GUI Development for Economic Dispatch Analysis on Sulselrabar Power Plant

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Abstract— The current utilization of the take or pay contract between PT. PLN (Persero) and Independent Power Producer (IPP), particularly the Barru steam power plant, is not optimal. The Barru steam power plant, which carries the main load, only operates for a maximum of 3-4 hours or during peak load as requested by the dispatcher. To address this issue, a study was conducted to compare the economy dispatch method to maximize the utilization of the Barru steam power plant. The lambda iteration method was used to determine the power allocation distribution between the two power plant units of the Barru steam power plant. To calculate the two methods, the fuel consumption characteristics of the power plant were calculated in advance based on primary data such as the electricity production results and fuel consumption from the coal feeder flow. The research results showed that the lambda iteration method could reduce production costs by Rp. 9.05 per KWH.

Keywords—Barru Steam Power Plant, Dispatcher, Economic dispatch, Lambda Iteration

I. Introduction

The Central Unit for the Control of the SULSERABAR of the South Sulawesi electricity network system has kept records of the growth of electricity demand until 2018. Surplus energy was observed during peak loads, indicating that the electricity demand in South Sulawesi is being met. Consequently, PLN does not always order a full load for the PLTU Barru, and typically only peak loads in the afternoon and minimum loads in the early morning are ordered. Ideally, the power plant should operate in Base Load, where the load should remain constant unless there is a problem. Running the plant at low loads decreases its efficiency, which is not ideal for an average PLTU. Due to these factors, the PLTU Barru cannot maximize its capacity factor and must comply with instructions from UP2B.

To prepare for load orders from UP2B that are less than the maximum load, PLTU Barru needs to identify which units are more cost-effective to operate at higher loads based on the efficient use of coal. This will enable the plant to generate more profit when there is a load order that is less than the maximum load from UP2B.

There are several methods for calculating the economic value, especially for the economic loading of power plants, namely the Deterministic method or the technical mathematical calculation approach and the deterministic method, including heuristics and probability techniques [1]. An example of a deterministic method is the lambda iteration method. At the same time, the deterministic approach is quadratic programming. Many researchers have calculated the economic burden on the electricity system throughout South Sulawesi, such as the Ant Colony Optimization method [1], Incremental Production Cost (IPC) in the case study of the Sulselrabar system [2], the Lagrange method at PT. Semen Bosowa [3], dynamic programming method on the South Sulawesi system [4]. The Particle Swarm Optimization method [5], specifically the analysis of economic generation for the Barru PLTU, has never been done before.

The Lagrange method, also called the lambda iteration method, is used to find the optimal value of the load distribution on a generator [6] where there is a power plant that has several generating units that must be shared in the load to achieve the power that is distributed by the power transmission network load regulator for a power plant [7]. The load distribution must be seen from the economic aspect by looking at the fuel consumption of each generating unit. Therefore, to calculate and find the optimal load-sharing results using lambda iteration. After getting the division's results, it is applied to each generating unit resulting from the division. The lambda iteration method adheres to or uses the iteration

calculation method [8, 9]. Where the calculation will continue to repeat if it does not reach the results that are dispatched. However, before calculating using the lambda iteration method, one must know the characteristics of each generating unit and make it into a quadratic equation [10].

GUI is an abbreviation for Graphical User Interface, which is an interface display provided by MATLAB that includes program components, commands, and tasks that enable users to execute programs easily [11]. A previous study had employed a GUI-based economic loading analysis using the evolutionary algorithm method [12-14]. In view of this background, this study aims to develop software based on the Guide User Interface (GUI) to conduct economic loading analysis of power plants using the Lagrange method. The case study was carried out at the Barru Steam Power Plant that has two generating units. Previously, there were no researchers who had accurately calculated the economic load for PLTU Barru.

II. Research Methodology

A. Data Collection Method

Data collection is the method or strategy taken to retrieve data from the research variables. The technique used in this research is collecting data from direct observation in the field. With this observation method, researchers can make precise and accurate observations and systematically record the investigated symptoms or phenomena.

This research used tools in the form of MATLAB simulator software and materials in the form of measurement data from the operation of PLTU Barru units 1 and 2. The state of data used in this study is as follows:

1. Quantitative data

Quantitative data is data in the form of numbers or data that can be calculated, such as measurement data of coal feeder flow and generator output power, so that the effect on the efficiency of operating costs.

2. Qualitative data

Qualitative data is data that cannot be measured and calculated, in the form of drawing descriptions, in this case in the form of single line diagrams of boilers, turbines, generators, and also HMI to determine the workflow of PLTU.

3. Primary data

Primary data is data obtained directly in the field, such as name plate generator data, boiler nameplate data, and coal feeder flow indicator data.

4. Secondary data

Secondary data, namely data obtained from literature studies with reference books, manuals, journals, diktat, internet relevant to the application of economic dispatch to coal-fired power plants using the lambda iteration method and the quadratic programming method.

B. Analysis Method

The implementation methodology in the comparative analysis between the lambda iteration method and the quadratic programming method is divided into several stages, with the aim that the implementation of activities can be neatly arranged and make it easier to identify problems.

Table 1. Implementation Methodology

No.	Description of activities
1.	Literature Study
2.	Collecting data on loading operations, coal prices, and coal consumption for each unit
3.	Creating an economic dispatch calculation program using the lambda iteration method in MatLab software
4.	Calculating and analyzing data with the lambda iteration method
5.	Creating an economic dispatch calculation program using the quadratic programming method in MatLab software
6.	Calculate and analyze data with the quadratic programming method
7.	Analyzing the comparison of the calculation results between the lambda iteration method and the quadratic programming method
8.	Preparation of reports

C. Calculation Stage

The calculation phase uses the Lambda Iteration method, namely:

1. Enter the parameters to be used in the calculation, namely fuel consumption unit i (CFi), power generated per unit i (Pi), and power demand (Pd).
2. Create an equation for the fuel consumption function for each generator using the 2nd Order Polynomial Regression method.

For example:

x_i = power generated unit to i.

y_i = unit fuel cost to i.

$$y_i = a_i + b_i x_i + c_i x_i^2 \qquad (1)$$

$$na_i + b_i \sum x_i + c_i \sum x_i{}^2 = \sum y_i$$

$$a_i \sum x_i + b_i \sum x_i{}^2 + c_i \sum x_i{}^3 = \sum x_i y_i \qquad (2)$$
$$a_i \sum x_i{}^2 + b_i \sum x_i{}^3 + c_i \sum x_i{}^4 = \sum x_i{}^2 y_i$$

entered in the form of a matrix as follows.

$$\begin{pmatrix} n & \sum x_i & \sum x_i{}^2 \\ \sum x_i & \sum x_i{}^2 & \sum x_i{}^3 \\ \sum x_i{}^2 & \sum x_i{}^3 & \sum x_i{}^4 \end{pmatrix} \begin{pmatrix} a_i \\ b_i \\ c_i \end{pmatrix} = \begin{pmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i{}^2 y_i \end{pmatrix} \qquad (3)$$

3. Solve the matrix so that each generating unit will obtain the fuel consumption function.
$$(P_i) = a_i + b_i P_i + c_i P_i{}^2 \qquad (4)$$
4. Assuming a large surcharge rate, λ^k.
$$\lambda = \frac{dF_i}{dP_i} \qquad (5)$$
5. Calculating the amount of power generated by the unit to i, P_i.
$$P_i{}^k = \frac{\lambda - b_i}{2c_i} \qquad (6)$$
6. Calculating the difference between the power demand and the amount of power generated by the unit, ΔP^k.
$$P_d = \sum_{i=1}^{n} \frac{\lambda - b_i}{2c_i} \qquad (7)$$
$$\Delta P^k = P_d - \sum_{i=1}^{ng} P_i{}^k \qquad (8)$$
7. Calculating the amount of $\Delta \lambda^k$ to get the amount of the new surcharge level, $(k+1)$.
$$\Delta \lambda^k = \frac{\Delta P^k}{\left(\frac{\partial f(\lambda)}{\partial \lambda}\right)^k} = \frac{\Delta P^k}{\sum_{i=1}^{ng}\left(\frac{dP_i}{\partial \lambda}\right)} = \frac{\Delta P^k}{\sum_{i=1}^{n}\frac{1}{2c_i}} \qquad (9)$$
8. Calculating the size of the new surcharge rate, $(k+1)$.
$$\lambda^{(k+1)} = \lambda^k + \Delta \lambda^k \qquad (3.12)$$
9. Recalculate the power generated, $P_i{}^{k+1}$ until the total power generated by the unit is equal to the load requirement.
10. Plugging the power, $P_i{}^k$ into Equation 4.
11. Calculate the total fuel consumption by adding up the fuel consumption of each generator.

Calculate the generation cost by multiplying the total fuel consumption by the fuel price in rupiah.

III. Results and Discussion

A. Operation Data Retrieval

The study was carried out at units 1 and 2 of PLTU Barru, where data was collected on the power produced in Mega Watts (MW) and the total coal feeder flow in tons per hour (t/h). The data was collected over a period of five days. On the first day, data was collected to create the characteristic function of each unit. During the first day of data collection, the operator's dispatch actions from

UP2B remained the same, with the load being equally divided for each unit. On the second and fourth days of data collection, the lambda iteration method was used for dispatch actions taken when ordered by UP2B.

B. Fuel and Production Characteristics

Calculation results using operating data obtained the characteristics of the cost of production or use of coal for each unit on different days, are shown in the table below.

Table 2. Characteristics of PLTU Barru Unit 1 and Unit 2

Day	Unit	Characteristics
1	1	$C_1 = -655024,83 + 551594,24\ P_1 + (-3122,11)\ P_1{}^2$
	2	$C_2 = 1613732,63 + 529540,50\ P_2 + (-3060,18)\ P_2{}^2$
2	1	$C_1 = -3616544,36 + 721299,75\ P_1 + (-5379,63)\ P_1{}^2$
	2	$C_2 = 546026,98 + 594832,21\ P_2 + (-2227,09)\ P_2{}^2$
3	1	$C_1 = -2337829,72 + 627110,06\ P_1 + (-3538,98)\ P_1{}^2$
	2	$C_2 = 5998485,19 + 227903,27\ P_2 + 1491,06\ P_2{}^2$
4	1	$C_1 = -936912,42 + 553420,55\ P_1 + (3048,06)\ P_1{}^2$
	2	$C_2 = 5973297,59 + 264403,86\ P_2 + 501,21\ P_2{}^2$

Once the fuel characteristics of unit 1 and unit 2 were obtained, the dispatch economy was calculated using either Matlab software or Graphical User Interface (GUI) Matlab. Prior to performing the calculation, it was necessary to determine the Lambda, which refers to the maximum and minimum power issued by the generator when operating on each unit. In the Lambda Iteration calculation, a Lambda value of 300000 was used, which was obtained through several trials and errors, and was adjusted after a few iterations. The maximum power that each generator unit could produce was 50 MW, and the minimum generator power that could be operated was 25 MW. The minimum generator power was based on the durability, lifetime, and efficiency of boilers, turbines, and other steam power-generating equipment, and it was agreed that 25 MW was the minimum power that the PLTU Barru generator could produce. The Matlab GUI was used for manual estimates with software assistance to facilitate calculations. The results of the analysis using the Matlab GUI are presented in table 2.

Table 3. Calculation Results of the Lambda Iteration Method

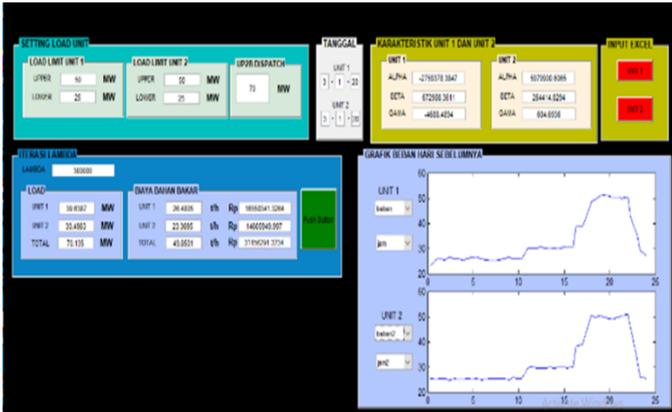| Day	Dispatch MW	P #1 MW	P #2 MW	P MW	BB #1 ton	BB #2 ton	Total BB ton
2	65	34,01	31,1	65,11	23,19	24,19	47,38
	80	41,46	38,70	80,17	26,96	28,04	55
	95	48,93	46,31	95,24	30,17	31,32	61,49
4	65	37,55	27,55	65,11	25,44	21,45	46,90
	80	32,08	48,09	80,17	22,46	32,65	55,11
	95	45,27	49,99	95,26	28,74	33,78	62,53

Figure 1. GUI Iteration Lambda Economic Dispatch PLTU Barru

During the second and fourth days of the study, we utilized the lambda iteration calculations from the previous day to determine the operating data for unit 1 and unit 2 of PLTU Barru. The allocation of total power for each unit was determined based on the dispatch instructions from PT. PLN UP2B South Sulawesi. The outcomes of the operation of PLTU Barru on those days are presented in Figure 2.
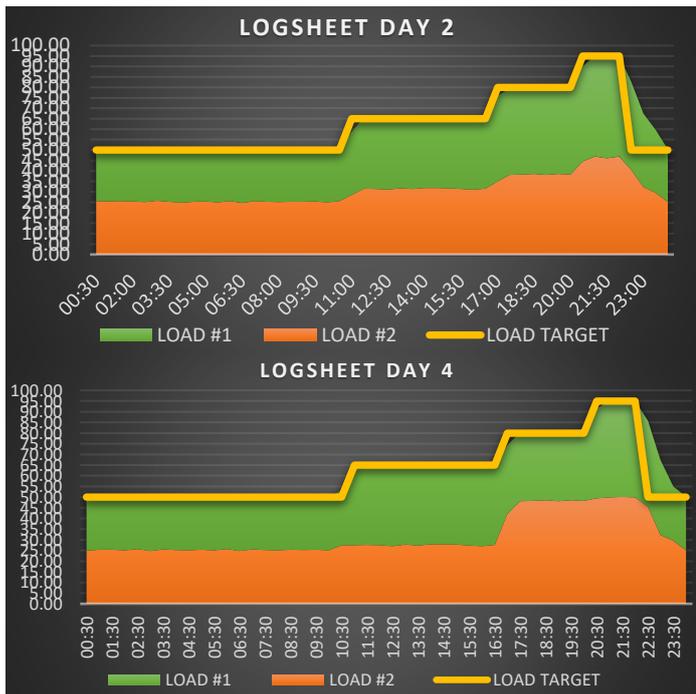

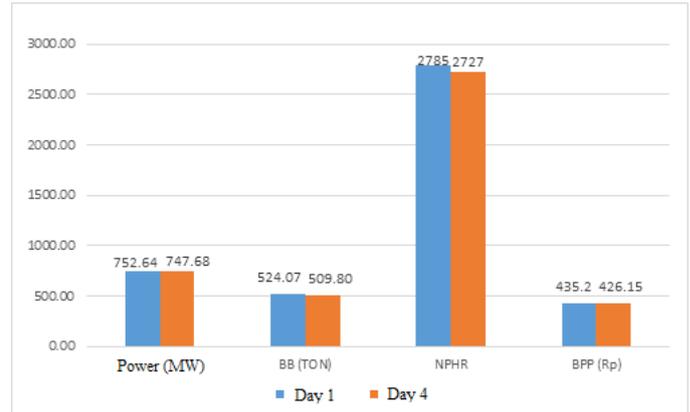Figure 2. Second and Fourth Day Logsheet Power Graph

Figure 3. Comparison of Lambda Iteration with Manual

The study compared the operational data from the first day to the fourth day. During the first day, power allocation decisions were made manually, resulting in an equal distribution of power to each unit. Meanwhile, on the second and fourth days, the lambda iteration method was employed, as demonstrated on the second day of the study. The comparison was made for a power plant with a stable state value, during the dispatch of loads by PT. PLN UP2B.

Based on the findings presented in Figure 3, it can be concluded that the operational efficiency of PLTU Barru was better on the fourth day of the study than on the first day. Moreover, it was observed that the use of the lambda iteration method led to better results with an NPHR of 57.89 compared to the manual method. NPHR is an important performance index that reflects the efficiency of a thermal power plant, where a lower NPHR value indicates higher efficiency. The manual method resulted in an NPHR of 2785 with a production cost of Rp. 435.20 per KWH, whereas the lambda iteration method resulted in an NPHR of 2727 with a production cost of Rp. 426.15 per KWH.

IV.   CONCLUSION

1. At PLTU Barru, the load distribution method used when instructed by UP2B was the manual method, which involved increasing both generating units simultaneously with equal values.
2. Based on the data collected on the first and fourth days, there was a difference of 57.89 in NPHR and a production cost of Rp. 9.05 per KWH when comparing the effects of using the manual method versus the lambda iteration method.
3. According to the data collected on the first, fourth, and fifth days, the lambda iteration method was more

cost-effective than the manual method. The lowest NPHR value achieved using the lambda iteration method was 2727, and the lowest production cost was Rp. 426.15.

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