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Compressed Natural Gas Technology for Alternative Fuel Power Plants

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Abstract. Gas has great potential to be converted into electrical energy. Indonesia has natural gas reserves up to 50 years in the future, but the optimization of the gas to be converted into electricity is low and unable to compete with coal. Gas is converted into electricity has low electrical efficiency (25%), and the raw materials are more expensive than coal. Steam from a lot of wasted gas turbine, thus the need for utilizing exhaust gas results from gas turbine units. Combined cycle technology (Gas and Steam Power Plant) be a solution to improve the efficiency of electricity. Among other Thermal Units, Steam Power Plant (Combined Cycle Power Plant) has a high electrical efficiency (45%). Weakness of the current Gas and Steam Power Plant peak burden still using fuel oil. Compressed Natural Gas (CNG) Technology may be used to accommodate the gas with little land use. CNG gas stored in the circumstances of great pressure up to 250 bar, in contrast to gas directly converted into electricity in a power plant only 27 bar pressure. Stored in CNG gas used as a fuel to replace load bearing peak. Lawyer System on CNG conversion as well as the power plant is generally only used compressed gas with greater pressure and a bit of land.

1 Introduction

Electricity consumption per capita is an index of living standard of a country. In Indonesia, with the increasing industrial activity and population, the need for electrical power also increased. Due to the increase in fuel prices today's world, PT. PLN (Persero) as one of the state electricity company should think businesses operating cost savings, of which 75% are in fuel costs. One effort that can be taken by PT. PLN (Persero) is the main power plant fuel switching from fuel oil (HSD and MFO) into natural gas.[1] [2]

Basically PLN operate Power Gas and Steam (Power Plant) as *peaker* plants (peak load) because operating costs are more expensive than base load generation (base load). Oil energy crisis that resulted in soaring oil prices caused the gas to be used as an alternative PLN for plant outside of peak load. During this time, when the load is low (outside of peak load), the supply of gas for the power plant is not absorbed optimally, as appropriate loading pattern in the Java-Bali system more filled by many ordinary coal plant production is cheaper. Nevertheless, the unabsorbed gas must still be paid, the gas supply contract is a take or pay. While at peak load gas supply is insufficient, so that some plants have to be operated using the fuel.[2]

Presence technology Compressed Natural Gas (CNG) is expected to be a solution to the problem mentioned above. Gas supply flow rate remain while outside of peak load, partially compressed into CNG tube pressurized to 250 bar for 10 hours. CNG use of technology for the generation of a rock thing, not in other countries. Much of the world uses Liquid Natural Gas (LNG) technology.

2 Gas Power Plant and Steam

Power Plant is a combination of the working principle of the power plant by gas and steam power plant or so-called combined cycle. Power plant using a gas turbine unit driving the generator, so that the working principle of the power plant following the working principle of the gas turbine. The gas turbine is designed and made for converting heat energy from burning fuel into mechanical energy. The system uses the principle of the Brayton cycle gas power plant. While the working principle of the power plant is converting the chemical energy in the fuel is converted into thermal energy in the form of vapor pressure and high temperature, the steam then changed to mechanical energy to drive generator. The system uses the principle of the Rankine cycle power plant. Figure 1 is a Grati power plant in East Java with a capacity of 526.850 MW which use the principle of combined cycle.[1] [3]

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Fig. 1. Grati Power Plant in East Java (Pasuruan)

Grati Power Plant in East Java (Pasuruan) consists of: Gas Turbine: 112.450 MW x 3; Steam turbine: 189.500 MW; Block output 526.850 MW.

2.1 Combined cycle

In improving the efficiency of gas turbines do combined cycle gas turbine with a steam turbine cycle in order to obtain the combined cycle which is commonly referred to as "co-generation". Meanwhile, to improve the thermal efficiency of the gas turbine is used combined cycle, forming a so-called "Combined Cycle" or Steam Gas Power Plant (Power Plant). Cycle power plant applying the Brayton cycle, whereas the ideal cycle Rankine cycle power plant apply.

2.2 Brayton cycle;

Brayton cycle (Brayton Cycle) shown in Figure 2 consists of isentropic compression process that ended with the release of heat at constant pressure. In Bryton cycle of each state processes can be analyzed as follows:[4]

1-2 (isentropic Compression).

Work required by the compressor:

2-3: Entry of the fuel at a constant pressure.

3-4: isentropic expansion in the turbine.

4-1: Discharge heat at constant pressure into the air.

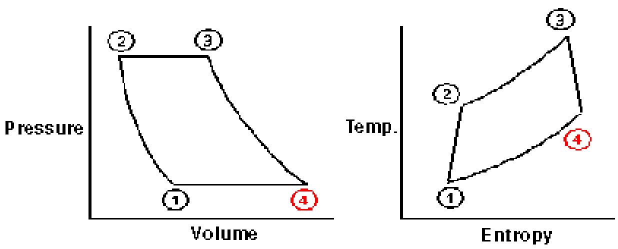

Fig. 2. *p-v and t-s Brayton Syklus Diagram*[3]

From Figure 2 on p-v diagram and t-s, it can be seen that the inclusion of heat takes place at a constant pressure:

$Q_{in} = m.c_p. (T_3\text{-}T_2)$ .... (1)

- Spending too hot at constant pressure:

$Q_{out} = m.c_p. (T_4\text{-}T_1)$ .... (2)

- Thus, useful work can be formulated as follows:

$W_u = Q_{in} - Q_{out}$ .... (3)

c. Rankine cycle;

Rankine cycle in Figure 3 is used in the steam turbine power plant system. The sequence steps as follows:

a - b: Water is pumped from the pressure p2 be p1. This step is a compression step isentropis, and this process occurs at the water pump filler.

b - c: Air pressure is increased the temperature until it reaches boiling point. Occurred in the LP heater, HP heater and Economizer.

c - d: Water transformed into saturated steam. This step is called evaporation with isobars isothermis process, occurred in the boiler is in the wall tube (riser) and the steam drum.

d - e: Steam is heated further until the vapor reaches a temperature further work into hot steam (superheated vapor). The move occurred in the boiler superheater with the isobars.

e - f: Steam does work so that the pressure and the temperature dropped. This step is a step isentropis expansion, and occur within the turbine.

f - a: Disposal of latent heat of the steam that turns into condensate water. This step is isothermis isobars, and occurs in the condenser.

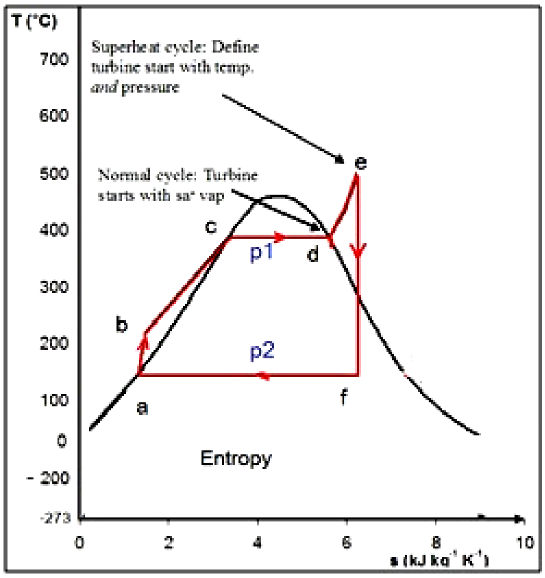

Fig. 3 Diagram T - s Rankine Cycle [5][4]

3 Compressed natural gas

Compressed Natural Gas (CNG) is a fluid gas that has been processed into a high-pressure natural gas compression in a tube. In general, the major components containing CNG methane (CH_3) and ethane (C_2H_8) with fraction of about 90%. CNG is made by compressing methane (CH_4), which is extracted from natural gas. CNG is stored and distributed through the packaging in the tank (pressure vessel or pressure vessel). Ideally, the pressure on the gas pipeline is 11 bar, while the CNG requires a pressure of 200 bar, or 197 atm, 197 times normal air pressure. With a pressure of 200 bar, charging the equivalent of 130 liters of premium gas can be done

within 3-4 minutes. Figure 4 shows an example of CNG tubes.[6] [7]
Calorific value is the amount of heat generated by the combustion of materials or fuels. Measured in units of energy per amount of material, for example kJ / kg. Calorific value of the fuel is divided into two kinds, namely: a calorific value above (HHV) and lower calorific value (LHV).

Fig. 4. pressure of 200 bar CNG Tubes

Higher Heating Value (HHV) or above is the calorific value calorific value derived from the combustion of 1 kg of fuel, taking into account the vapor condensation heat (water resulting from combustion are in liquid form). HHV gas = 1089 Btu / ft3 = 52.225 MJ / kg.

Lower Heating Value (LHV) or lower calorific value is obtained calorific value of combustion heat regardless vapor condensation (water produced from burning was on gas / steam). LHV gas = 983 Btu / ft^3 = 47.141 MJ / kg.

A fuel flash point is the lowest temperature at which the fuel can be heated so that steam output flame briefly when passed a flame. Flash point -187.80C CNG temperature. Burning point is the lowest temperature at which sufficient oxygen conditions, spontaneous combustion can occur. Burning point unit is degrees (^{0}) or degrees Celsius (^{0}) Fahrenheit. CNG point at a temperature of 540^0C. Octane number is a number that shows the number as a percentage (%) volume of isooctane in a mixture that consists of n-heptane issoctane and that does not cause outbreaks in the fuels being tested in a compression chamber of a combustion chamber.[8] [9]

According to the science of thermodynamics, the higher the ratio / percentage of compression used, the higher the efficiency of combustion in the combustion chamber. CNG octane value of the percentage of 130%.
Tube specifications for CNG fuel is as follows:[8]
Capacity = 50-100 (m^3)
Dimensions = 11657 x 2428 x 3028
Massa Netto = 10760 kg
Nominal Diameter = DN80
Material = 16 MNR
The selected specification is commercial fleet refuel CNG compressor station, with a pressure of 1.4-250 bar and a capacity of 1.3 m^3 / h.

4 Output Power Cng Capacity Analysis

4.1 Technical Analysis

Grati power plant that has the capacity of 3.5 MMSCF CNG with gas turbine efficiency of 45% and CF = 0.8 / year in operation for 6 hours output power can be determined as follows:
Production MWh = (SCF x 922 x η) / 3413
= (3.5 x 1,000,000 x 922 x 0.45) / 3413
= 425.476 MWh
Output power = (Production MWh) / (operating time)
= (425.476 MWh) / (6 h)
= 70.91 MW

Fuel is needed to generate power output of 70.91 MW are as follows:
BBG = (3413 x Power Output) / η
= (3413 x 70.91) / 0.45
= 538 MMBTU
= 512,380.9524 ft3
= 14,508,579.05 lt
with:
1 ft^3 = 1050 btu
1 ft^3 = 28.316 lt = 28.316 dm^3

4.2 Economical analysis [6]

4.2.1 Fixed costs

According to the above matter at Grati power plant installed two units of CNG with a capacity of 2 x 70.91 MW. If the interest rate i of 12% by age 25 years plants can be seen:
CRF = $(i (1 + i)^n) / ((1+ i)^{n-1})$ = $(0.12 (1 + 0.12)^{25}) / ((1 + 0 , 12)^{25-1})$ = 0.127
Development costs PLT-CNG = 5.94864 \$ / kWh
CF = 80%
CC = (cost of construction of generating capacity x CRF) / W
= (5.94864 x 400 x10^3 x 0.127) / (400 x 10^3 x 0.8 x 6 x 365)
= 4.4 x 10^{-4} \$ / kWh

4.2.2 Operating and maintenance costs

O & M = (total cost of O & M) / (CF x time x cap) = (20347106.98 (\$)) / (0.8 x 6 x 365 x 400 x 10^3 (kWh)) = 0.03 \$ / kWh

4.2.3 The cost of fuel

Fc = (Ui 860) / 0.45 = (860 x 7.313 x $10^{(-7)}$) / 0.45 = 1.4 x 10^{-3} \$ / kWh

4.2.4 Total cost

Tc = CC + O & M + Fc = 4.4 x 10-4 1.4 x 10-3 + 0.03 = 0.03184 \$ / kWh

5 Conclusion

From the analysis of the utilization of CNG fuel at Grati power plant can be concluded that:

1. The use of CNG is useful to reduce system losses on gas purchases at gas power plant (power plant) in take or pay that lead to wasted unused gas.
2. Costs required by CNG stations is equal to 0.03184 $ / kWh with details:
   a) Construction of 4.4 x 10^{-4} Cost $ / kWh
   b) Operation and Maintenance Costs $ 0.03 / kWh
   c) Cost of Fuel 1.4 x 10^{-3} $ / kWh

CNG has a lower density than air, so it is not flammable.

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