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A Boiler Feed Pump Speed Control to Reduce Its Own Power Consumption According to Pump Affinity Law

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Abstract. The change in water flow required at the BFP pump at the Barru Power Plant is only regulated by a valve located on the pressure side, causing excess power consumption and its own power consumption. One effort to save energy usage is to make frequency adjustments that refer to the right pressure and water flow. To determine the effect of frequency adjustments on the expected pump pressure, a simulation of frequency inverter modeling is performed using the SPWM switching method based on the pump affinity law using Matlab application software. The simulation results obtained that by adjusting the frequency range of the inverter from 45.5 Hz to 50 Hz and keeping the pump pressure above the minimum limit of 13.2 MPa, the operating power savings of the BFP motor are obtained from 46 kW to 378 kW.

1. Introduction

In an operation of a power generation system, mainly steam electric power is generation in producing distributed electrical power in an electrical network, the power generation needs auxiliary devices in operation[1]. The devices need electrical power; the consumed power of the additional devices is called its own use., Boiler Feed Pump (BFP) motors are the most consumed power of all auxiliary devices [2] The Boiler Feed Pump (BFP) is rotated using a 6.3 kV motor. In the full load condition (100% TMCR), BFP motors need power consumption of around 2.5% of the total power production. The consumed power of BFP is 1426.90 kW (Test Report for Unit No.2 Electric Section Attachment C. Coal Fired Steam Power Plant Project Barru, South Sulawesi, Indonesi in 2012).

BFP operates continuously as long as the power generation units produce electricity, and rotation (RPM) on the BFP is constant. In the changed load (MW), the produced debit of BFP should also change [3][4]. The changing debit on this BFP is not from the decreasing motor speed (RPM) but from the feed water regulating valve and recycling regulating valve, which automatically controls the debit. Therefore, the debit control system's disadvantage can waste power when the condition of needed debit does not reach 100%. Based on that case, this research is about the simulation of regulation of motor speed on the Boiler Feed Pump (BFP) using an inverter with software simulation. Using an inverter, the motor pump's rotation can be reduced when the needed debit is not maximal and is expected to reduce the power consumption of its own use [5].

2. Methodology

2.1 Research Flow

The applied inverter's simulation design on the BFP motor needs several steps, as shown in figure 1.

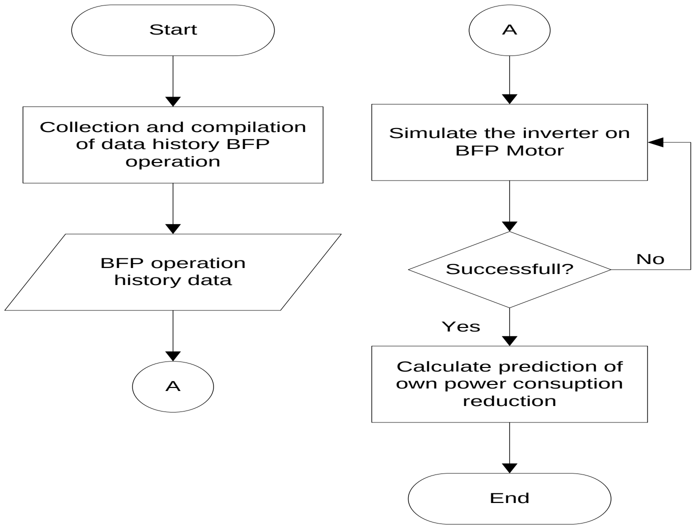

Figure 1. Applied inverter on BFP motor flowchart

2.2 Tools and Materials

In this research, the simulation is run under simulator software (Matlab) [6], and the input data are from the measured data of BFP pumps operation.

2.2.1 BFP Motor Data

The following data are from the nameplate and the manual book of the motor [2].

Speed (N2) = 2985 RPM (50 Hz) = 312.5 rad / s Slip (S) = 0.5%
Rs = 0.5 ohm Lls = 0.0013283 H
Rr' = 0.0812 ohm Llr' = 0.0013283 H
Lm = 0.6 H Inertia = 33.3 J
Friction Factor = 0.45 N.m.s Pole pairs = 1
Power = 1600 KW = 2145 HP

Pump Torque Equation

T = P / Nr (rad/s) T = 1.6 106 / 312.5
T = 5120.5 Nm K = T / Nr
K = 5120 / 312.5 2 = 0.0524
Therefore, T = 5.24e-2*N^2 (1)

2.2.2 BFP Pump Performance Data

Table 1. Pressure Head BFP Data

Pressure (Mpa)	**% Pressure side valve openings**
16.20	13.5
15.85	15.27
15.90	18.26
15.58	23.02
15.71	24.91
15.60	25.61
15.43	25.62
15.44	26.41
15.28	27.5
14.16	30.68
14.59	31.58
14.48	32.37
13.68	39.06

Table 2. Flow and Power BFP Data

Load Range (MW)	Flow (t/h)	Power (KW)
0 – 5	39.58	1416.41
5 – 10	47.54	1423.84
10 – 15	74.11	1477.97
15 – 20	90.05	1370.61
20 – 25	112.04	1379.05
25 – 30	139..40	1285.01
30 – 35	164.34	1309.20
35 – 40	167.84	1477.93
40 – 45	193.42	1365.51
45 – 50	210.67	1535.98

From the data history of both tables, every maximum value of each parameter indicates the rate data from each parameter, such as pressure (H2) 16.2 Mpa, flow (Q2) 210.67 t/h, and power (P2) 1535.98 kW.

a. Pump flow (Q) equations $Q1 = (N1/2985) * 210$ (2)
b. Pump pressure (H) equations $H1 = (N1/2985)^{2} * 16.2$ (3)
c. Pump Power (P) equations $P1 = (N1/2985)^{3} * 1535$ (4)

3. Results and Discussion

3.1. SPWM Circuit

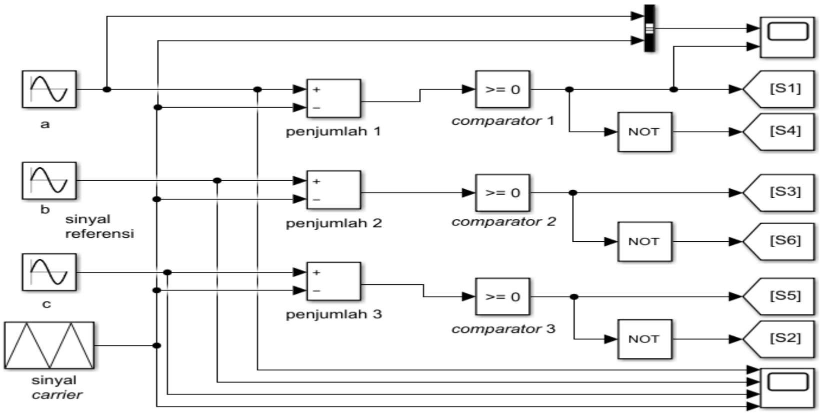

Figure 2. SPWM circuit

The reference signal's amplitude or sinusoidal signal (a,b,c) is given the carrier signal's same value. In this case, the modulation index value is 1. Therefore, the inverter peak voltage output is remaining the same as the input voltage (Vdc).

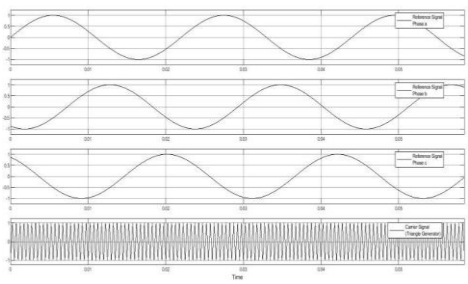

Figure 4. SPWM Output Display

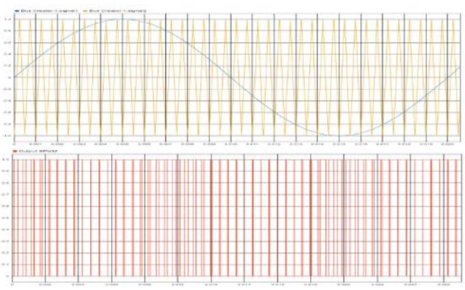

Figure 3. SPWM Output Display

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Figure 3 shows one of the reference signal phase comparing to the carrier signal. When Ar>Ac, the output signal, as shown in figure 4 from the SPWM circuit, is 1, and on the contrary, the value will be 0. The output signal of SPWM becomes the fundamental of switching at the switching gate of the inverter circuit.

3.2. Inverter Circuit

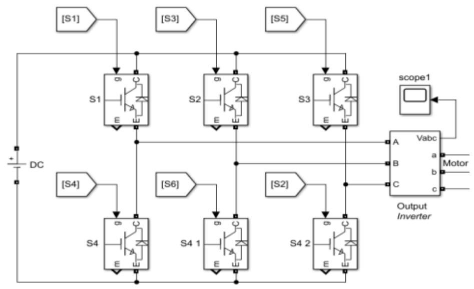

Figure 5. Inverter Circuit

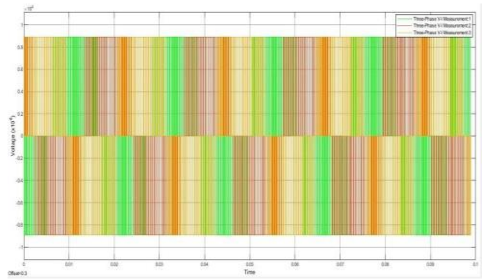

Figure 6. Inverter output voltage display

The given value of DC input voltage in the DC supply is √2 V_{rms}. In this case, the motor load needs 6.3 kV (rms) to operate. Therefore, Vdc is equaled to 8.9 kV. Figure 6 shows that the output signal from the inverter is similar to the SPWM signal. The difference is found in the amplitude with the inverted signal output of 8.9 kV. It is suitable with input voltage (V_{dc}).

3.3. Motor Circuit

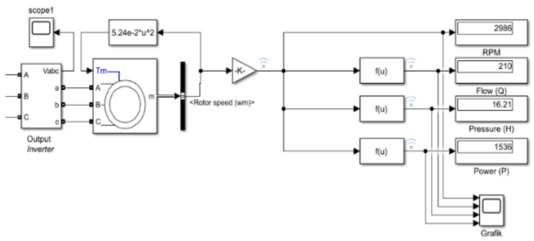

Figure 7. BFP Motor Circuit

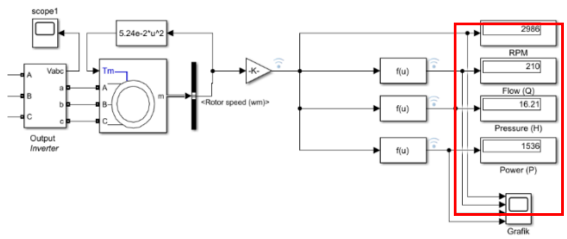

Figure 8. Pump parameter N,Q,H,P

Figure 7 is the continued circuit of the inverter circuit. It means the source or BFP motor supply is connected to the inverter circuit and included the SPWM circuit. To obtain accurate parameters, the function of 1,2,3,4 is needed by using equation (10), (11), (12), and (13). Figure 8 shows the simulation results with the input frequency 50 Hz, and the output value of the pump parameter (red square border) follows the rate data N2, Q2, H2, and P2. Meanwhile, the signal form of the four parameters can be seen in figure 9.

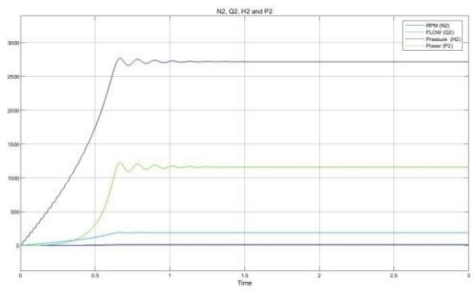

Figure 9. Pump graph of P, N, Q, H

Figures 8 and 9 show the motor's simulation results using an inverter in the original frequency or system frequency 50 Hz. The measured rotation is 2985 rpm, the value of pump flow from the simulation is 210 t/h, then pressure is 16.2 Mpa, and the power is 1536 kW. The values can be assumed as the performance of the motor before connecting the inverter.

3.4. *The impact of motor frequency change*

On the operation of the BFP pump in the Barru Steam Power Station, pump pressure should be higher than 13.2 MPa to ensure the fluid flowing to the drum boiler with a certain level height [7]. Therefore, the obtained equation from the affinity law can predict that the pump's frequency will produce a pressure of more than 13.2 Mpa.

Table 3. The impact of the pump parameter on the changing frequency

Frequency (Hz)	Speed (RPM)	Flow (t/h)	Pressure (Mpa)	Power (KW)	Power reduction(kW)
50.00	2985.00	210.00	16.20	1535.00	0
49.50	2955.15	207.90	15.88	1489.41	46
49.00	2925.30	205.80	15.56	1444.73	90
48.50	2895.45	203.70	15.24	1400.95	134
48.00	2865.60	201.60	14.93	1358.07	177
47.50	2835.75	199.50	14.62	1316.07	219
47.00	2805.90	197.40	14.31	1274.95	260
46.50	2776.05	195.30	14.01	1234.69	300
46.00	2746.20	193.20	13.71	1195.29	340
45.50	2716.35	191.10	13.42	1156.73	378

Simulation result for 45.5 Hz has been suitable with the calculation results, as shown in table 3. The following are the comparison graph for 45.5 Hz to the motor with 50 Hz without inverter (Green for 45.5 Hz, Blue for 50 Hz).

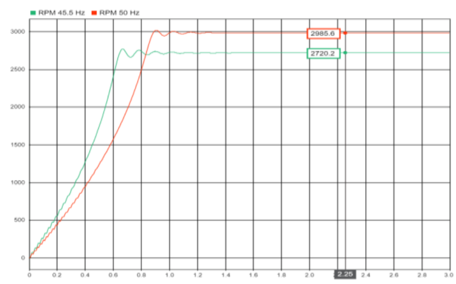

Figure 10. Rotating rotor comparison

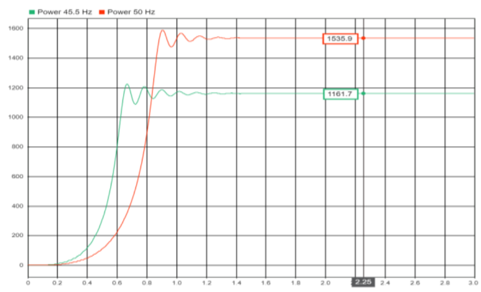

Figure 11. Power comparison

The rotating rotor's value for the frequent 45.5 Hz is 2716.35 rpm and for 50 Hz is 2985 rpm. Therefore the rotation for 50 Hz is higher than 45.5 Hz. Otherwise, the Consumed power at 45.5 Hz is 1156.73 kW, and it is lower around 378 kW than the consumed power when the motor works at 50 Hz.

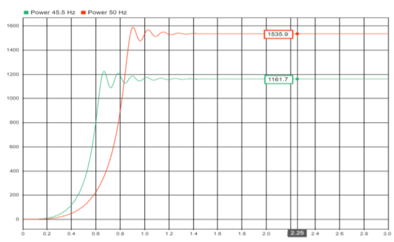

Figure 12. The flow of pump

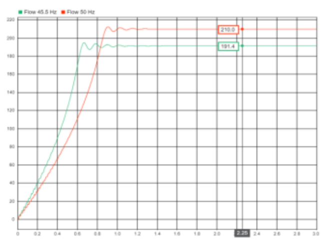

Figure 13. The pressure of the pump

From the figure 12 and 13, the resulted rate flow (Q1) and pressure (H1) of the pump when the motor works at 45.5 Hz is lower 19 t/h and 2.78 Mpa than when the motor works at 50. Moreover, at frequency 45.5 Hz, consumed power is less than 378 kW than the working motor at frequency 50 Hz by keeping the pressure remains constant at >13.5 MPa and the flow rate (Q1) 191.1 t/h. Therefore, this frequency is safely used for load with the water flow around 191.1 t/h. Furthermore, the lower the flowing rate of the BFP pumps or the working motor's lower frequency, the more efficient the motor's consumed power.

4. Conclusion

Based on the simulation results of this research, it can be concluded that:

a. The power consumption of the BFP motor at the Barru Power Plant can be reduced by adjusting the frequency range of the inverter between 45.5 Hz to 50 Hz, speed 2716 rpm, and keeping the pressure variable above the minimum limit of 13.2 MPa.
b. The obtained power reduction from the frequency adjustment of the BFP pump is around 45 kW to 378 kW.

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