic machines. By the late 19th century, the electrical generator was developed and could now be coupled with hydraulics. The growing demand for the Industrial Revolution would drive development as well. In 1878, the world's first house to be powered with hydroelectricity was Cragside in Northumberland, England. The old Schoelkopf Power Station No. 1 near Niagara Falls in the U.S. side began to produce electricity in 1881. The first Edison hydroelectric power plant - the Vulcan Street Plant - began operating September 30, 1882, in Appleton, Wisconsin, with an output of about 12.5 kilowatts. By 1886 there were about 45 hydroelectric power plants in the U.S. and Canada. By 1889, there were 200 in the U.S.

At the beginning of the 20th century, a large number of small hydroelectric power plants were being constructed by commercial companies in the mountains that surrounded metropolitan areas. By 1920 as 40% of the power produced in the United States was hydroelectric, the Federal Power Act was enacted into law. The Act created the Federal Power Commission whose main purpose was to regulate hydroelectric power plants on federal land and water. As the power plants became larger, their associated dams developed additional purposes to include flood control, irrigation and navigation. Federal funding became necessary for large-scale development and federally owned corporations like the Tennessee Valley Authority (1933) and the Bonneville Power Administration (1937) were created. Additionally, the Bureau of Reclamation which had begun a series of western U.S. irrigation projects in the early 20th century was now constructing large hydroelectric projects such as the 1928 Boulder Canyon Project Act. The U.S. Army Corps of Engineers was also involved in hydroelectric development, completing the Bonneville Dam in 1937 and being recognized by the Flood Control Act of 1936 as the premier federal flood control agency.

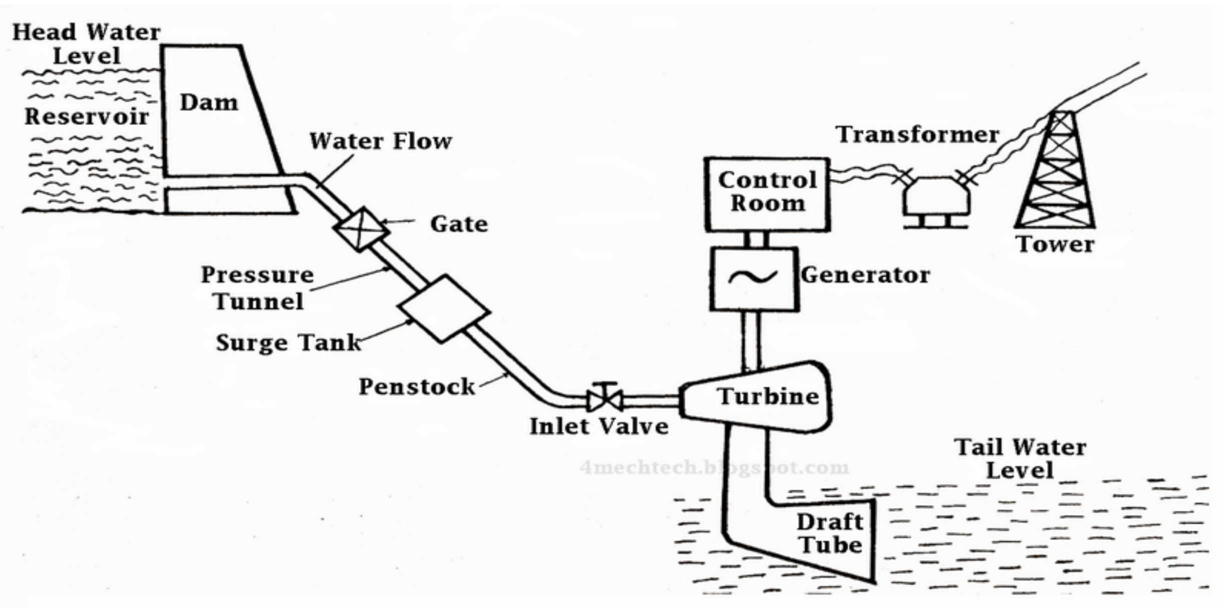

Figure 7. Layout of hydro electric power plant

Hydroelectric power plants continued to become larger throughout the 20th century. After the Hoover Dam's initial 1,345 MW power plant became the world's largest hydroelectric power plant in 1936 it was soon eclipsed by the 6809 MW Grand Coulee Dam in 1942.Brazil's and Paraguay's Itaipu Dam opened in 1984 as the largest, producing 14,000 MW but was surpassed in 2008 by the Three Gorges Dam in China with a production capacity of 22,500 MW. Hydroelectricity would eventually supply countries like Norway, Democratic Republic of the Congo, Paraguay and Brazil with over 85% of their electricity. The United States currently has over 2,000 hydroelectric power plants, which supply 49% of its renewable electricity (Atkins, William (2003). "Hydroelectric Power". Water: Science and Issues 2: 187–191)

3 OPERATION AND MAINTENANCE OF A STEAM POWER PLANT CYCLE

Steam is the most common working fluid used in vapor power cycles because of its many desirable characteristics, such as low cost, availability, and enthalpy of vaporization. Other working fluids used include sodium, potassium, and mercury for high-temperature applications. Steam power plants are commonly referred to as coal plants, nuclear plants, or natural gas plants, depending on the type of the fuel used to supply heat to the steam. But the steam goes through the same basic cycle in all of them. Therefore all can be analyzed in the same manner.

3.1 The carnot vapor cycle

The Carnot cycle is the most efficient cycle operating between two specified temperature levels making use of steam as the working fluid. Thus it is natural to look at the Carnot cycle first as a prospective ideal cycle for vapor power plants. If we could, we would certainly adopt it as the ideal cycle. But as explained below, the Carnot cycle is not a suitable model for power cycles. The assumption is that steam is the working fluid used since it is the working fluid predominantly used in vapor power cycles. (P. K. Nag, “Power Plant Engineering,” Tata McGraw Hill, New Delhi, 2007).

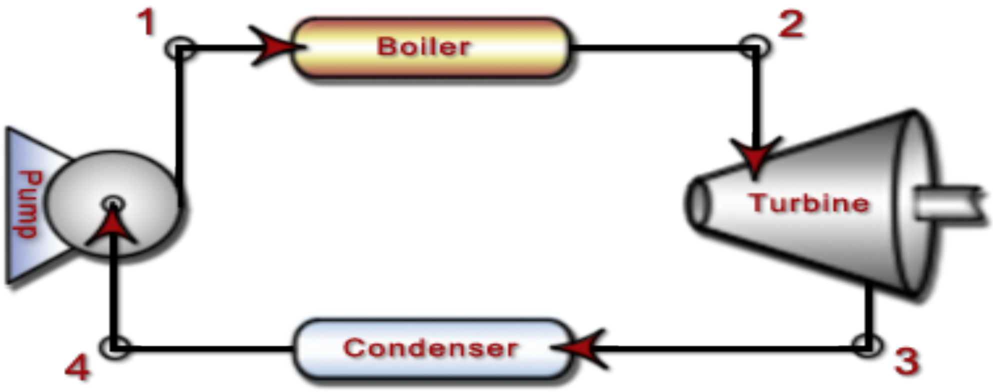

Figure 8. Carnot vapor cycle T-S diagram

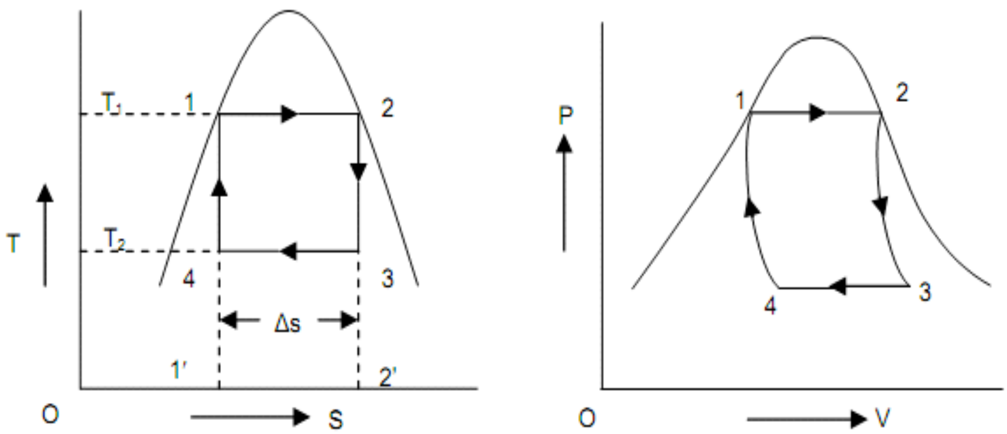

Figure 9. *Carnot Cycle on P-V and T-S Diagram*

Consider a steady-flow Carnot cycle executed within the saturation dome of a pure substance. The fluid is heated reversibly and isothermally in a boiler (process 1-2), expanded isentropically in the turbine (process 2-3), condensed reversibly and isothermally in the condenser (process 3-4), and compressed isentropically by the compressor to the initial state (process 4-1).

Several impracticalities are associated with this cycle.

- Isothermally heat transfer to or from a two-phase system is not difficult to achieve in practice since maintaining a constant pressure in the device will automatically fix the temperature at the saturation value. Therefore, processes 1-2 and 3-4 can be approached closely in the actual boilers and condensers. Limiting the heat transfer processes to the two-phase systems, however, severely limits the maximum temperature that can be used in the cycle (it has to remain under the critical-point value, which is 374ºC for water). Limiting the maximum temperature in the cycle also limits the thermal efficiency. Any attempt to raise the maximum temperature in the cycle will involve heat transfer to the working fluid in a single phase, which is not easy to accomplish isothermally.

- The isentropic expansion process (process 2-3) can be approximated closely by a well-designed turbine. However, the quality of the steam decreases during this process as shown on T-s diagram. Thus the turbine will handle steam with low quality, that is, steam with high moisture content. The impingement of liquid droplets on the turbine blades causes erosion and is the major source of wear. Thus steam with qualities less than 90% cannot be tolerated in the operation of power plants. The problem could be eliminated by using a working fluid with a very steep saturated vapor line.
- The isentropic compression process (process 4-1) involves the compression of a liquid-vapor mixture to a saturated liquid. There are two difficulties associated with the process. First, it is not easy to control the condensation process so precisely as to end up with the desired quality at state 4. Second, it is not practical to design a compress that will handle two phases.

3.2 Rankine cycle: The ideal for vapor power cycles

Many of the impracticalities associated with the Carnot cycle can be eliminated by superheating the steam in the boiler and condensing it completely in the condenser as shown schematically on T-s diagram. The cycle that results is the Rankine cycle, which is the ideal cycle for vapor power plants (P. K. Nag, "Power Plant Engineering," Tata McGraw Hill, New Delhi, 2007). The ideal Rankine cycle does not involve any internal irreversibility and consists of the following four processes:

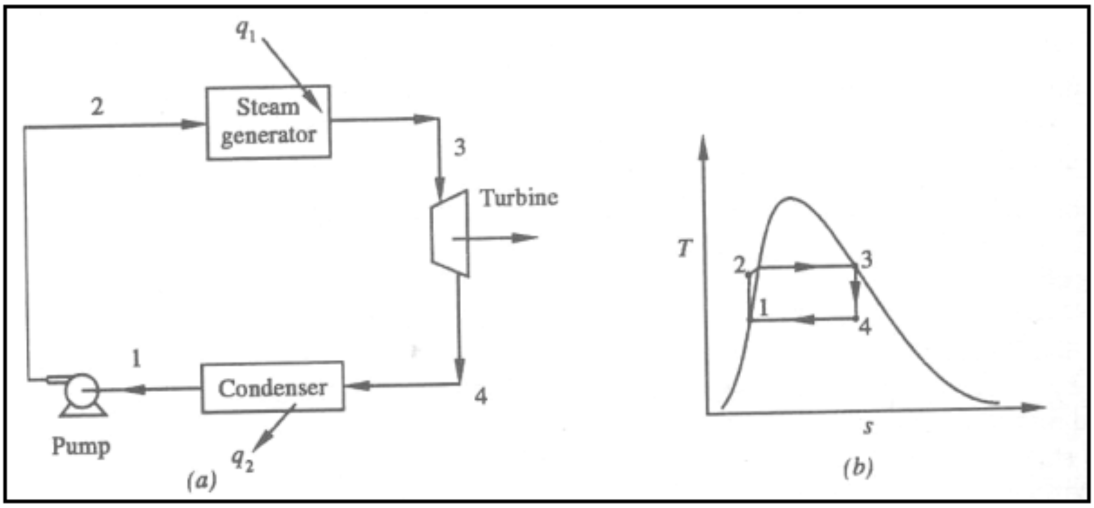

Figure 10. Rankine cycle

1-2 isentropic compression in a pump

2-3 constant pressure heat addition in boiler

3-4 isentropic expansion in a turbine

4-1 constant pressure heat rejection in a condenser

3.3 OPERATIONS

Water enters the pump at state 1 as saturated liquid and is compressed isentropically to the operating pressure of the boiler. The water temperature increases somewhat during this isentropic compression process due to slight decrease in the specific volume of the water. The vertical distance between states 1 and 2 on T-s diagram is greatly exaggerated for clarity.

Water enters the boiler as a compressed liquid at state 2 and leaves as a superheated vapor at state 3. The boiler is basically a large heat exchanger consisting of an economizer, an evaporator, and superheater where heat originating from combustion gases, nuclear reactor or other sources is transferred to the water essentially at constant pressure. The boiler, together with the section where the steam is superheated (the superheater), is often called the steam generator.

The superheated vapor at state 3 enters the turbine, where it expands isentropically and produces work by rotating the shaft connected to an electric generator. The pressure and the temperature of the steam enters the condenser. At this state, steam is usually a saturated liquid-vapor mixture with a high quality. Steam is condensed at constant pressure in the condenser, which is basically a large heat exchanger, by rejecting heat to a cooling medium such as lake or a river or atmosphere. Steam leaves the condenser as saturated liquid and enters the pump, completing the cycle. In areas where water is precious, the power plant operates by air instead of water. This method of cooling which is also used in car engines is called dry cooling. Several power plants in the world and a few in the United States use dry cooling to conserve water.

Remembering that the area under the process curve on the T-s diagram represents the heat transfer for internally reversible processes, it is seen that the area under the process curve 2-3 represents the heat transferred to the water in the boiler and the area under the process curve represents the heat rejected in the condenser. The difference between these two is the work produced during the cycle.

3.4 Energy analysis of the steam cycle

All four components associated with the Rankine cycle (pump, boiler, turbine and condenser) are steady-flow devices, and thus all four processes that make up Rankine cycle can be analyzed as steady-flow processes. The kinetic and potential energy changes of the steam are usually small relative to the work and heat transfer terms and are therefore usually neglected. Then the steady-flow energy equation per unit mass of steam reduces:

For 1 kg fluid, the SFEE for the pump as the control volume gives

$$h_1 + w_p = h_2 ,$$ where h =enthalpy and wp= workdone in the pump

$$w_p = h_2 - h_1$$

The SFEE for the boiler as the control volume gives

$$h_2 + Q_1 = h_3 ,$$ where Q = heat energy

$$Q_1 = h_3 - h_2$$

Similarly, the SFEE for the turbine

$$h_3 = W_T + h_4 ,$$ where W_T =workdone in turbine

$$W_T = h_3 - h_4$$

And the SFEE for the condenser gives

$$h_4 + Q_2 = h_1$$

$$Q_2 = h_1 - h_4$$

The efficiency of the Rankine cycle is then given by:

$$= \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{(h_3 - h_4) - (h_2 - h_1)}{h_3 - h_2}$$

The thermal efficiency of Rankine cycle can be improved by:

- Increasing the inlet pressure and temperature conditions.
- Increasing the condenser vacuum, i.e. lowering the exhaust pressure.

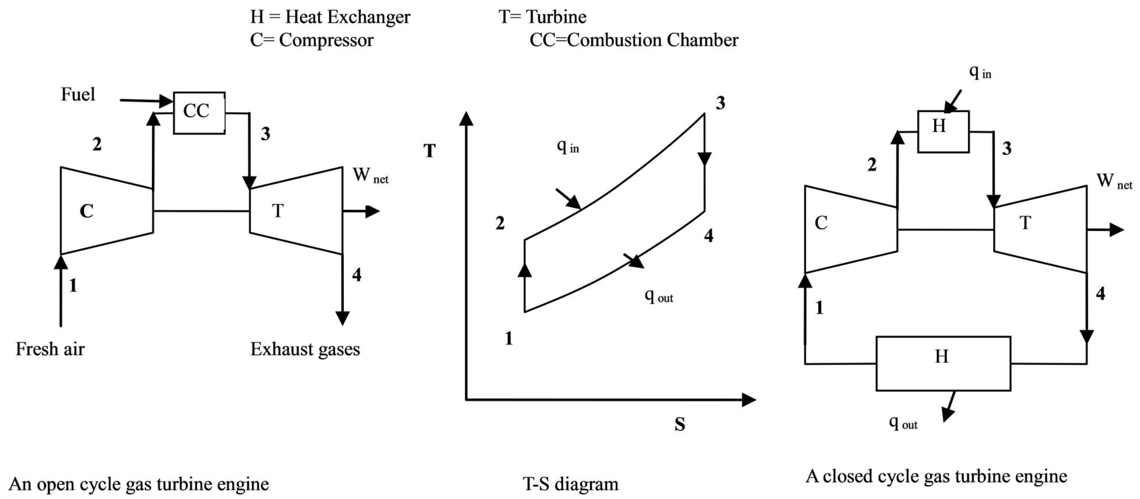

Figure 11. Energy cycle analysis diagram

Now increasing the inlet steam pressure for the given inlet steam temperature and condenser pressure would result in increase in work, increase in thermal efficiency, and always an increase in initial steam temperature would always result in increase in work and thermal efficiency (since heat will be added in the cycle at a higher temperature) and decrease in moisture content of steam at turbine exhaust. So there is no upper limit for initial steam temperature. It is limited by the materials used in the boiler tubes and the turbine. Most modern steam turbines are limited to a maximum operating temperatures of 535ºC to 595ºC (I. H. Aljundi, "Energy and Exergy Analysis of a Steam Power Plant in Jordan," Applied Thermal Engineering, Vol. 29, No. 2-3, 2009, pp. 324-328). The following are the typical recommended values for initial steam pressure for various rating turbines:

50MW	50 to 90 atm
50-100MW	90 to 130 atm
100-200MW	130 atm
200-300MW	130 to 170 atm
300MW and above	130 to 240 atm

Condenser pressure: Lowering the condenser pressure results in an increase in thermal efficiency and useful work but also an increase in moisture content of steam at turbine exhaust. Lower exhaust pressure also means larger volume of steam towards the end of its expansion which results in bigger low pressure turbine and condenser. However, the increased capital cost is offset by an increase in thermal efficiency. The minimum condenser pressure is limited by the lowest available temperature of water or air that acts as a receiver. Then the condenser pressure will be saturated pressure corresponding to the cooling water/air temperature. As there is no control on cooling water temperature, there is no control on condenser pressure. The cooling water temperature usually ranges from 24ºC (rivers) to 36ºC (sea) giving condenser pressures of 0.06 to 0.12 atm.

From the above discussion the only undesirable factor resulting from increased inlet steam pressure and decreased condenser pressure is an increase in the moisture content at the turbine exhaust. Now towards the turbine exhaust, the steam pressure and its density are very low. This low density steam produces very high flow velocities in the low pressure part of the turbine. The water droplets present in the steam would erode the surface of the low-pressure turbine blades. Due to this it is recommended that the moisture content at the turbine exhaust should not exceed about 10%. For this, instead of expanding the steam in only one turbine, it is expanded in 2/3 turbines. After the steam has expanded in H.P turbine, the steam is returned to a reheater where additional heat is supplied to it at constant pressure, thereby, increasing its superheat and then it is expanded in the IP and LP turbines. This improvement in simple Rankine cycle permits the use of very high steam pressure without excessive moisture at the turbine exhaust. Steam after partial expansion is usually reheated to the initial steam temperature at pressure 0.15 to 0.30 times the initial pressure.

3.5 Reheat cycle

There are two reasons for the use of Reheat cycle. Firstly, there are limits to the degree of superheat due to metallurgical conditions, so that it is not possible to get all super heat in one stage. And secondly, the inevitable effects of higher pressures are that saturation line is reached earlier during isentropic expansion and most of the turbine stages operate in the relatively undesirable saturated steam region. Due to the impact of particles of suspended water on the turbine blades, there will be blade erosion. The safe maximum limit of moisture in the exhaust steam should be in order of 12%. Therefore, reheating is necessarily practiced in high pressure plants. The reheating is accomplished by constructing the turbine so that all the steam may be extracted at a suitable point, superheated in the reheat boiler and then readmitted to the remaining stages of the turbine for further expansion. Or the superheated steam can be expanded in the pressure turbine and its exhaust reheated and then expanded in the low pressure turbine.

The advantages of Reheat cycle are

- The moisture in the exhaust steam is greatly reduced and due to this the erosion of the turbine blade is greatly reduced tremendously.
- The thermal efficiency of the turbine is increased by 4% to 5% if the reheat temperature is equal to the initial throttle temperature.
- Condenser size is reduced by 7% to 8%.
- The size of the boiler is reduced because the steam flow is reduced by about 15% to 18%.
- The size of the low pressure turbine is reduced due to reduction in specific volume by about 7% to 8%.
- Station heat rate is improved due to reduction in the feed pump power by about 15% to 18%.

The limitations of Reheat cycle are that the cost of extra pipes and controls makes this cycle more expensive than the non-reheat cycle. For a more economical plant, the base load capacity should be 50MW.

There are two methods of reheating namely:

- Gas reheating
- Live steam reheating

The advantages of the latter over the former are:

- The use of large piping can be avoided by placing the reheater near the turbine.
- As less piping is required, more than one reheating can be employed.
- Since the change in combustion does not affect the live steam reheater performance, temperature control is simple.
- Wet steam can also be reheated (A. Khaliq and S. C. Kaushik, "Second-Law Based Thermodynamic Analysis of Brayton/Rankine Combined Power Cycle with Reheat," Applied Energy, Vol. 78, No. 2, 2004, pp. 179-197).

3.6 Regenerative cycle

In this cycle, the feed water is preheated by means of steam taken from some sections of the turbine, before it enters the boilers from the condenser. This process of draining steam from the turbine at certain point during its expansion and using this steam for heating the feed water supplied to the boiler is known as bleeding. The effect of this is to supply the boiler with hotter water while small amount of work is lost by the turbine. There is a slight increase, in the efficiency but there is also a decrease in the power developed. The incidental advantages of improved thermal efficiency and reduced steam flow to the condenser are:

- Smaller condenser and boiler

- The difficulty of passing large volumes of steam through the last stage in the low pressure turbine is lessened
- Improved turbine drainage, hence less trouble from erosion
- Increased blade heights in the high pressure turbine to accommodate
- The initial increased steam consumption (A. Khaliq and S. C. Kaushik, "Thermodynamic Performance Evaluation of Combustion Gas Turbine Cogeneration System with Reheat," Applied Thermal Engineering, Vol. 24, No. 13, 2004, pp. 1785-1795).

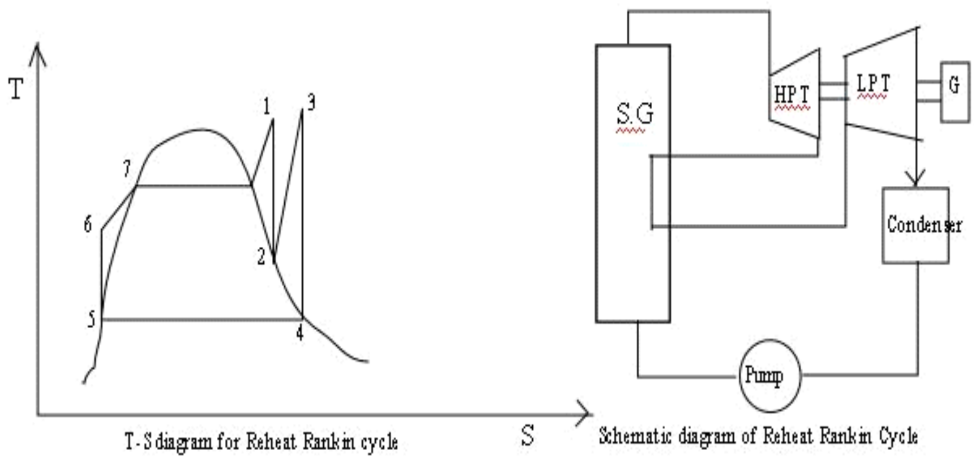

Figure 12. Regenerative cycle

3.7 Maintenance of steam power plant accessories

The definition of maintenance often states that maintenance is an activity carried out for any equipment to ensure its reliability to perform its functions.

Maintenance to most people is any activity carried out on an asset in order to ensure that the asset continues to perform its intended functions, or to restore to its favorable operating condition. The purpose of maintenance is to extend equipment lifetime, or at least the mean time to the next failure the repair of which may be costly. Furthermore, it is expected that effective maintenance policies can reduce the frequency of service interruptions and the many undesirable consequences of such interruptions. Maintenance clearly impacts on component and reliability; if too little is done ,this may result in an excessive number of costly failures and poor system performance and therefore, reliability is degraded, done often, reliability may improve but the cost of maintenance will sharply increase. In a cost effective scheme, the two expenditures must be balanced.

Maintenance is just one of the devices for up keeping or if necessary improving the level of reliability of components and systems. Over the years, many new strategies have been implemented as maintenance strategies which are intended to overcome the problems which are related to equipment breakdown. Some of the common maintenance strategies are as follows.

1. Breakdown Maintenance

This is one of the earliest maintenance programs being implemented in the industry. The approach to maintenance is totally reactive and acts only when equipment needs to be fixed. This strategy has no routine maintenance task and it is also described as no scheduled maintenance strategy. To rectify the problem, corrective maintenance is performed onto the equipment. Thus, this activity may consist of repairing, restoration or replacement of components. The strategy is to apply only the corrective maintenance activity, which is required to correct a failure that has occurred or is in the process of occurring.

2. Preventive Maintenance

This is the time-based maintenance strategy where on a predetermined periodic basis, equipment is taken off-line, opened up and inspected. Based on visual inspection, repairs are made and the equipment is then put back on-line. Thus under this equipment maintenance strategy, replacing, overhauling or remanufacturing an item is done at fixed intervals regardless of its condition at the time. Although this is a well-intended strategy, the process can be very expensive as typically 95% of the time everything was alright. Nevertheless, some preventive maintenance is necessary as some regulation such as DOSH regulation require that annual/bi-annual boiler inspection to be conducted.

3. Predictive Maintenance

Predictive maintenance is a more condition-based approach to maintenance. The approach is based on measuring of the equipment condition in order to assess whether an equipment will fail during some future period, and then taking action to avoid the consequences of those failures. This is where predictive maintenance technologies (i.e. vibration analysis, infrared thermographs, ultrasonic detection, etc.) are utilized to determine the condition of equipment, and to decide on any necessary repairs. Apart from the predictive technologies, statistical process control techniques, equipment performance monitoring or human senses are also adapted to monitor the equipment condition. This approach is a more economically feasible strategy as labors, materials and production schedules are used much more efficiently.

4. Proactive Maintenance

Unlike the three type of maintenance strategies which have been discussed earlier, proactive maintenance can be considered as another new approach to maintenance strategy. Dissimilar to preventive maintenance that biased on time intervals or predictive maintenance concentrate on the monitoring and correction of root causes to equipment failures. The proactive maintenance strategy is also designed to extend the useful age of the equipment to reach the wear-out stage by adaptation of a high mastery level of operating precision.

The table below summarizes the four different strategies of maintenance which are being commonly practiced in the industry.

Table 3 Type of Maintenance Strategy

Maintenance Strategy	Maintenance Approach	Signification
Breakdown Maintenance	Fix-it when broke	Large maintenance budget
Preventive maintenance	Scheduled maintenance	Periodic component replacement
Predictive maintenance	Conditioned-based monitoring	Maintenance decision based on equipment
Proactive maintenance	Detection of sources of failure	Monitoring and correcting failing root causes

The aspect of maintenance being carried out in Egbin thermal power plant is preventive maintenance.

3.7.1 Maintenance of boiler

A boiler is a closed vessel in which water, under pressure, is transformed into steam by the application of heat; open vessels and those generating steam at atmospheric pressure are not considered to be boilers. In the furnace, the chemical energy in the fuel is converted into heat; it is the function of the boiler to transfer this heat to the water in the most efficient manner.

Most conventional steam boilers are classed as either fire-tube or watertube types. In the fire-tube type, the water surrounds the steel tubes through which hot gases from the furnace flow. The steam generated collects above the water level in a cylindrically shaped drum. A safety valve is set to allow escape of steam at pressures above normal operating pressure; this device is necessary on all boilers, because continued addition of heat to water in a closed vessel without means of steam escape results in a rise in pressure and, ultimately, in explosion of the boiler. Fire-tube boilers have the advantage of being easy to install and operate. They are widely used in small installations to heat buildings and to provide power for factory processes. Fire-tube boilers are also used in steam locomotives.

In the water tube boiler, the water is inside tubes with the hot furnace gases circulating outside the tubes. When the steam turbo generator was developed early on the 20th century, modern water tube boilers were developed in response to the demand for large quantities of steam at pressures and temperatures far exceeding those possible with fire-tube boilers. The tubes are outside the steam drum, which has no heating surface and is much smaller than in the fire-tube boiler. For this reason, the drum of the watertube boiler is better able to withstand higher pressures and temperatures. A wide variety of sizes and designs of water tube boilers are used in ships and factories. The express boiler is designed with small water tubes for quick generation of steam. The flash boiler may not require a steam drum, because the tubes operate at such high temperatures that the feed water flashes into steam and superheats before leaving the tubes.

The procedure to be followed in the operation and maintenance of a boiler plant depends to a large extent upon the size, type of combustion equipment, operating pressures, steam requirements, and other factors pertinent to the specific plant. There are, however, standard practices which must be followed to assure safe, continuous service and efficient operation. A boiler efficiency improvement program must include two aspects :(1) action to bring the boiler to peak efficiency and (2) action to maintain the efficiency at the maximum level. Good maintenance and efficiency start with having a working knowledge of the components associated with the boiler, keeping records, etc., and end with cleaning heat transfer surfaces, adjusting the air-to-fuel ratio, etc.

3.7.2 General Requirements for a Safe and Efficient Boiler Room

1. Keep the boiler room clean and clear of all unnecessary items. The boiler room should not be considered an all-purpose storage area. The burner requires proper air circulation in order to prevent incomplete fuel combustion. Use boiler operating log sheets, maintenance records, and the production of carbon monoxide. The boiler room is for the boiler.

2. Ensure that the whole personnel operating or maintaining the boiler room are properly trained on all equipment, controls, safety devices, and up-to-date operating procedures.

3. Before start-up, ensure that the boiler room is free of all potentially dangerous situations, like flammable materials, mechanical, or physical damage to the boiler or related equipment. Clear intakes and exhaust vents; check for deterioration and possible leaks.

4. Ensure a thorough inspection by a properly qualified inspector.

5. After any extensive repair or new installation of equipment, make sure a qualified boiler inspector re-inspects the entire system.

6. Monitor all new equipment closely until safety and efficiency are demonstrated.

7. Use boiler operating log sheets, maintenance records, and manufacturer's recommendations to establish a preventive maintenance schedule based on operating conditions, past maintenance, repair, and replacement that were performed on the equipment.

8. Establish a checklist for proper startup and shutdown of boilers and all related equipment according to manufacturer's recommendations.

9. Observe equipment extensively before allowing an automating operation system to be used with minimal supervision.

10. Establish a periodic preventive maintenance and safety program that follows manufacturer's recommendations.

Maintenance of boiler is carried out on frequent basis depending on the component part. Maintenance can be done daily, weekly, monthly, quarterly or annually.

3.7.3 Maintenance of steam turbine

A steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it into rotary motion. There are several classifications for modern steam turbines. These types include condensing, noncondensing, reheat, extraction and induction.

- Noncondensing or backpressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp, and paper plants, and desalination facilities where large amounts of low pressure process steam are available.
- Condensing turbines are most commonly found in electrical power plants. These turbines exhaust steam in a partially condensed state, typically of a quality near 90%, at a pressure well below atmospheric to a condenser.

- Reheat turbines are also used almost exclusively in electrical power plants. In a reheat turbine, steam flow exits from a high pressure section of the turbine and is returned to the boiler where additional superheat is added. The steam then goes back to the intermediate pressure section of the turbine and continues its expansion.
- Extraction type turbines are common in all applications. In an extracting type turbine, steam is released from various stages of the turbine, and used for industrial process needs or sent to boiler feed water heaters to improve overall efficiency. Extraction flows may be controlled with a valve, or left uncontrolled. Induction turbines introduce low pressure steam at an intermediate stage to produce additional power.

Steam turbines are used in all major natural gas fired power stations to drive the generators or alternators, which produce electricity. The turbines themselves are driven by steam generated in 'Boilers' or 'Steam Generators' as they are sometimes called. Energy in the steam after it leaves the boiler is converted into rotational energy as it passes through the turbine. The turbine normally consists of several stages with each stage consisting of a stationary blade (or nozzle). Stationary blades convert the potential energy of the steam (temperature and pressure) into kinetic energy (velocity) and direct the flow onto the rotating blades. The rotating blades convert the kinetic energy into forces, caused by pressure drop, which results in the rotation of the turbine shaft. The turbine shaft is connected to a generator, which produces the electrical energy. The rotational speed is 3000 rpm for Nigerian (50Hz) systems and 3600 for American (60Hz) systems.

In typical larger power stations, the steam turbines are split into three separate stages, the first being the High Pressure (HP), the second the Intermediate Pressure (IP) and the third the Low pressure (LP) stage, where high, intermediate and low describe the pressure of the steam. After the steam has passed through the HP stage, it is returned to the boiler to be reheated to its original temperature although the pressure remains greatly reduced. The reheated steam then passes through the IP stage and finally to the LP stage of the turbine.

Steam turbine generators are reliable machines, and often operate continuously for many months. Such operation at steady outputs can lead to deposition from the steam on the fixed and moving blades. Deposits cause output and efficiency to drop, by reducing the efficiency of energy transfer and eventually restricting steam flow. This occurs less on sets which vary in load, as they undergo a regular blade washing effect. Vibration analysis can detect the occurrence of such shaft rubbing and other conditions of the rotor line, but cannot detect the extent of internal wear or deposition. It is well suited for other quite different failure modes, such as when blades or parts of them come off and cause consequential damage. As with the application of all condition monitoring, the rule is to choose techniques to match the likely failure/wear out modes. As steam turbines are critical machines, all the main techniques have their place. Performance analysis can be applied to most machines, rotating and stationary. It is the one condition monitoring technique which allows the optimum time for restorative maintenance to be calculated, where the deterioration results in increased fuel consumption, or in reduced output, or both. For some plants items, it is possible to use the normal plant instruments and data processing system to determine condition parameters. In the case of steam turbines, a more refined method using test quality instruments is needed to give warning well in advance of changes evident from permanent instrumentation systems. This paper describes some performance tests used for monitoring turbines condition and their application.

In Table 3.1, the main wears out problems with steam turbines are summarized, together with an outline of how condition monitoring can detect them.

Part Affected	Wear out Problem	Comments, suitable condition monitoring
Blading	Erosion by solid particles (also erosion by water droplets on latter LP blades	Usually occurs gradually, worst at inlet blading. Less usual on sets with drum boilers and/or sub-

		critical inlet steam conditions, or with bypass systems. Performance analysis detects.
Blading	Parts breaking off	Usually sudden. Vibration analysis detects.
Bearings	Scoring damage to white metal	Performance analysis, vibration analysis, wear particles in oil (but representative sampling at each bearing is rare).
Rotors	Rubbing, temporary unbalance, cracking, misalignment	Vibration analysis, and off-line, some NDT (not detailed in this paper)
Valve spindles shaft and interstage glands (seals),	Leakage due to wear, distortion, breakage	Likely to occur gradually, but can be sudden. Performance analysis detects. Effect of seal water is relatively greater for HP blading. For impulse machines, the relative lost output for each 25m increase above design clearance of about 600 m is: HP: blade tips, 5KW; interstage seals, 6KW per stage; end glands 15 to 25KW.

casing joints LP manhole gaskets Internal steam piping and fittings		IP: blade tips, 2.5KW; interstage 2KW per stage; end glands 5KW LP: blade tips and interstage, 1.5KW per stage; end glands 2KW. For reaction blading, the effect will be greater
Steam valve strainers, valves spindles,	Deposits (more prevalent with base loaded sets as cyclic loading tends to have a blade washing effect)	Likely to occur gradually, mostly in areas around 260ºC. Some on load blade washing occurs with forced steam cooling. Performance analysis detects. Blade surface roughness has biggest effect at higher steam pressures. One case gave 17% drop in output
blading		From deposits varying between 250 to 2300m in thickness. Permissible roughness for LP blading can be 100 coarser than for HP blading. One test with surface finish equivalent to 500 grit emery paper caused 5% to 7% less efficiency in HP blading, about 2% in LP.
Generator rotor, stator	Insulation faults	Electrical plant testing several techniques (not detailed in this

		paper)
Condenser	Air in leakage Tube fouling	Performance analysis (not detailed in this paper)
Feedwater heaters	Air in leakage, tube fouling by scale or oil	Performance analysis (not detailed in this paper)
Valves- HP, IP bypass	Leakage	Performance analysis. Acoustic leakage detection is also possible

4 PERFORMANCE ANALYSIS OF A STEAM POWER PLANT

The instrument being used to measure the performance of a steam power plant is the KEY PERFORMANCE INDICATOR (KPI). Some of which are:

- Energy generated (MWH)
- Percentage consumption (%)
- Station consumption (MWH)
- Number of trips/categorisation of faults
- Make up water loss (Tons)
- Generation utilisation index (%)
- Capacity utilisation index (%)
- Fuel utilisation index (SCF/MWH)
- Routine maintenance index (%)

- Plant reliability index (%)
- Generated thermal efficiency (%)

4.1 Formula

(Calculations and results from Egbin thermal station database)

- GENERATION - ENERGY GENERATED
- % CONSUMPTION -
- STATION CONSUMPTION - What the station Consumes
- GENERATION UTILIZATION INDEX-
- CAPACITY UTILIZATION INDEX -
- FUEL UTILIZATION INDEX -
- ROUTINE MAINTENANCE INDEX -
- PLANT RELIABILITY INDEX - Where T_d = Down time, T_e = Expected Running Time
- GENERATED THERMAL EFFICIENCY -
- ENERGY SENT OUT - Total (1) –Total (3)
- % ENERGY SENT OUT -
- AVAILABILTY FACTOR -
- AVERAGE AVAILABILITY -
- AVERAGE GENERATION -
- TOTAL GENERATED EFFICIENCY -

The performance indicator of Egbin thermal Power station from January-December 2009 is calculated below.

CALCULATIONS

JAN 2009

- Energy generated

  ST 1 – 116,762 (MWH)

  ST 2- 0

  ST 3- 0

  ST 4- 83651

  ST 5- 132537

  Total- 332940

- Energy consumed (MWH)

  ST 1 – 6363.7

  ST – 0

  ST 3-0

  ST 4- 4952.14

  ST 5- 6242.02

  TRF A – 1006.50

  TRF B – 669.90

  TRF C – 652.60

  Total – 19886.86

- Energy sent out

  Energy generated – Energy consumed

  332940 – 19886.86

  = 313052.14

- Percentage Energy Sent Out

  x 100 = 94.03%

- Generated Utilization Index/ Availability %

  ST 1- = 71.34

  ST 2 – 0

  ST 3 – 0

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 –

  ST 2 = 0

  ST 3 = 0

  ST 4 = X 100 = 96.54

  ST 5 =

- Availability Factor

- Average Availability

  = 0.68%

- Average Generation

- Total Generation Efficiency

FEB 2009

- Energy generated

  ST 1 – 91849(MWH)

  ST 2- 0

  ST 3- 0

  ST 4- 53936

  ST 5- 107267

  Total- 253052

- Energy consumed (MWH)

  ST 1 – 5290.5

  ST – 0

  ST 3- 3317.06

  ST 4- 5416.98

  TRF A – 948.7

  TRF B – 832.2

  TRF C – 703.4

  Total – 16508.84

- Energy sent out

  Energy generated – Energy consumed

  253052 – 16508.84

  = 236543.16

- Percentage Energy Sent Out

  x 100 = 93.48%

- Generated Utilization Index/ Availability %

  ST 1- = 59.98%

  ST 2 – 0

  ST 3 – 0

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 = 0

  ST 3 = 0

  ST 4 = X 100 = 69.97%

  ST 5 =

- Availability Factor

- Average Availability

  X 100= 0.55%

- Average Generation

- Total Generation Efficiency

MARCH 2009

- Energy generated

ST 1 – 68951(MWH)

ST 2- 0

ST 3- 0

ST 4- 37,360

ST 5- 63242

Total- 169,553

- Energy consumed (MWH)

ST 1 – 4274.96

ST – 0

ST 3- 0

ST 4- 2802

ST 5 – 3826.14

TRF A – 1123.9

TRF B – 805.8

TRF C – 1067

Total – 13900.6

- Energy sent out

Energy generated – Energy consumed

169553 – 13900.6

= <u>155652.4</u>

- Percentage Energy Sent Out

x 100 = 91.8%

- Generated Utilization Index/ Availability %

ST 1- = <u>42.13%</u>

ST 2 – 0

ST 3 – 0

ST 4 -

ST 5 –

- Plant Running factor/ plant Reliability Index

ST 1 – %

ST 2 = 0

ST 3 = 0

ST 4 = X 100 = 62.78%

ST 5 =

- Availability Factor

- Average Availability

X 100= 0.35%

- Average Generation

- Total Generation Efficiency

APRIL 2009

- Energy generated

  ST 1 – 119344(MWH)

  ST 2- 16900

  ST 3- 0

  ST 4- 120102

  ST 5- 134389

  Total- 390,735

- Energy consumed (MWH)

  ST 1 – 5788.18

  ST – 1014.00

  ST 3- 0

  ST 4- 5800.93

  ST 5 – 5429.32

  TRF A – 1925.5

  TRF B – 423.7

  TRF C – 110.7

  Total – 21492.33

- Energy sent out

  Energy generated – Energy consumed

  390,735 – 21492.33

= 369242.67

- Percentage Energy Sent Out

x 100 = 94.5%

- Generated Utilization Index/ Availability %

ST 1- = 75.34%

ST 2 –

ST 3 – 0

ST 4 -

ST 5 –

- Plant Running factor/ plant Reliability Index

ST 1 – %

ST 2 =

ST 3 = 0

ST 4 = X 100 = 97.86%

ST 5 =

- Availability Factor

- Average Availability

X 100= 0.62%

- Average Generation

- Total Generation Efficiency

MAY 2009

- Energy generated

  ST 1 – 81,508(MWH)

  ST 2- 93585

  ST 3- 0

  ST 4- 27735

  ST 5- 90,036

  Total- 292,864

- Energy consumed (MWH)

  ST 1 – 4817.12

  ST – 4651.17

  ST 3- 0

  ST 4- 1228.66

  ST 5 – 4744.90

  TRF A – 1352.3

  TRF B – 444.1

  TRF C – 1849.2

  Total – 19087.45

- Energy sent out

  Energy generated – Energy consumed

  292864 – 19087.45

  = 273776.55

- Percentage Energy Sent Out

  x 100 = 93.48%

- Generated Utilization Index/ Availability %

  ST 1- = 49.80%

  ST 2 –

  ST 3 – 0

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 =

  ST 3 = 0

  ST 4 = X 100 = 30.38%

  ST 5 =

- Availability Factor

- Average Availability

  X 100= 0.45%

- Average Generation

- Total Generation Efficiency

JUNE 2009

- Energy generated

  ST 1 – 10848(MWH)

  ST 2- 117801

ST 3- 7

ST 4- 74933

ST 5- 117934

Total- 321576

- Energy consumed (MWH)

  ST 1 – 747.43

  ST – 5312.83

  ST 3- 0

  ST 4- O.O.S

  ST 5 – 5448.55

  TRF A – 1707.7

  TRF B – 2719.1

  TRF C – 2571.1

  Total – 18506.71

- Energy sent out

  Energy generated – Energy consumed

  321516 – 18506.71

  = <u>303009.29</u>

- Percentage Energy Sent Out

  x 100 = 94.24%

- Generated Utilization Index/ Availability %

  ST 1-

  ST 2 –

  ST 3 – 0

ST 4 -

ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 =

  ST 3 = 0

  ST 4 = X 100 = 55.60%

  ST 5 =

- Availability Factor

- Average Availability

    X 100= 0.51%

- Average Generation

- Total Generation Efficiency

JULY 2009

- Energy generated

  ST 1 – 96,920(MWH)

  ST 2- 107,633

  ST 3- 0

  ST 4- 97,812

  ST 5- 101,618

Total- 403983

- Energy consumed (MWH)

 ST 1 – 5262.76

 ST – 5166.38

 ST 3- 0

 ST 4- 0

 ST 5 – 5243.49

 TRF A – 682.60

 TRF B – 3259.00

 TRF C – 3167.50

 Total – 22781.73

- Energy sent out

 Energy generated – Energy consumed

 403983 – 22781.73

 = <u>381201.27</u>

- Percentage Energy Sent Out

 x 100 = 94.36%

- Generated Utilization Index/ Availability %

 ST 1- = <u>59.21%</u>

 ST 2 –

 ST 3 – 0

 ST 4 -

 ST 5 –

- Plant Running factor/ Plant Reliability Index

ST 1 – %

ST 2 =

ST 3 = 0

ST 4 = X 100 = 19.03%

ST 5 =

- Availability Factor

- Average Availability

  X 100= 0.62%

- Average Generation

- Total Generation Efficiency

SEPTEMBER 2009

- Energy generated

  ST 1 – 100819(MWH)

  ST 2- 94482

  ST 3- 41477

  ST 4- 97020

  ST 5- 100421

  Total- 390,735

- Energy consumed (MWH)

  ST 1 – 5645.86

  ST – 4979.20

ST 3- 2401.52

ST 4-

ST 5 – 5513.11

TRF A – 1062.40

TRF B – 3810.50

TRF C – 3098.70

Total – 26511.29

- Energy sent out

  Energy generated – Energy consumed

  434219 – 26511.29

  = 40770.71

- Percentage Energy Sent Out

  x 100 = 93.90%

- Generated Utilization Index/ Availability %

  ST 1- = 63.65%

  ST 2 –

  ST 3 –

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 =

  ST 3 =

  ST 4 = X 100 = 99.8%

ST 5 =

- Availability Factor

- Average Availability

X 100= 0.55%

- Average Generation

- Total Generation Efficiency

OCTOBER 2009

- Energy generated

ST 1 – 127,797(MWH)

ST 2- 141,048

ST 3- 130,944

ST 4- 135,916

ST 5- 61,425

- Energy consumed (MWH)

ST 1 – 6415.16

ST – 6474.10

ST 3- 6311.50

ST 4- 0

ST 5 – 3089.68

TRF A – 917.30

TRF B – 4382.30

TRF C – 3798.50

Total – 26511.29

- Energy sent out

  Energy generated – Energy consumed

  597130 – 31388.79

  = <u>565741.21</u>

- Percentage Energy Sent Out

  x 100 = 94.74%

- Generated Utilization Index/ Availability %

  ST 1- = <u>78.08%</u>

  ST 2 –

  ST 3 –

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 =

  ST 3 =

  ST 4 =

  ST 5 =

- Availability Factor

- Average Availability

X 100= 0.73%

- Average Generation

- Total Generation Efficiency

NOVEMBER 2009

- Energy generated

ST 1 – 88122(MWH)

ST 2- 100372

ST 3- 74120

ST 4- 62478

ST 5- 20348

Total- 345460

- Energy consumed (MWH)

ST 1 – 4978.89

ST – 5108.93

ST 3- 4352.02

ST 4- 0

ST 5 – 1306.34

TRF A – 906.50

TRF B – 3404.80

TRF C – 2332.90

Total – 22390.38

- Energy sent out

  Energy generated – Energy consumed

  345460 – 22390.38

  = <u>323069.62</u>

- Percentage Energy Sent Out

  x 100 = 93.52%

- Generated Utilization Index/ Availability %

  ST 1- = <u>55.63%</u>

  ST 2 –

  ST 3 –

  ST 4 -

  ST 5 –

- Plant Running factor/ plant Reliability Index

  ST 1 – %

  ST 2 =

  ST 3 =

  ST 4 = X 100 = 70.27%

  ST 5 =

- Availability Factor

- Average Availability

X 100= 0.44%

- Average Generation

- Total Generation Efficiency

DECEMBER 2009

- Energy generated

  ST 1 – 42813(MWH)

  ST 2- 83358

  ST 3- 78088

  ST 4- 84001

  ST 5- 78521

  Total- 866,781

- Energy consumed (MWH)

  ST 1 – 2911.28

  ST – 4993.14

  ST 3- 4927.35

  ST 4-

  ST 5 – 4884.01

  TRF A – 935.70

  TRF B – 3308.00

  TRF C – 2941.00

  Total – 24972.48

- Energy sent out

Energy generated – Energy consumed

366781 – 24972.48

= 341808.52

- Percentage Energy Sent Out

x 100 = 93.119%

- Generated Utilization Index/ Availability %

ST 1- = 26.16%

ST 2 –

ST 3 –

ST 4 -

ST 5 –

- Plant Running factor/ plant Reliability Index

ST 1 – %

ST 2 =

ST 3 =

ST 4 = X 100 = 100%

ST 5 =

- Availability Factor

- Average Availability

X 100= 0.45%

- Average Generation

- Total Generation Efficiency

(Egbin electric power business unit database).

It is observed that the month of October generated the highest among other months in terms of power generation, meanwhile, the month of March generated the least among other months in terms of power generation. The plant is being faced with the challenge of limited supply of gas from the NNPC and also it is observed that the months of JAN-MARCH only three units are on standby, three units are out of service due to station fault and boiler explosion that occurred in 2007.

But of April-July four stations/units are working, but still did not meet up with the set target due to system/plant/gas trouble. The month of October supplies the highest in all the months of the year 2010, this was due to plant shutdown in August so as to carry out all necessary maintenance work. This kind of shutdown is always carried out once in a year due to crevices or scales built up on the plant component. At this month (October); five units out of six are working, supplying power. But due to gas and systems/plant troubles the month of October generated 82.9% of the target (720,000MW).

At a glance faults are being encountered at the plant and it is classified into 3 categories:

- System fault
- Plant fault
- Gas fault

In total, various faults are identified, 96 system faults, 27 plant faults, and 10 gas faults. All this hinders the efficiency and reliability of the power plant to function properly. It is also observed that proper routine maintenance is being carried out.

5 SUMMARY AND CONCLUSIONS

The reliability of a power plant unit is one of the most important performance parameters

which reflect the quality and standards. The great care and effort devoted to increasing the reliability and quality of electrical power is an indication of the economic implication for the power industry. This study has investigated the reliability and availability of Egbin power station units in relation to implementation of a preventive maintenance programme. The availability analysis shows different results for each unit indicating differences in their system installation, maintenance and operation. The availability and reliability of the turbines presented in this study reflect on site behavior, including the effects of changes in auxiliary systems maintenance policy. Identifying the effects of component failure on the system under analysis, based on the failure effects classification, a maintenance policy can be formulated to reduce their occurrence probabilities.

Better aims and specific targets are needed for the Egbin power station to improve maintenance management systems and productivity. This should be based on a new maintenance paradigm that will improve maintenance control and other technical activities. The managers must formulate wise strategies, make decisions and monitor progress against plans by collecting, retrieving and analyzing data.

To reduce downtime and achieve high production capabilities, the aim should be to find ways to increase equipment reliability and extend the equipment life through cost effective maintenance. To achieve these, PHCN, must move away from the traditional reactive maintenance mode to proactive maintenance and management philosophies. There should be maintenance processes that fully address Total Quality Maintenance (TQM) and Total Productive Maintenance (TPM) operating modes. Such change requires a complete shift to a Total Planned Quality Maintenance (TPQM) approach, which is a maintenance and management philosophy that advocates planning all maintenance (*i.e.* preventive, predictive and corrective), as well as the control of quality in maintenance operations.

The reliability evaluation of Egbin thermal power station was calculated with the help of the key performance indicator (kpi). It can be seen from the analysis that the key performance indicator of the month of October is the highest among others in terms of percentage generation efficiency, percentage availability factor, average generation and energy generated, and this happened after a shutdown in August so that the annual maintenance routine can be carried out. It is also discovered that the plant is generating below its maximum capacity.

- It is highly recommended that adequate maintenance of equipment is carried out so as to meet the demands of consumers.
- It is also recommended that the Government should set up programs that will aid the effectiveness of the equipment at the plant.
- Supply of gas is also a major setback, so therefore availability of gas should be in abundance for the running of the plant for effectiveness.
- There should be adequate personnel operating each unit.
- It is also recommended that the two units that have been out of service since 2007 should be fully repaired and restored to normal working condition.
- It is also recommended that only demineralized water should be used as a working medium in the plant to avoid scaling or crevices to the boiler or turbine parts.
- It is recommended that the plant should be expanded by the addition of more units to boost power supply.

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Appendix

POWER HOLDING COMPANY OF NIGERIA PLC, EGBIN ELECTRIC POWER BUSINESS UNIT.

MONTHLY KEY PERFORMANCE INDICATORS (KPI), JANUARY, 2010

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
		1	144,000	116,762	Lower (Gas Limitation)

1	Generation (MWH)	2	144,000	0	Unit Overhaul
		4	144,000	83,651	Lower (Gas Limitation)
		5	144,000	132,572	Lower (Gas Limitation)
		Total	576,000	332,940	Lower (Gas Limitation)
2	% Consumption	1	5.0%	5.45%	Higher (Gas Limitation)
		2	5.0%	-----	Unit Overhaul
		4	5.0%	5.92%	Higher (Gas Limitation)
		5	5.0%	4.71%	O.K
3	Station Consumption (MWH)	Trf A	------	1006.5	
		Trf B	------	669.9	
		Trf C	-----	652.6	
		Total	------	2329.0	This is 0.70% of total Generation
4	Number of Trips/Categorization of faults	1	0	4	(3-SF, 1-PF)
		2	0	----	Unit Overhaul
		4	0	4	(3-SF, 1-PF)
		5	0	3	(3-SF)
		Total	0	11	(9-SF, 2-PF)
5	Make Up Water Loss (Tons)	1	7350	8444.91	
		2	6809.7	-----	
		4	7350	12648.11	
		5	7350	21382.19	
		1	90%	7.34%	Lower (Gas Limitation)

6	Generation Utilization Index(%)	2	90 %	-----	Unit Overhaul
		4	90 %	51.11 %	Lower (Gas Limitation)
		5	90%	80.97%	Lower (Gas Limitation)
		1	100 %	100 %	
7	Capacity Utilization Index(%)	2	100%	----	Unit Overhaul
		4	100 %	100 %	
		5	100 %	100 %	
8	Fuel Utilization Index(SCF/MWH)	1	10800	11033.16	
		2	10800	----	
		4	10800	11955.55	
		5	10800	11018.83	
9	Routine Maintenance Index(%)	1	100%	97.26%	
		2	100%	98.17%	
		4	100%	98.73%	
		5	100 %	98.25 %	
10	Plant Reliability Index(%)	1	100 %	71.34 %	Lower (System Trips)
		2	100 %	----	Unit Overhaul
		4	100 %	51.11 %	Lower(repair of no 5 &6 HP heaters)
		5	100 %	80.97 %	Lower (System Trips)
11	Generated Thermal Efficiency(%)	1	41.54	36.07 %	
		2	----	----	Unit Overhaul
		4	41.18 %	32.41 %	

		5	41.50 %	36.76 %	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), FEBRUARY,2010

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	91,762	Lower (Gas Limitation)
		2	144,000	0	Unit Overhaul
		4	144,000	53,936	Lower (Gas Limitation)
		5	144,000	107,267	Lower (Gas Limitation)
		Total	576,000	253,052	Lower (Gas Limitation)
2	% Consumption	1	5.0 %	5.76 %	Higher (Gas Limitation)
		2	5.0 %	----	Unit Overhaul
		4	5.0 %	6.15 %	Higher (Gas Limitation)
		5	5.0 %	5.05 %	Fair
3	Station Consumption (MWH)	Trf A	------	948.7	
		Trf B	------	832.2	
		Trf C	-----	703.4	
		Total	------	2484.3	This is 0.98% of total

					Generation	
	4	Number of Trips/Categorization of faults	1	0	2	(2-PF)	
			2	0	—-	Unit Overhaul	
			4	0	1	(1-PF)	
			5	0	1	(1-PF)	
			Total	0	4	(4-PF)	
	5	Make Up Water Loss (Tons)	1	7350	11 877,96		
			2	6809.7	-----		
			4	7350	10 476,75		
			5	7350	12,430.4		
	6	Generation Utilization Index(%)	1	90 %	59.98 %	Lower (Gas Limitation)	
			2	90 %	– —-	Unit Overhaul	
			4	90 %	35.22 %	Lower (Repair of no 5&6HP heater)	
			5	90 %	70.05 %	Lower (Gas Limitation)	
	7	Capacity Utilization Index(%)	1	100%	100 %		
			2	100%	----	Unit Overhaul	
			4	100 %	68.97 %	Lower(Repair of no 5&6 H heaters)	

		5	100 %	100 %	
8	Fuel Utilization Index(SCF/MWH)	1	10800	11,839.25	
		2	10800	----	
		4	10800	11,266.89	
		5	10800	11,049.00	
9	Routine Maintenance Index (%)	1	100%	99.07%	
		2	100%	-----	
		4	100%	98.89%	

		5	100%	99.31%	
10	Plant Reliability Index(%)	1	100%	99.04%	Lower (Plant fault)
		2	100%	---	Unit Overhaul
		4	100%	68.97%	Lower (Plant Fault)
		5	100%	99.49%%	Lower (Plant Fault)
11	Generated Thermal Efficiency (%)	1	41.54	34.59%	
		2	-----	-----	Unit Overhaul
		4	41.18%	30.96%	
		5	41.50%	37.02%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), MARCH,2009

S/N	KPI	UNIT	TAR	ACTU	REMARKS

			GET	AL	
1	Generation (MWH)	1	144,000	68,951	Lower(Gas Limit/High Condensate)
		2	144,000	0	Unit Overhaul
		4	144,000	37,360	Lower (Gas Limit/Condenser)
		5	144,000	63,242	Lower (Gas Limit/High Condensate
		Total	576,000	169,553	Lower (Gas Limit/High Condensate)
2	% Consumption	1	5.0 %	6.20 %	Higher (Gas Limitation)
		2	5.0%	-----	Unit Overhaul
		4	5.0 %	7.50 %	Higher (Gas Limitation)
		5	5.0 %	6.05 %	Higher (Gas Limit)
3	Station Consumption (MWH)	Trf A	------	1123.9	
		Trf B	------	805.8	
		Trf C	-----	1067.8	
		Total	------	2997.5	This is 1.77% of total Generation
4	Number of Trips/Categorization of faults	1	0	2	(1-SF, 1-PF)
		2	0	----	-----
		4	0	0	0
		5	0	2	(1-SF, 1-PF)
		Total	0	4	(2-SF, 2-PF)

5	Make Up Water Loss	1	7350	4511.35	
		2	6809.7	----	
	(Tons)	4	7350	11515.56	
		5	7350	10306.84	
6	Generation Utilization Index(%)	1	90 %	42.13 %	Lower (Gas Limitation)
		2	90 %	----	Unit Overhaul
		4	90 %	22.83 %	Lower (Gas Limitation)
		5	90 %	38.64 %	Lower (Gas Limitation)
7	Capacity Utilization Index(%)	1	100 %	100 %	
		2	100 %	---	Unit Overhaul
		4	100 %	70.97 %	Condenser Cleaning
		5	100 %	100 %	
		1	1080	11016.	

8	Fuel Utilization Index(SCF/MWH)		0	34	
		2	10800	----	
		4	10800	13019.77	
		5	10800	12212.92	
9	Routine Maintenance Index (%)	1	100%	99.75%	
		2	100%	---	
		4	100%	98.47%	
		5	100%	98.90%	
10	Plant Reliability Index (%)	1	100%	79.27%	High Condensate flow
		2	100%	-----	Unit Overhaul
		4	100%	62.78%	Condenser Cleaning
		5	100%	79.35%	High Condensate flow
11	Generated Thermal Efficiency (%)	1	40.63%	34.58%	
		2	-----	-----	Unit Overhaul
		4	38.65%	30.41%	
		5	40.29%	34.10%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), APRIL,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	119,344	Lower (Gas Limit/Water crisis)
		2	144,000	16900	Lower (tests after overhaul)
		4	144,000	120,102	Lower (Gas Limit/System trouble)
		5	144,000	134,389	Lower (Gas Limit/Water crisis)
		Total	576,000	390,735	Lower (Gas Limit/Water crisis)
2	% Consumption	1	5.0 %	4.85 %	O.K
		2	5.0 %	6.00 %	Tests after overhaul
		4	5.0 %	4.83 %	O.K
		5	5.0 %	4.04 %	O.K
3	Station Consumption	Trf A	-----	1925.5	
		Trf B	-----	423.7	
		Trf C	----	1110.7	
	(MWH)	Total	-----	3459.9	This is 0.89% of total Generation
4	Number of Trips/Categorization of faults	1	0	5	(4-SF, 1-PF)
		2	0	---	Reliability tests in progress
		4	0	4	(4-SF)
		5	0	3	(3-SF)
		Total	0	12	(11-SF, 1-PF)
5	Make Up Water Loss (Tons)	1	7350	8534.49	
		2	6809.7	432.70	
		4	7350	8143.47	
		5	7350	4499.15	

6	Generation Utilization Index(%)	1	90 %	75.34 %	Lower (Gas Limit/Water crisis)
		2	90 %	10.67%	Lower (Unit Overhaul)
		4	90 %	75.82 %	Lower (Gas Limit/system trouble)
		5	90 %	84.84 %	Lower (Gas Limit/water crisis)
7	Capacity Utilization Index(%)	1	100 %	100 %	O.K
		2	100 %	13.33 %	Unit Overhaul
		4	100 %	100 %	
		5	100 %	100 %	
8	Fuel Utilization Index(SCF/MWH)	1	10800	10986.99	
		2	10800	9773.53	
		4	10800	10840.09	
		5	10800	10802.70	
9	Routine Maintenance Index (%)	1	100%	98.57%	
		2	100%	93.62%	
		4	100%	99.80%	
		5	100%	94.63%	
10	Plant Reliability Index (%)	1	100%	91.90%	Lower (System Fault)
		2	100%	16.97%	Unit Overhaul
		4	100%	97.86%	Lower (system fault)
		5	100%	92.90%	Lower (System fault)
11	Generated Thermal Efficiency (%)	1	41.29%	33.96%	
		2	40.25%	35.62%	
		4	41.26%	36.36%	

		5	41.38%	37.97%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), MAY,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	81,508	Lower (poor water quality/gas)
		2	144,000	93,585	Lower (poor water quality/gas)
		4	144,000	27,735	Lower (no 6 HP heater/gas limit)
		5	144,000	90,036	Lower (poor water quality/gas)
		Total	576,000	292,864	Lower (poor water quality/gas)
2	% Consumption	1	5.0 %	5.91 %	
		2	5.0 %	4.97 %	O.K
		4	5.0 %	4.43 %	O.K
		5	5.0%	5.27 %	O.K
3	Station Consumption (MWH)	Trf A	------	1352.3	
		Trf B	------	444.1	
		Trf C	-----	1849.2	
		Total	------	3645.6	This is 1.24% of total Generation
4	Number of Trips/Categorization of faults	1	0	6	(6-SF)
		2	0	5	(5-SF)
		4	0	2	(2-SF)
		5	0	7	(7-SF)
		Total	0	20	(20-SF)
		1	7350	5928.23	

5	Make Up Water Loss (Tons)	2	6809.7	1073.92	
		4	7350	3211.87	
		5	7350	3211.87	
6	Generation Utilization Index (%)	1	90 %	49.80 %	Lower (poor water quality/gas)
		2	90 %	57.18 %	Lower (poor water quality/gas)
		4	90 %	16.94 %	Lower (no 6 HP heater/gas limit)
		5	90 %	55.01 %	Lower (poor water quality/gas)
	Capacity Utilization Index(%)	1	100 %	90.32 %	
		2	100 %	90.32 %	Lower (poor water quality)
		4	100%	32.26 %	Lower (no 6 HP heater job)
		5	100 %	90.32 %	Lower (poor water quality)
8	Fuel Utilization Index(SCF/MWH)	1	10800	12120.27	
		2	10800	11471.36	
		4	10800	11471.36	
		5	10800	12770.00	
9	Routine Maintenance Index(%)	1	100%	96.59%	
		2	100%	100.00%	
		4	100%	97.86%	
		5	100%	98.70%	
10	Plant Reliability Index (%)	1	100%	83.35%	Lower (poor water quality)
		2	100%	84.47%	Lower poor water quality)
		4	100%	30.38%	Lower (no 6HP heaters)
		5	100%	84.84%	Lower (poor water quality)

11	Generated Thermal Efficiency (%)	1	40.90%	34.63%	
		2	41.17%	35.81%	
		4	40.66%	33.56%	
		5	41.07%	35.81%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), JUNE,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	10,848	Lower(secondary super heater tube leakage)
		2	144,000	117,801	Lower (system troubles)
		4	144,000	74,933	Lower (system/plant troubles)
		5	144,000	117,934	Lower (system/gas limitation)
		Total	576,000	321,516	Lower (system/gas limitation)
2	% Consumption	1	5.0 %	6.89 %	Higher (sec superheater leakag)
		2	5.0 %	4.51 %	O.K
		4	5.0%	– --	Unit out of service
		5	5.0 %	4.62 %	O.K

3	Station Consumption (MWH)	Trf A	------	1707.7		
		Trf B	------	2719.1		
		Trf C	----	2571.1		
		Total	-----	6997.9	This is 2.18% of total generation	
4	Number of Trips/Categorization of faults	1	0	3	(3-SF)	
		2	0	10	(9-SF, 1-PF)	
		4	0	6	(4-SF, 2-PF)	
		5	0	9	(9-SF)	
		Total	0	28	(25-SF, 3-PF)	
5	Make Up Water Loss (Tons)	1	7350	1258.61		
		2	6809.7	12737.66		
		4	7350	1849.04		
		5	7350	7593.17		
6	Generation Utilization Index(%)	1	90 %	6.85%	Lower (secSH Tube leakage)	
		2	90 %	74.37 %	Lower system troubles)	
		4	90 %	47.31 %	Lower (system/plant troubles)	
		5	90 %	74.45 %	Lower (system/gas limit)	
7	Capacity Utilization Index(%)	1	100 %	40.00 %	Lower (sec. S/H Tube leak)	
		2	100 %	96.67 %	Lower system troubles)	
		4	100 %	93.33 %	Lower (water limitation)	
		5	100 %	100%	Ok	
		1	10800	13340.1		

8	Fuel Utilization Index(SCF/MWH)			1	
		2	10800	10716.41	
		4	10800	11619.79	
		5	10800	11106.32	
9	Routine Maintenance Index (%)	1	100%	96.93%	
		2	100%	98.01%	
		4	100%	97.84%	
		5	100%	97.86%	
10	Plant Reliability Index(%)	1	100%	14.92%	Lower (superheater tube leak)
		2	100%	89.94%	Lower (system troubles)
		4	100%	55.60%	Lower (system/plant troubles)
		5	100%	85.79%	Lower (system troubles)
11	Generated Thermal Efficiency (%)	1	39.56%	31.54%	
		2	41.43%	34.44%	
		4	41.25%	34.22%	
		5	41.43%	36.46%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), JULY,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS

1	Generation (MWH)	1	144,000	96,920	Lower (system/plant/gas troubles)
		2	144,000	107,633	Lower (system/plant/gas troubles)
		4	144,000	97,812	Lower (system/plant/gas troubles)
		5	144,000	101,618	Lower (system/plant/gas troubles)
		Total	576,000	403,983	Lower (syst/plant/gas troubles)
2	% Consumption	1	5.0 %	5.43 %	Higher
		2	5.0 %	4.80 %	OK
		4	5.0 %	---	Unit out of service
		5	5.0 %	5.16 %	Higher
3	Station Consumption (MWH)	Trf A	------	682.60	
		Trf B	------	3259.00	
		Trf C	-----	3167.50	
		Total	------	7109.10	This is 1.76% of total generation
4	Number of Trips/Categorization of faults	1	0	5	(3-SF, 1-PF, 1-GF)
		2	0	5	(2-SF, 2-PF,1-GF)
		4	0	3	(1-SF, 1-PF,1-GF)
		5	0	3	(1-SF,2-GF)
		Total	0	16	(6-SF,5-PF,5-GF)
5	Make Up Water Loss (Tons)	1	7350	7195.47	
		2	6809.7	1250.01	
		4	7350	2192.52	
		5	7350	8179.32	

6	Generation Utilization Index(%)	1	90 %	59.21 %	Lower (system/plant/gas troubles)
		2	90 %	65.76 %	Lower (system/plant/gas troubles)
		4	90 %	59.76 %	Lower (system/plant/gas troubles)
		5	90 %	62.08 %	Lower (system/plant/gas troubles)
7	Capacity Utilization Index(%)	1	100%	100 %	OK
		2	100%	100%	OK
		4	100%	100%	OK
		5	100%	100%	OK
8	Fuel Utilization Index(SCF/MWH)	1	10800	11,466.62	
		2	10800	11 342,54	
		4	10800	11 153,78	
		5	10800	11 324,88	
9	Routine Maintenance Index(%)	1	100 %	99.18 %	
		2	100 %	98.76 %	
		4	100 %	98.99 %	

		5	100 %	98.36 %	
10	Plant Reliability Index(%)	1	100 %	17.99 %	Lower (system/plant/gas troubles)

		2	100 %	13.79 %	Lower (system/plant/gas troubles)
		4	100 %	19.03 %	Lower (system/plant/gas troubles)
		5	100 %	14.59 %	Lower (system/plant/gas troubles)
11	Generated Thermal Efficiency(%)	1	39.56%		
		2	41.43%		
		4	41.25%		
		5	41.43%		

MONTHLY KEY PERFORMANCE INDICATORS (KPI), SEPTEMBER,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	100,819	Lower (system/plant/gas troubles)
		2	144,000	94,482	Lower (system/plant/gas troubles)
		3	144,000	41,477	Lower (system/plant/gas troubles)
		4	144,000	97,020	Lower (system/plant/gas troubles)
		5	144,000	100,4	Lower (system/plant/gas

				21	troubles)	
			Total	720,000	434,219	Lower (system/plant/gas troubles)
2		% Consumption	1	5.0 %	5.60 %	Higher (Gas Limitation)
			2	5.0 %	5.27 %	Higher
			3	5.0 %	5.79 %	Higher
			4	5.0 %	----	Unit X former out of service
			5	5.0 %	5.49 %	Higher
3	Station Consumption (MWH)		Trf A	------	1062.4	
			Trf B	------	3810.5	
			Trf C	-----	3098.7	
			Total	------	7971.6	This is 1.84% of total generation
4	Number of Trips/Categorization of		1	0	2	(2-PF)
			2	0	1	(1-GF)
			3	0		Commissioning in progress
			4	0	1	(1-SF)

	faults	5	0	1	(1-SF)	
		Total	0	5	(2-SF, 2-PF, 1-GF)	
5	Make Up Water Loss (Tons)	1	7350	9386.13		
		2	6809.7	8490.51		
		3	7350	1792.40		
		4	7350	5638.12		
		5	7350	438.89		
6	Generation Utilization Index(%)	1	90 %	63.65 %	Lower (system/plant/gas troubles)	
		2	90 %	63.91 %	Lower (system/plant/gas troubles)	
		3	90 %	26.18 %	Lower (system/plant/gas troubles)	
		4	90 %	26.18 %	Lower (system/plant/gas troubles)	
		5	90 %	61.25 %	Lower (system/plant/gas troubles)	
		1	100 %	100 %	OK	

7	Capacity Utilization Index(%)	2	100 %	93.33 %		
		3	100 %	39.47 %	Overhaul outage	
		4	100 %	100 %	Ok	
		5	100 %	100 %	Ok	
8	Fuel Utilization Index(SCF/MWH)	1	10800	11 370,51		
		2	10800	11 146,99		
		3	10800	11 246,06		
		4	10800	11 578,56		
		5	10800	11 856,78		
	Routine Maintenance	1	100 %	98.69		

9	Index(%)			%	
		2	100 %	97.73 %	
		3	100 %	96.39 %	
		4	100 %	98.51 %	
		5	100 %	97.88 %	
10	Plant Reliability Index(%)	1	100 %	98.9 %	Lower (system/plant/gas troubles)
		2	100 %	93.90 %	Lower (system/plant/gas troubles)
		3	100 %	53.30 %	Lower overhaul outage
		4	100 %	99.80 %	Lower (system/plant/gas troubles)
		5	100 %	99.50 %	Lower (system/plant/gas troubles)
11	Generated Thermal Efficiency (%)	1	41.68%	35.23%	
		2	41.71%	34.72%	
		3	40.80%	34.72%	
		4	41.62%	34.54%	
		5	41.63%	38.11%	

MONTHLY KEY PERFORMANCE INDICATORS (KPI), OCTOBER,2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation (MWH)	1	144,000	127,797	Lower(system/plant/gas troubles)
		2	144,000	141,048	Lower (system/plant)
		3	144,000	130,944	Lower (system/plant/gas troubles)
		4	144,000	135,916	Lower (system/plant/gas troubles)
		5	144,000	61,425	Lower (system/plant/gas troubles)
		Total	720,000	597,130	Lower (system/plant/gas troubles)
2	% Consumption	1	5.0 %	5.02 %	Higher
		2	5.0 %	4.59 %	Ok
		3	5.0 %	4.82 %	Ok
		4	5.0%	-----	Unit X former out of service
		5	5.0 %	5.03 %	Higher
		Trf A	– –--	917.30	

3	Station Consumption (MWH)	Trf B	– ----	4382.30	
		Trf C	– – -	3798.50	
		Total	– – –	9098.10	This is 1.52% of total Generation
4	Number of Trips/Categorization of faults	1	0	2	(1-SF, 1-GF)
		2	0	– –	(1-SF, 1-PF)
		3	0	2	(1-SF, 1-GF)
		4	0	2	(1-SF, 1-GF)
		5	0	3	(1-SF, 1-PF, 1-GF)
		Total	0	11	(5-SF, 2-PF, 4-GF)
5	Make Up Water Loss (Tons)	1	7350	9 996,36	
		2	6809.7	57	
		3	7350	3 846,20	
		4	7350	7980.58	
		5	7350	1 011,81	
6	Generation Utilization Index(%)	1	90 %	78.08 %	Lower(system/plant/gas troubles)
		2	90 %	86.17 %	Lower(system/plant/gas troubles)
		3	90 %	80.00 %	Lower(system/plant/gas troubles)
		4	90 %	83.04 %	Lower(system/plant/gas troubles)
		5	90 %	37.53 %	Lower(system/plant/gas

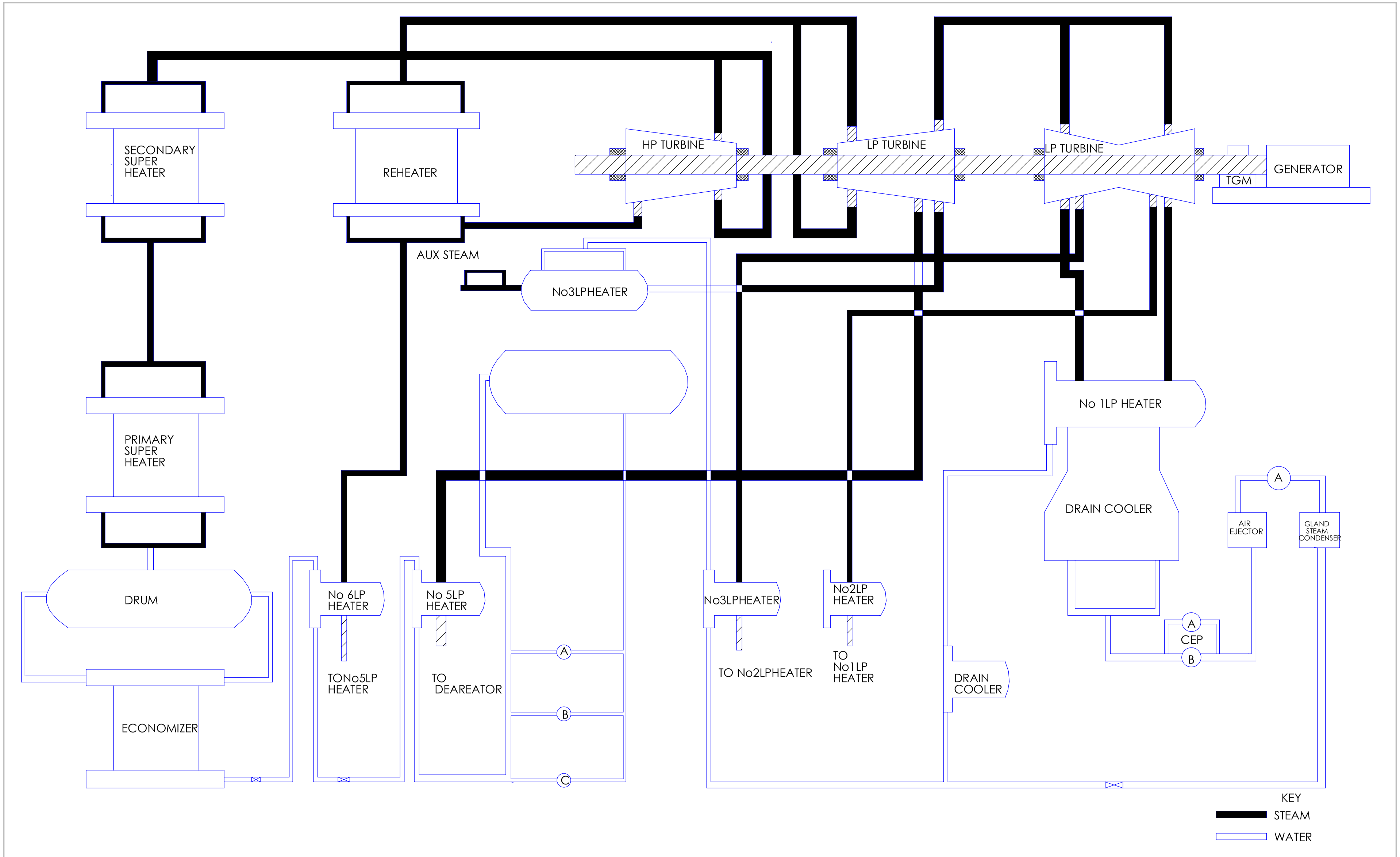
					troubles)
7	Capacity Utilization Index(%)	1	100 %	100 %	
		2	100 %	93.33 %	OK
		3	100 %	39.47 %	OK
		4	100 %	100 %	OK
		5	100 %	100 %	OK
8	Fuel Utilization Index(SCF/MWH)	1	10800	11 370,51	
		2	10800	11 146,99	
		3	10800	11,246.06	
		4	10800	11 246,06	
		5	10800	11 578,56	
9	Routine Maintenance Index(%)	1	100 %	98.48 %	
		2	100 %	98.68 %	
		3	100 %	98.68 %	
		4	100 %	98.68 %	
		5	100 %	98.56 %	
10	Plant Reliability Index(%)	1	100 %	98.69 %	Lower (system/gas troubles)
		2	100 %	98.58 %	Lower (system/gas troubles)
		3	100 %	98.07%	Lower (system/gas troubles)
		4	100 %	98.07 %	Lower (system/gas troubles)
		5	100 %	48.91 %	Lower (system/gas troubles)
11	Generated Thermal	1	41.40 %	35.30 %	

	Efficiency(%)	2	41.45%	35.95 %		
		3	41.43 %	37.30 %		
		4	41.32 %	33.49 %		
		5	41.30 %	37.71 %		

MONTHLY KEY PERFORMANCE INDICATORS (KPI) NOVEMBER, 2009

S/N	KPI	UNIT	TARGET	ACTUAL	REMARKS
1	Generation(MWH)	1	144,000	88,122	Lower (system/plant/gas limit)
		2	144,000	100,372	Lower(system/plant/gas limit)
		3	144,000	74,140	Lower(system/plant/gas limit)
		4	144,000	62,478	Lower(system/plant/gas limit)
		5	144,000	20,348	Lower(system/plant/gas limit)
		total	720,000	345,460	Lower(system/plant/gas limit)
2	% consumption	1	5.0 %	5.65 %	Higher
		2	5.0 %	5.09 %	Higher

		3	5.0 %	5.87 %	Higher
		4	5.0 %	–	Unit X former out of service
		5	5.0 %	6.42 %	Higher
3	Station consumption MWh	Trf A	---	906.50	
		Trf B	---	3404.80	
		Trf c	--	2332.90	
		Total	--	6644.20	This is 1.92% of total generation
4	Number of trips/categorization of faults	1	0	4	(3-SF, 1-PF)
		2	0	3	(3-SF)
		3	0	6	(3-SF, 3-PF)
		4	0	5	(3-SF, 2-PF)
		5	0	2	(2-SF)



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH: OKWUEJUNTI EMEKA 1101204 KEHINDE BOLAJI 1101203	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
NAME	SIGNATURE	DATE		TITLE: FLOW DIAGRAM OF STEAM/FEED WATER LINE(LTS EGBIN)	
DRAWN					
CHK'D NISONEN JUKKA					
APPV'D					
MFG					
Q.A			MATERIAL:	DWG NO. THESIS	A2
			WEIGHT:	SCALE:1:1	SHEET 1 OF 1