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The Efficiency of Fuel Comsumption using the Power Factor Improving of Thermal Power Plant: *New Approach for CO2 Emission Reduction*

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Abstract

Impact of the thermal power plant for CO2 emissions was a crucial problem in the global warming. Therefore, the CO2 reduction commitments continued effort through a various methods and technologies to improve the efficiency of thermal power plant. By using the method of load flow analysis, showed improvement in the quality of the power factor of electric power system has been verified to improving the power plant output. Proposed have showing relationship between power factor improvement to the reduction of CO2 emissions from thermal power. From the results obtained by using the IEEE 30 bus test system modified proved that there was of the CO2 emissions reduction especially on the rate of the power factor > 0.97 (lagging).

Keywords: power factor improving, CO2 emission, thermal power plant.

Introduction

Recently, thermal power plant in the world as the electricity power source have been contribute to overall emissions [1]. By reference from reported in [1,2] that the thermal plant fuel coal, oil and gas are the major contributors of CO2 emitter of greenhouse. Case studies for other sectors for example; transport, industrial processes, etc., power plant have contributes 21.3% of the causes of increase CO2 world. The International Energy Agency, report estimates that 70% of the greenhouse gases are produced within the cities [3]. Reported in [4], China, India, Indonesia contributed as much as 38%, respectively, 51%, 21% and 33% in CO_2 emission from electric power generation sector. The CO_2 emissions in 2020 are estimated to achieve 236 million ton of CO2 [5].

The growth of world energy consumption continuously increase, therefore number of thermal power installation also growing. The production of electricity from thermal energy in the European Union has reached 54% of the power plant total in year 2005. Include Indonesia with electricity demand growth by average is 7% annually require electricity supply mainly comes from thermal power plant.

In [2], Java and Bali power system, through the baseline scenario estimate of accelerating of projects generating 20,000 MW, there will be the addition of a conventional coal power plant by 27,000 MW. Total production is equivalent to the production of 72.8% of the total production in 2020 (Coal, Oil, Geothermal, hydro power).

Efforts to reduce CO2 emissions through the development of technology and policy of the emission reduction [6]. In ref. [7] reported a future energy storage that consider model by adjustable-speed pumped hydro storage (*AS-PHS*). Two cases has been studied; with and without AS PHS showing that considering AS PHS resulted in a significant reduction in gas generation, total system operating cost and CO2 emissions of power plant. In this case, an article in the Protocol Kyoto set the "carbon market" which gives compensation to power plant operators in determining the selling price of electricity. Kyoto Protocol (1997) that have been ratified by almost all countries have become the reference of CO2 emission reduction of greenhouse gas producer (GHS).

Concept design to reduce GHS propose using the of offshore platform supply vessel system based on hybrid diesel generator and fuel cell power plant [8]. In ref.[9] introduce a develop new technology to capture and store CO2 currently emitted by fixed sources such as turbines, heaters and boilers. Ref.[10] reported that near-zero-carbon-emission for power plant can be use of the renewable energy storage medium. While, by power plant integration in an oil refinery can be to reduce CO2 emissions using Oxy-combustion [11]. In this proposal describes the impact of the power distribution system efficiency improvements of coal-fired thermal electricity to load centers through improved power factor. Load power factor of less than 0.9 will affect the power loss in the channel [12].

The paper organized as follow, In section II contains a problem description about power flow analysis and fuel characteristic of thermal power plant. For section III is a describe impact the power factor to output power plant (generator). To application proposed will be found in section IV and the discuss. Finally, for section V is contains conclusion.

PROBLEM DECRIPTION

To improving the efficiency of the transmission line can be obtained by using the improved power factor at the load, using: reactive power compensation,

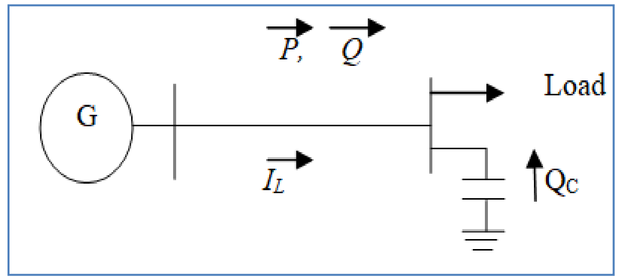

Fig. 1: Single line diagram with capasitor compensation.

For that load flow studies should be done to determine the amount of power loss and power output on the power system. The equation relationship between line current and node voltage on the electric power grid point can be expressed as follows:

Where [Y] = Admitance

[V] = Voltage matrix

[I] = Line current

$$I = \sum_{j=1}^{n} Y_{ij}.V_j \quad \text{(i=1, 2, 2, 3,...n)} \qquad (1)$$

$$I = \frac{P_i - jQ_i}{V_i} \quad \text{(i=1,2,...n)} \qquad (2)$$

Where P and Q are active and reactive power injection at Node, so:

$$I = \frac{P_i - jQ_i}{V_i} = \sum_{j=1}^{n} V_{ij}.\hat{V}_j \quad \text{(i=1,2,...n)} \qquad (3)$$

Loss of power after power factor improvement is expressed as follows:

$$P_L'+jQ'=\sum_{i=1}^{NB}\sum_{j=1}^{NB}Z_{ij}\left(\left|I_j'\right|\cos\phi_j'+j\left|I_j'\right|\sin\phi_j'\right)-\left(\left|I_i'\right|\sin\phi_i-j\left|I_i'\right|\sin\phi_i'\right) \quad (4)$$

So the output power at the plant can be expressed as

$$P_{Gi}=P_{Di}+P_{Li} \quad (5)$$

Where: are a power demand (load) and the power loss in line at the i-th transaction.

To determine requirement each power plant fuels (Thermal power plant) can be obtained based on the characteristics of Input - Output fuel. Input-output characteristics illustrate the relationship between the input and output of fuel produced by the power plant (MW) as shown in figure 1.

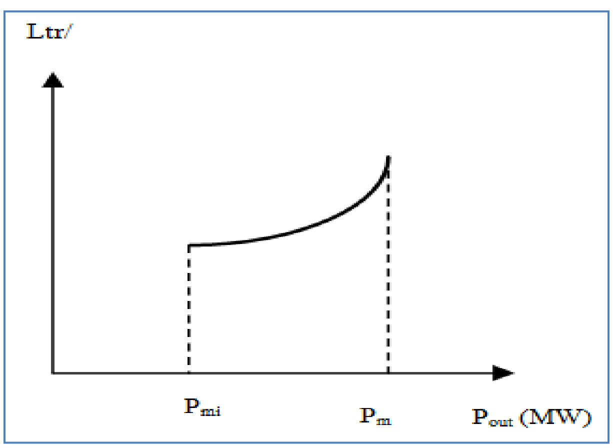

Fig. 2: Input-output fuel consumption characteristic of thermal power plant

In the thermal power plant, input-output characteristics can be obtained through an approach based on second order polynomial functions are:

$$H_i=\alpha_i+\beta_i P_{ti}+\gamma_i P_{ti}^2 \quad (6)$$

Where:

H_i = Fuel consumption of thermal power plant - i (liter/hour)

$\alpha_i,\beta_i,\gamma_i$ = Output of power plant - i (MW)

P_{ti} = Input-output parameter unit termal - i.

III. Propose method

The output power each generator on each bus is a function of the impedance and current of each transmission line. Flow line can be increased if there is a change in power load at bus i-th. Changes in the active power or reactive power will lead to changes in power loss on the line.

By defining the power factor or is the ratio of active power and apparent power, we can expressed equation of active power delivering as :

$$P_i=V_tI_ix\cos\phi_i^{act} \quad (7)$$

So that the delivery of any thermal power plant can be expressed as a function that depends on the power factor. According to equation (7) above, then:

$$P_{out,\cos\phi_{act}}=P_i f(\cos\phi_i^{act}) \quad (8)$$

To obtain the input-output characteristics of thermal power plant taking into account the actual power factor, the equation (7) substituted into a (8), to obtain:

$$H_{i,\cos\phi_{act}} = \alpha_i + \beta_i P_{ti,\phi_{act}} + \gamma_i P^2_{ti,\cos\phi_{act}} \qquad (9)$$

To determine of CO2 emmission for thermal power plant based on power factor using:

$$Emmission\_GHG, \cos\phi_{act} = F_{consump,\cos\phi_{act}} * E_{GHG,fuel} \qquad (10)$$

Table 1: Emmision factor recommended IPPC [13]

Source	Emmison factor
US. Dept. Energy	0.69
Japan Energy and Economic	0.68
China Energy Reseach Institut of National Development and Reform Commission	0.67

IV. Case Study and Result

A. The 30 Bus IEEE test system

As an illustration of the verification method proposed, the proposal has been tested on 30 bus IEEE test system. Scenario at bus 7, 12 and 21 are inductive load with a power factor will be improved by the injection of reactive power. And for the slack bus is a thermal power plant (steam / gas) by fuel MFO (Marine Fuel Oil).

Power factor is tolerated from 0.84 (in accordance with the initial conditions IEEE 30 bus system) to the maximum power factor (cos phi = 1). Due to a leading power factor will result in power loss greater than cos phi = 1 (unity).

Based on the picture, it is obtained that the power loss is reduced if the power factor increasing

- Determine the input equation out fuel power plant:
- Assumptions:Bus#1 consists of 4x100 MW generator with fuel MFO (Thermal power plant.
- Fuel consumption of each generator are:
  1. Output 100 MW = 0.20 ltr/h
  2. Output 80 MW = 0.23 ltr/h
  3. Output 60 MW = 0.25 ltr/h
  4. Output 50 MW = 0.27 ltr/h

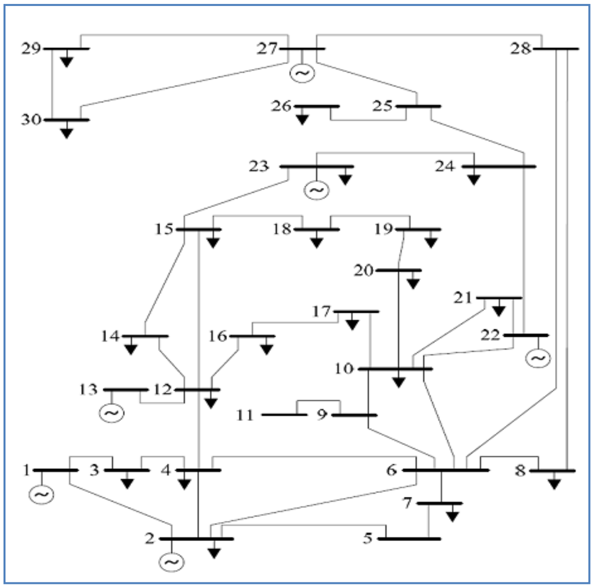

Fig 3: Single line diagram the 30 bus IEEE test systems

B. The Result

In Figure [4], showing the power losses maximum according to scenario initial conditions by 19.917 MW and output power at G1 (slackbus) is 262.316 MW. With the improvement of power factor (load) hence,the biggest loss is based on scenario; L # 12 by the power factor 0.95, by amount 19.902 MW and the output of G1 is 263.302 MW. While for scenario with all loads (L7; L12 and 21) have a power factor 1 (unity) then the power losses is 19.614 and the G1 output is 263.013 MW.

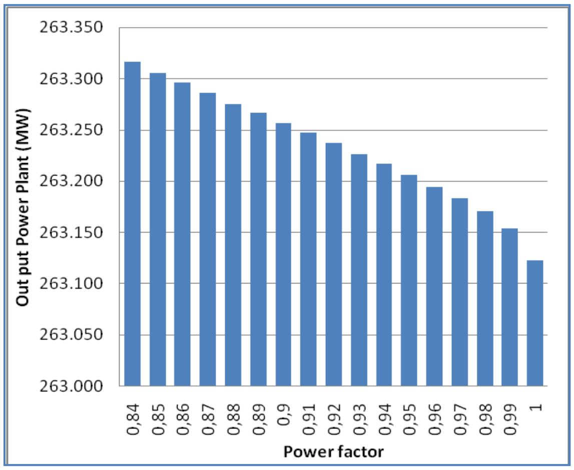

Fig. 4: Impact of output power plant to the load power factor

Figure 4 shows that a change on power factor will cause a change in output power at bus 1 (slack: bus). Power factor is tolerated from 0.84 (in accordance with the initial conditions IEEE 30 bus system) to power factor (cos phi = 1). The higher the power factor at bus # 21 hence, will decrease the power output at Bus 1.

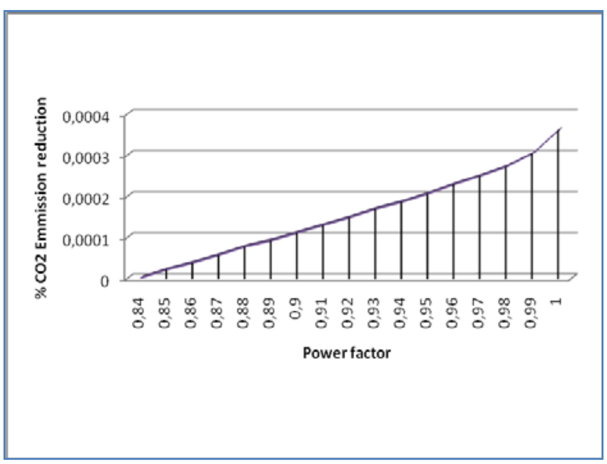

***Fig. 5:** CO2 emission reduction based on power factor*

Based on Figure [5] shows a reduction of CO2 emissions produced by the power plant at bus # 1 (slack bus) as a result of the improvement of the power factor. In this graph also illustrate the relationship increased CO2 similar to the characteristics input-output of power plant fuel. At cos phi values between 0.97 to 1, then the reduction in CO2 emissions was relatively higher than at cos phi <0.97

Conclussion

The proposal shows that the improvement in power factor will improve the efficiency of power distribution systems. Based on testing on IEEE 30 bus system by assuming thermal power plant at slack bus at bus # 1, shows that the improvement of power factor will be able to reduce CO2 emissions. This is related due to decrease of fuel consumption of thermal power plant. This proposal also shows reduction of CO2 emissions that signifikant with cos phi between 0.97 to 1. while for cos phi <0.97, showing a stable trend.

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