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"Modeling of a Power Plant (A Case Study of Savannah Sugar Power Plant)."North-Eastern Nigeria.

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Abstract: The system under scrutiny in this paper is a thermal power plant in Savannah Sugar Company Numan (SSCN) factory, Nigeria. The final power output of the plant is affected by random events such as equipment failures. Whenever such random events occur, the power plant's output is unstable due to the electrical power demand by the factory instruments and estate. Unavailability of plant means shorter production periods and hence profit loss, these effects should be minimized, which is not a trivial matter because the plant is a highly complex system. This paper presents the principal dynamic phenomena that determine the model of boiler-turbine-generator system. The formation of the model is based on fundamental physical and thermodynamic laws. The nonlinear nature of the model is made up of differentials and algebraic equations, steam tables and the use of algebraic polynomial formulae provided the means of obtaining required data for the modelling. Raw data was taken from this power plant for period of two years. The derived model is realized in the MATLAB/SIMULINK 7.10 environment using the SSCN power plant raw input data. Validation result shows that the plant's outputs (Steam Pressure and Electrical Power) are within acceptable range of the manufacturer's recommended values. This model can be said to be the true representation of SSCN power plant.
Keywords: model, dynamic phenomena, raw data, simulation, steam pressure, electrical power, algebraic equation, differential equations.

INTRODUCTION

The SSCN Thermal Power Plant Unit (TPPU) supplies 3200kPa steam at 0.2083kg/s which rotates turbine-generator at 6000rpm for the production of 4.8 MW power.
The electrical power production is dependent on steam generated from boiler system but due to its complexity and flexibility, it requires a simulator (model) to predict the plant behaviour (Stefano, 2000).

Using models cut down the time of project realization and reduce all the risks associated with the work on the real object.To facilitate this study; mathematical models are derived to represent the plant (Flynn and O' Malley, 1999 and Baligh et al., 2010).
The modelling of power plant is divided into four stages based on thermodynamic engineering principles (Cellier, 1982; Jiya and Gumpy, 2008, Maffezzoni, 1997 and Bolis et al., 1993).

2 The Savannah Sugar Company Numan power plant

This plantl produces electric power from fossil fuel through several energy conversion processes, using water as a working fluid (Thermal Power Plant). The chemical energy of the fossil fuel is transformed into steam thermal energy by the boiler; it is transformed into rotational mechanical energy by the turbine, and finally the generator produce electrical power energy by electromagnetic induction principle. Concurrently, the working fluid in the boiler is alternately vaporized and condensed in a closed circuit following a thermodynamic cycle (Leva and Maffezoni, 2003 and Yu et al., 2010). The block diagram of the energy conversion process is shown in figure1.

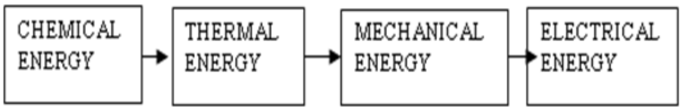

Figure 1: Block diagram of the Energy Conversion processes.

2.1 SSCN thermal power plant process diagram

The steam boiler in a power plant serves for energy conversion to transform the input chemical energy of oil, into the mechanical energy acting on the turbine and generator as shown in figure 2, (Jiya and Gumpy, 2008; Wen and Fang, 2008; Tor-Martin and Carl-Johan, 2006 and Bolis et al., 1993).

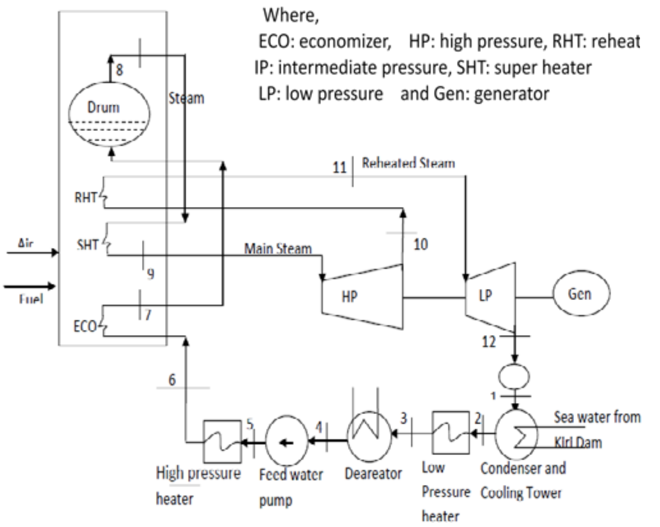

Figure 2 SSCN Thermal Power Plant process diagram

The block diagram of boiler-turbine-Generator system is shown in figure 3.

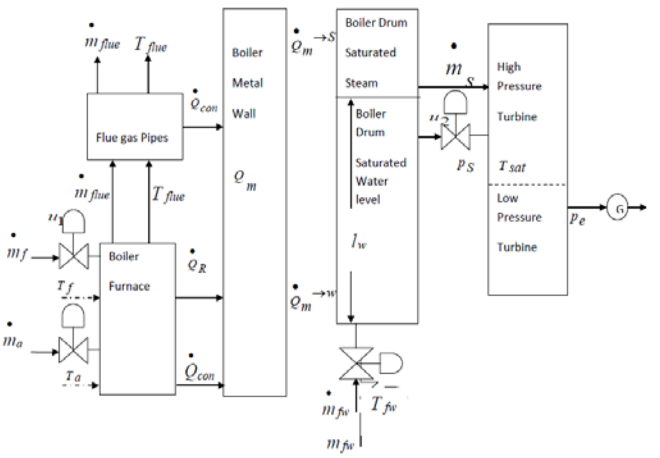

Figure 3 Block diagram of modeled boiler-turbine-generator system Source: Solberg et al., (2005).

Where

G is generator, L_{sw} is saturated water level in meters, P_s is steam pressure in kilo pascal, P_e is electrical power in megawatt, $\dot{m}_a$ is air mass flow rate in kilogram per second, $\dot{m}_f$ is oil mass flow rate, in kilogram per second, $\dot{m}_s$ is steam mass flow rate in kilogram per second, $\dot{m}_{fw}$ is feed water flow rate in kilogram per second, $\dot{m}_{flue}$ is flue mass flow rate in kilogram per second, T_a is air temperature in degree Celsius, T_f is oil temperature in degree Celsius, T_{flue} is flue temperature in degree Celsius, T_{fw} is feed water temperature in degree Celsius, $\dot{Q}_{con}$ is conduction heat flow in kilojoules, $\dot{Q}_{m \rightarrow s}$ is metal heat flow to steam is in kilojoules, $\dot{Q}_{m \rightarrow sw}$ is metal heat flow to saturated water is in kilojoules, u_1 is oil flow control valve, u_2 is steam flow control valve and u_3 is feed water control valve.

The corresponding changes in the thermodynamic cycle offigure 2 are shown in Figure 4, in which, a "point" refers to a physical location.

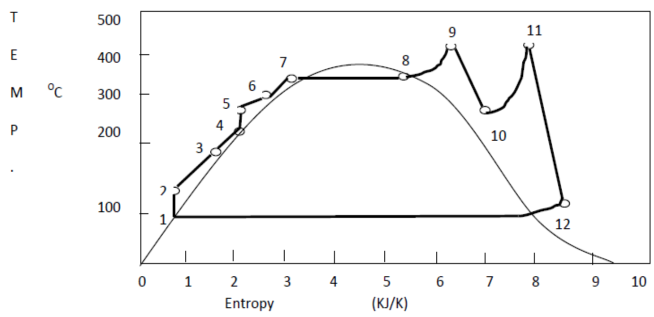

Figure 4 SSCN Temperature-Entropy diagram

3.0 THE STUDY AREA

The plant is located in Numan and Guyuk Local Government areas of Adamawa State in north-east Nigeria. The plant consists of three baggasse/oil fired "Clark Chapman" steam boilers with cane handling and milling systems. The boiler supplies 3200kPa high pressure steam to turbine for 4.8MW electrical power generation. The turbine 2700kPa exhaust steam is discharged into the process house for processing sugar. A small portion of the high pressure steam is supplied directly from boiler to mill for its operation.

3.1 Data collection

The raw data was taken using pressure, temperature gauges and electrical power meter during the plant's normal operation for a period of two years.

3.2 Savannah Thermal Power Plant Manufacturer's Data

The control valve's position is determined using the rate values in table1, while table 2 are the manufacturer's plant specifications and table 3 are the steam table values of enthalpies and densities at specified points (see figure 4).