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Conceptual Condition Monitoring and Operational Modelling of a Palm Kernel Shell Fueled Micro Power Plant

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Abstract – The incessant machinery breakdown is a function of the poor maintenance upkeep designed for the facilities. Hence the need for the development of an integrated condition monitoring for micro power plant to monitor its critical parameters. An Integrated Condition Monitoring System (ICMS) was designed for a micro power plant to monitor the critical parameters which include operating temperature, flow rate, current, voltage, speed and pressure since Steam power plant plays essential roles in the generation of electrical energy. Steam power plant was divided into two types which are conventional steam power plant and nonconventional steam power plant. The major type of steam power plant used is thermal power plant or coal power plant which account for almost 41% of the world electric generation with efficiency ranges from 32% to 42%. Besides, this paper reviews the features and characteristic of the common fuels used, the waste products from the fuels, advantages and disadvantages of the fuels and cost of the fuels. It is marked that several common type of fuels used in steam power plant are identified as fossil fuels, waste heats, waste fuels, and nuclear fuels.

Keywords: Steam power plant, classification of power plants, types of fuels, plant efficiency

I. INTRODUCTION

Human society of today is such that it is dependent on continuous and adequate supply of power at every moment and thus cannot be satiated. Increased economic competitiveness necessitates reorganization of power plant operations, many maintenance groups are determined towards condition-based maintenance rather than periodic or corrective maintenance [1]. Changes in condition-based calibration strategies require instruments to be physically recalibrated only when their performance is degraded. Continuous monitoring of the instrument's calibration performance will allow power plants to reduce the efforts necessary to assure that the instrument is in calibration Simoyan and Fasina[2], Sapenabano *et. al.* [3] identified the benefits of continuous sensor validation to include the reduction of unnecessary maintenance and more confidence in actual sensed parameter values. Reduced maintenance will result in cost savings and reduced outage times while a better knowledge of the actual state of the process could result in increased product quality and reduced equipment damage [4].

In order to implement preventive or condition-based maintenance techniques it is essential that early warning of developing faults is provided so that appropriate decisions may be taken and correct actions planned in advance [5]. For this reason, various condition monitoring techniques are developed which generally involve power plant health monitoring using case-based reasoning [6]. In the past, at the moment and in the future, there must be a means of power generation that can adjust to changing power needs in a quick manner [7]. The advancement in various industries and the demand for energy has grown rapidly for the past few decades. This increasing need of power and energy can only be satisfied with the construction of additional power plant or by optimizing and increasing the efficiency of the existing plants. The latter actions are more beneficial considering high cost of establishing a new plant which involves many stakeholders [8]. One pervasive factor that decreases the efficiency of a power plant is the forced outages or unplanned equipment downtime [9]. Low availability can lead to major costs in the form of lost production hours and expensive repair work and therefore the most important goal of a power operator is to maximize plant's availability and performance with minimum costs [10]. Predictive maintenance as one of optimization action has emerged to provide condition-based early warning. In power generation industry condition monitoring provides early warning of asset failure in combustion turbines, steam turbines, boilers, feed water pumps and cooling water pumps Sapenabano *et. al.* [3], Firas *et. al.* [11] identified that in order to improve a power plant's operational reliability, fault diagnostic accuracy and condition monitoring precision, it is necessary to validate the acquired data, isolate any failed sensor and recover the failed critical measurement in control or fault diagnosis mechanisms. Preventing sensor failure would provide a return on the investment, by minimizing potential down-time. Additional benefits of online intelligent condition monitoring system are safety and enhancement of the knowledge [2,12].

II. Steam Power Plant Types and Design

The world energy consumption in the last thirty years has doubled and keeps increasing with about 1.5 % per year. Fifty percent of the electrical power produced in Finland is produced in steam power plants [13]. Majority of the electricity used in the United States also is generated in steam power plants [14]. Steam power plant is a power plant which comprises pressurized feed water tank, high-pressure steam turbine, high-pressure steam boiler, water-cooled steam condenser, and low-pressure steam turbine that connected in series in a closed circuit [15]. Steam power plant consists combustion chamber, compressor, gas turbine, steam generator and steam turbine [16]. Besides, steam turbine comprises steam engine and operator-controlled throttle for regulating the flow of the steam, supplying heat, prime mover operable and simultaneously regulation [17]. Steam power plant also has feed water heater, circulating pump, evaporator, reheater, combine jet, air condenser, and pressurized boiler [15]. Figure 1 shows the essential of steam power plant equipment.

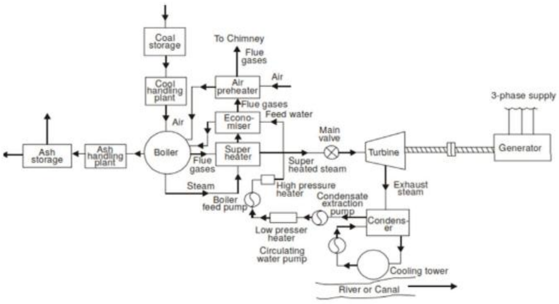

Figure 1: Steam Power Plant Equipment

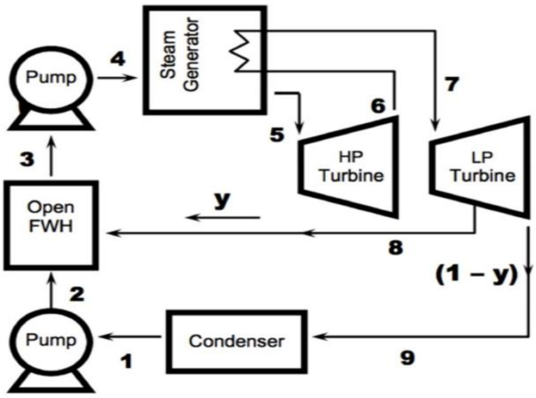

Figure 2: Rankine cycle flow

Steam power plants have been in use for about two hundred years for generating electricity mostly in the 20th century [15]. Steam power plant are generally operating by using Rankine cycle process. Rankine cycle process is the cycle of boiling of water to steam, expansion of steam from high pressure to low pressure, condensation of steam and feed water pump to return the water into the boiler [18]. In the simple Rankine cycle process, steam flow to a turbine, where some of its energy is converted to mechanical energy that is transmitted by rotating shaft to drive an electrical generator. The reduced energy steam is then condenses to liquid water in the condenser. Next, the pump returns the condensed liquid to the steam generator or boiler[14]. Figure 2 and Figure 3 shows the Rankine cycle flow and T-s diagram respectively.

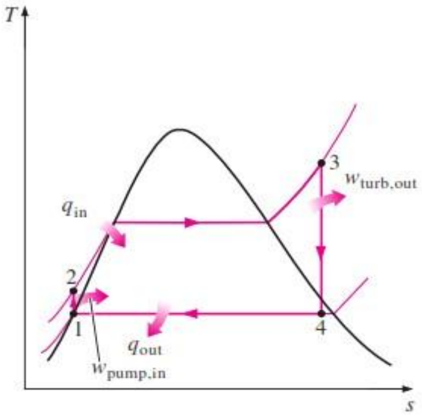

Figure 3: T-s Diagram

Several types of steam power plants are thermal power plant, gas turbine power plant and nuclear power plant. Thermal power plant or coal fired thermal power plant is the most conventional plant of generating electric power with high efficiency. In thermal power plant, the fuel is burnt into the furnace of steam boiler to produced high pressure steam. The steam is then passed through super heater and entered into turbine at high speed. The steam force rotates the turbine blades which caused the conversion of potential energy to mechanical energy and generation of electricity [19]. Nuclear power plant generates electrical power by nuclear reaction. In nuclear power plant, the heat generated by nuclear fission is used to produce steam from water in the boiler. The steam is then used to drive a steam turbine which then generate electrical energy by alternator[20]. Gas turbine can be used in several different modes such as power generation, aviation, and smaller related industries. A gas turbine essentially brings together compressed air and fuel that are then ignited. The resulting gases are expanded through a turbine which caused rotation of turbine’s shaft and drive the compressor continuously. The electrical energy is then generated[21].

Next, there are several types of fuel used in different type of steam power plants which are fossil fuel, waste heat, waste fuel and nuclear fuel. Fossil fuel consist of coal, oil, and natural gas while waste heat consist of gas turbine exhaust and diesel. Besides, waste fuel consist of biomass while nuclear fuel consist of uranium, MOX, and thorium. In thermal power plant, the common fuel used to boil the water to superheated steam is coal. Generally in India, bituminous coal or brown coal are used as fuel of boiler as the volatile content ranging from 8% to 33% and ash content from 5% to 16%[19]. In nuclear power plant, the availability of nuclear fuel is not plenty but very less amount of nuclear fuel can generate high amount of electrical energy. As example, one kg of uranium can produce as much heat as can be produced by complete combustion of 4500 metric tons high grade coal[20]. In geothermal power plant, the fuel used to extract steam is the hot underground rocks while in renewable energy plant and biomass fuelled power plant, the common fuel used are the waste from sugar cane, landfill methane, municipal solid waste and others[22].

2.1 The Major Components of a Steam Power Plant

Kehinde and Okwujuenti [23], MCNeil *et. al* [24] classified the major components of a steam power plant such as; turbine (high, intermediate and low pressure), boiler (economizer, evaporator, drum and superheater), generator, condenser and feed pumps. Chenduran *et. al.* [25] referred to steam turbine as a form of heat engine in which the energy of the steam is transformed into kinetic energy by expansion through nozzles, and the kinetic energy of resulting jet is in turn converted into force doing work on rings of blades mounted on a rotating disc. The majority of steam turbines have two important elements the nozzle and the blade (rotor). In blade the stream of steam particles has its direction and hence its momentum changed. A blade force results from the difference between the momentum entering and the momentum exiting of the rotor blade row. Also, a steam boiler is a power generation device, used for generating steam by applying the heat energy to water [26]. The boiler is used whenever a steam source is necessary, and the size, type mainly depends on the type of application like mobile steam engines locomotives, and road vehicles. Generally, power stations or stationary steam engines have a separate large steam generating capacity, boilers types are: water tube, fire tube, package and stoker [27].

2.3 Classification of Power Plant

Deshpande [28], Petr and Viadimir [29] classified power plants as conventional (which can be any of the following: steam engines, steam turbines, diesel, gas turbines, hydro-electric, nuclear) and non-conventional (which are thermoelectric generator, thermionic generator, fuel-cells, photovoltaic solar cells, fusion reactor, biogas, biomass energy, geothermal energy, wind energy, ocean thermal energy conversion, wave (tidal wave and energy plantation scheme). All the above-mentioned power plants are classified according to the ways in which steam is being generated, which could be Nuclear Power Plant that use nuclear reactor's heat to operate as team turbine generator, Geothermal Power Plant that uses steam extracted from hot underground rocks. Whereas, Petr and Viadimir [29] identified that renewable Energy Plant may be fueled by waste from sugarcane, municipal solid waste, land fill methane or other forms of biomass as fuel because of its low initial capital, availability of its raw materials freely within the country and its adaptability to suite any purpose (i.e. small, medium and large-scale electricity generation), which shall eventually be supportive to the existing power plants, Solar thermal electric plants use sunlight to boil water which turns the generator. Hence, Renewable energy plant was chosen for this study while palm kernel shell will be used as source of energy for producing the steam to turn the generator [30].

2.4 Condition Monitoring

Hashizume *et. al.* [31] referred to Condition Monitoring System as a system to continuously or intermittently acquire data remotely from several sensors, such as vibration sensors, displacement sensors and temperature sensors which are attached to the target machinery, for early detection of component anomalies based on the acquired data. Condition based maintenance consists of parameter and performance monitor in grand subsequent actions. In the words of [32] "Machine faults produce certain signals which monitors can monitor', i.e. there has to be the aligning of Fault–Signal–Monitor.

Marwala [33] proposed a generalized condition monitoring frame work as illustrated in Figure 4, with each box representing one device. The first box contains data acquisition; whose primary function is to acquire data from the system. Data acquisition devices usually include measurement devices, such as; thermometers, accelerometers or strain gauges. Often some preprocessing is integrated to data acquisition to reduce the data transfer and storing requirements. The preprocessed data are processed further in feature selection device, which is a process of identifying and quantifying specific aspects of the data that are proper indicators of faults in the structure or process. In the decision-making device, the selected features are interpreted to obtain condition diagnosis as the outcome.

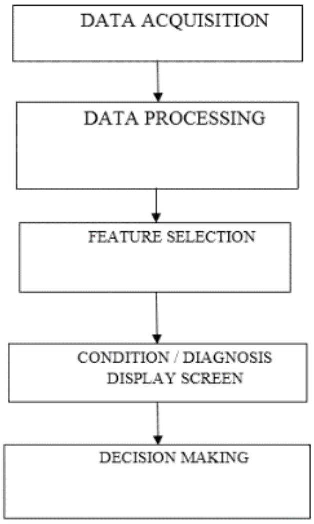

Figure 4: Condition monitoring framework. [33]

2.4.1 Fault Detection, Diagnosis and Prognosis

Three important stages in which condition monitoring can be identified: fault detection, fault diagnosis and prognosis. Fault detection is a process to recognize abnormal operating conditions indicating faults in the monitored system. Diagnosis in turn, is a process to analyze the existence and the cause of the problem, whose objective is to examine symptoms and syndromes to determine the nature of faults and failures [34]. Diagnosis is comprised of fault isolation, which is a task to locate the faulty component, and of fault identification, which is a task to determine the nature and severity of the fault. [32]. The final and most appealing stage of condition monitoring process is prognosis, which is a process of predicting a future condition from present signs and symptoms. Prognosis aims to predict faults before they occur determining the failure mode, when the fault will occur and its chance of happening [35]. However, it should be highlighted that fault diagnosis and prognosis require clear differentiation between different faults, which in turn requires a fault library of the possible fault of the monitored item which must have distinct identities with known fault mechanisms.

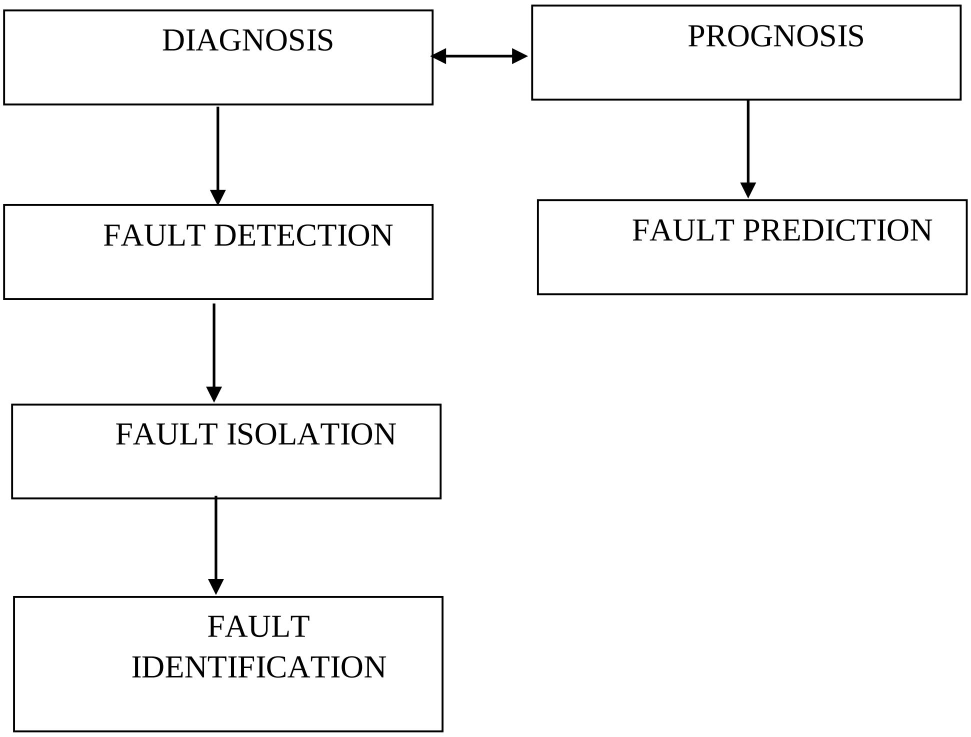

Figure 5: Stages of condition monitoring to decision making [35]

2.4.2 Condition Monitoring Measurement Techniques

Several measurement techniques have been applied in condition monitoring aiming at providing information of the actual condition of the monitored component or system [36]. The simplest forms of condition monitoring are routine inspection carried out by plant personnel to detect local abnormalities, such as noise smell or vibration in the running component. While the importance of inspections by experienced personnel cannot be neglected, more accurate automatized and intelligent condition monitoring systems are desired, especially for decentralized production and remote support services. Some of the most common sensing techniques are vibration monitoring, lubricant analysis, wear particle analysis, monitoring of performance parameters and deterioration monitoring using non-destructive techniques. [33,37,38].

2.4.3 Vibration Monitoring

All running machines vibrate while running. Changes in vibration levels and patterns can be used for detecting faults and identifying the health of equipment. Vibration monitoring is the most used measurement technique in condition monitoring, especially with rotating machines such as pumps, compressors, turbines and electrical generators and motors. Typical measured parameters are acceleration, velocity and displacement of moving mechanical components. These parameters can be measured directly at the component of interest but more often vibration is measured at an available surface giving an indication of internal events without disrupting the process. Vibration monitoring equipment consists of three main items: transducers for data acquisition, signal processing system and an algorithm for condition assessment. Typically, the raw vibration data is processed into overall vibration levels, frequency spectra or high frequency emission. [3,37,38].

2.4.4 Lubricant Analysis and Wear Particle Analysis

Lubricant analysis measures the additives, contaminants and debris, which reveal the condition of the lubricant. The analysis aims at scheduling lubricant change intervals optimally to maintain satisfactory equipment operation. Lubricant analysis is often coupled with wear particle analysis when samples of lubricant oil are collected and analyzed in predetermined intervals. Rate change of debris collection indicates changes in the system condition.

Wear particle analysis is also important to avoid high level of wear particle from rubbing surfaces in the machinery [38,39].

2.4.5 Non-Destructive Deterioration Monitoring

Several non-destructive techniques, which evaluate the properties of a material without affecting the integrity of the component under test, are being used to monitor deterioration of some components [40]. Typically, non-destructive testing is used for static equipment, such as pressure vessels, piping systems and structural components which undergo high stresses due to high temperature and pressure or are prone to corrosion and erosion [29]. Non-destructive techniques allow inspections of difficult-to-reach hot spot stress are as without interfering the process. It is also possible to define the importance of detected defects for structural integrity to define the need for maintenance actions. The most used non-destructive techniques include magnetic particle inspection, eddy current inspection, acoustic emission testing, radiographic inspection and ultrasonic inspection. Thermographic inspection, which measures infrared energy emissions, is also considered as non-destructive technique but, it is usually used to evaluate possible cumulative damage evolution in electrical equipment [38,41].

2.4.6 Performance Monitoring

Juha [36] identified that monitoring the performance of equipment is an important aspect of condition monitoring. The performance, which can be inspected by monitoring performance or process parameters, such as pleasure, flow rate or energy consumption of an equipment, can indicate the condition of a machine. These indications can be used to diagnose the system operational condition. Failure condition can be recognized using fixed limit values or by detecting abnormalities. Traditionally, experienced personnel are required to detect and identify failure modes from process parameters, but the recent development of computational methods have led to appoint, where the need for human diagnosis and localized inspection techniques can be greatly reduced using computational methods [37]. Computational intelligence methods, such as artificial neural networks, have gained a great deal of attention and led to the development of global methods, which can use changes in measured data as a basis for fault detection reducing human effort and detecting faults at early states invisible to traditional approaches [38,41]

III. Environmental Impact

3.1 Environmental Well Being

Using natural gas in substitution to heavy oil, results in the reduction of SO2 and other pollutants. Heavy oil contains large amounts of sulfur (about 3% mass) while this is insignificant in natural gas. Therefore fuel switching from heavyoil to natural gas will decrease the SO2 emissions considerably[42].

3.2 Waste Fuel

Based on the thesaurus or dictionary, waste fuels are directly referred to the biomass. Biomass can be explained as fuel that is developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power [43]. Biomass can make up from scrap lumber, forest debris, certain crops, manure and some types of waste residues.

Biomass is classified as renewable source because waste residues will always exist which is in terms of scrap wood, mill residuals and forest resources; and also properly managed forests will always have more trees, and we will always have crops and the residual biological matter from those crops [44].

Biomass power is carbon neutral electricity generated from renewable organic waste that would otherwise be dumped in landfills, openly burned, or left as fodder for forest fires. When burned, the energy in biomass is released as heat. If you have a fireplace, you already are participating in the use of biomass as the wood you burn in it is a biomass fuel. In biomass power plants, wood waste or other waste is burned to produce steam that runs a turbine to make electricity, or that provides heat to industries and homes. Fortunately, new technologies including pollution controls and combustion engineering have advanced to the point that any emissions from burning biomass in industrial facilities are generally less than emissions produced when using fossil fuel [45].

3.3 Positive Aspect of Biomass

A comparison between biomass with the fossil fuel has been made, it shows that biomass have lower carbon emission. Biomass is not entirely clean, some greenhouse gas (GHG) emission are still produced. But the GHG emission production by biomass is far less compared to fossil fuel[45].

Table 1: Greenhouse Gas Emission Reductions is 981.68 kg CO2 Equiv. per year [46]

Greenhouse gas emission reductions.					
Fuel	Greenhouse Gas Emission Reductions				
	(kg CO2equiv)				
	CO2	CH4	N_2O	CO	TNMOC
Fuel wood	0	243.75	150.17	216.39	152.78
Charcoal	0	43.36	10.54	53.48	68.65
LPG	22.21	0.01	0.73	0.22	1.35
Kerosene	16.69	0.04	0.3	0.19	0.82
Total	38.9	287.16	161.74	270.28	223.6

It shows that the green house reductions by the combustion of fuel wood are higher than the other types of fuels such as charcoal, liquid petroleum gas and kerosene. The total reduction of GHG emission was 981.68 kg CO2 equiv. per year. The 100 kWe biomass generating system in the United Kingdom (UK) will lead to a CO2 emission reduction of around 600 t per unit each year; this is compared with emissions from fossil fuel fired heat and electricity production. This is a significant saving which will greatly benefit the environment by reducing the release of CO2 and GHGs, into the atmosphere. The total GHG mitigation by implementing the Dan Chang bio-energy (bagasse-fired) project in Thailand by combustion process is expected around 278,610 t of CO2 equivalent per year [46].

3.4 Negative Aspect of Biomass

The negative impact of biomass energy can describes as: The occupational injuries and illness associated with agriculture and forest biomass energy production systems are several times more than underground coal mining and oil mining operations [44]. In terms of a million kilocalories of output, forest biomass has 14 times more occupational injuries and illnesses than underground coal mining and 28 times more than oil and gas extraction [47]. A wood-fired steam plant requires 4 times more construction workers and 3–7 times more plant maintenance and operation workers than a coal-fired plant. Including the labor required to produce corn, about 18 times more labor is required to produce a million kcal of ethanol than an equivalent amount of gasoline [44]. The safe harvesting practices and equipment should be developed to reduce the occupational injuries while harvesting and agricultural production for energy [47]. The high rank of burden of disease is attributed to Bangladesh, India, Myanmar and Pakistan with percentage ranging from 3.2 to 4.6. The international commitment was built from the EU member countries to work and tackle these issues together. The urgent need of improving access of the poor to cleaner energy sources was agreed by the international community [48].

3.6 Manually Calculated Values

The power generation cycle need some basic parameters such as output power and speed of the turbine [51]. Sizing steam pipe line table was used to determine steam nozzle orifice, steam capacity and steam inlet pressure for 5.5kW power output [52]. The steam inlet pressure in sizing steam table was used to determine inlet superheated steam temperature T_1 and entry specific enthalpy $h_{1,}$ in the steam table. The specifications for the micro turbine based on targeted electrical power output of 5.0 kW with 10% total mechanical losses. Super-heated steam temperature T_1 and pressure P_1 are the output of synergetic designed boiler which are 250°C and 0.4 MPa respectively at enthalpy h_1 is 2964.5 kJ/kg. While specific volume $\forall$ is 0.59520 m^3/kg, shaft speed n as 2000rpm according to [53]

$W = K\dot{m}\Delta h$ [51] (1)

Where W is the actual power, m is the steam mass flow rate, Δh is the change in enthalpy
$\Delta h = W/\dot{m}$ (2)
$\Delta h = \frac{5.5}{0.0315} = 174.603$ kJ/kg (3)
Inlet pressure P_1 is 4 bar, Super-heated inlet steam temperature T_1 is 250°C,
Inlet enthalpy h_1 is 2964.5 kJ/kg
Specific entropy S is 7.1723 kJ/kg
Specific volume ∀ is 0.59520 m^3/kg.
Shaft rotational speed N is 2000rpm
Blade angle α is 20°
$\Delta h = h_1 - h_2$ [54] (4)
$h_2 = \Delta h - h_1$ (5)
$h_2 = 2964.5 - 174.603 = 2789.90$ kJ/kg (6)
According to Steam table in Appendix 3 when change in enthalpy ΔH is 174.603 kJ/kg, steam outlet temperature; T_2, pressure; P_1 and outlet enthalpy h_2 are 120.21°C, 0.2 MPa and 2789.7 kJ/kg respectively.
For a typical steam plant, according to [54]
$P_{in} = P_{out} + P_{loss}$ (7)
Where P_{in} refers to the power input into the turbine, where P_{out} refers to the mechanical power generated by the turbine, where P_{loss} refers to the power losses in the turbine,
The generator efficiency η is calculated according to [55] using
Generator effiIciency $(\eta) = \frac{P_{out}}{P_{out}+P_{loss}}$ (8)
where; P_{turb} is Power input from turbine (kW), P_{out} is Power output of generator (kW)

Power of the turbine: P_{loss} is 0.5 kW, P_{in} is 5.5 kW, P_{out} is 5 kW. (Design consideration)
Thus, power of the turbine (P_{turb}) required to generate 5 kW of electricity was 5.5 kW
$m_s = \frac{P_{turb}}{C_{pm}\eta_t(T_{in}-T_{out})}$ [55] (9)
where; P_{turb} is Power of the turbine (W), η_t is Efficiency of steam turbine (%),
C_{pm} is mean specific heat capacity of steam (kJ/mol^{0}C,)
m_s is mass flow rate of steam entering turbine (kg/s),
T_{in} is Inlet steam temperature (^{0}C), and
T_{out} is Outlet steam temperature (^{0}C)
For Steam, C_p is 1.8723 $\frac{kJ}{kgK}$ and C_v is 1.4108 kJ/kgK [56]
The outlet temperature, is given by [54].
$T_{out} = T_{in}\left(\frac{P_{out}}{P_{in}}\right)^{\frac{\gamma-1}{\gamma}}$ (10)
But, $\gamma = \frac{C_p}{C_v}$ (11)
For 5 kW power rating, T_{in}, P_{in} and P_{out} are 400°C, 0.45MPa and 0.1MPa, respectively. These were the state properties of superheated steam obtained from V-FLO Pump and System, [55] defined the mean specific heat capacity C_{pm} over the temperature range T_{in} to T_{out} as follow and stated in equation 12 below,

$$C_{pm} = \frac{\int_{T_{in}}^{T_{out}} C_p dT}{\int_{T_{in}}^{out} C_p dT} \quad (12)$$

Outlet temperature of the steam (T_{out}) is calculated from Eq. (10)

$$T_{out} = 400\left(\frac{0.15}{0.45}\right)^{\frac{1.327-1}{1.327}} = 276.1\,^{o}C \quad (13)$$

From Eq. (12) C_p for steam at temperature range 276.1 ^{o}C to 400 ^{o}C

$$C_{pm} = \frac{\int_{276.1}^{400}[0.03346T+(0.688\times10^{-5})T+(0.7604\times10^{-8})T^2]dT}{\int_{276.1}^{400} dT} \quad (14)$$

$$=[0.03346T + 0.344 \times 10^{-5}T^2 + 0.2535 \times 10^{-8}T^3]_{276.1}^{400} \div [T]_{276.1}^{400}$$

$$=[14.09664-9.5539]\div[400-276.1]$$
$$=0.03666\ kJ/\,mol\,^oC\quad thus, 1mol = 0.018kggm$$
$$=2.036\ kJ\ kg^oC$$

Mass flow rate of steam (m_s) is determined from Eq. (9)

$$m_s = 5.5/[(0.8\times 2.036\times(400-276.1)] = 0.0275\,\frac{kg}{s} \qquad (15)$$

Frequency (F_{re}) According to [57] F_{re} can be obtained from (16).

$$F_{re} = \frac{\text{RPM x NP}}{120} \qquad (16)$$

Where NP is Number of poles is 3, RPM is Revolution per minutes,

hence $F_{re} = \frac{2000 \text{ x } 3}{120}$ = 50hz. (17)

Current (I) and Voltage (V) can be obtained from equation 18.

$$\text{Power output(Pout)} = \text{voltage(V)x current (I)} \qquad (18)$$

$$p = VI \qquad [57] \qquad (19)$$

Since P is 5kw, V is 220v hence, $I\ is\ \frac{P}{V}\ is\ \frac{5000}{220}\ is$ 22.73 Amp.

IV. CONCLUSION

Steam power plant have been used for about 200 years to generate electricity. There are several types of steam power plant such as thermal power plant, gas power plant and nuclear power plant. Among the various power plants, thermal power plant or coal power plant account for almost 41% of the world electric generation with efficiency ranges from 32% to 42% while natural gas power plant covered almost 20% of the world electricity generation with efficiency ranges from 32% to 38%. The efficiency for nuclear power plant is only 0.27%[58].

This study examines the common types of fuel used in the various type of steam power plant such as thermal, gas and nuclear power plants. Based on the study, it is found that the common fuel used in steam power plant are fossil fuel, waste fuel (biomass) and nuclear fuel. Fossil fuel consist of coal used in thermal power plant, oil and gas used in gas power plant. Gas turbine exhaust and diesel are the common waste heat while biomass is the waste fuel which used in the biomass fuelled power plant. Nuclear fuel consists of uranium, MOX and thorium which had used in fission process to produce steam in nuclear power plant. The condition monitoring of the identified power plants was as well studied which covers fault detection, diagnosis and prognosis with a view to ensure a drastic reduction in down-time due to maintenance failure through effective adaptability to a micro power plant.

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