Energy Conservation Opportunity with a Variable Frequency Drive in Boiler Feed Pump

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ABSTRACT

Energy saving is necessary for saving fuel and energy cost in industry. The energy saving has become one of the main objectives of the international and national policies. Most pumps and fans are oversized for the duties they perform. Electric motors use two-thirds of all electricity in industry, so any chance to reduce this load, even by single figures, is highly significant. Boiler feed pumps consume a large fraction of the auxiliary power (in excess of 4% of unit capacity) used internally within a power plant in pressurizing and forcing the feed water through economizer to the boiler. The changing rotation speed is the most effective and economical way of improving the pump efficiency. Adjustments made to rotation speed causes only a slight decrease in the pump efficiency compared to operation with fixed revolutions. This type of control allows a reduction in electricity consumption in a wide range of loads. The VFD installation cost and the financial burden is balanced against the earning resulting from the associated energy saving.

Keywords: VFD, VSD, BFP, Pinched Point, MCR

1. INTRODUCTION

Energy cost is a significant factor in economic activity. The imperatives of energy shortage call for energy conservation measures, which essentially mean using less energy for the same level of activity. The problem of energy waste is made worse by the fact that many motors are oversized using more energy than the application actually needs. This is because motors are only available with a certain number of fixed speeds. Users tend to fit the next bigger size relative to the requirement and then throttle the output. Normally, electric motors only have one speed; if you want a different speed you must buy a different motor.

2. BOILER FEED PUMP SYSTEM

A boiler feed water pump is a specific type of pump used to pump feed water into a steam boiler. Boiler feed pump is used to feed water to steam generator boiler drum at desired pressure and temperature. The water may be freshly supplied or returning condensate produced as a result of the condensation of the steam produced by the boiler. These pumps are normally very high pressure units that take suction from a condensate return system and can be of the centrifugal pump type or positive displacement type.

Figure 1. Pressure head v/s Flow rate
• The boiler is running at a constant pressure head ‘H’, but the steam demand is changing continuously with time.
• The boiler feed water capacity must vary with the steam demand, but the pressure or head must remain constant as shown in graph.

3. PUMP PERFORMANCE CURVES

![Figure 2. Pump characteristic curve](image)

- The increases in discharge flow rate, the discharge pressure decreases.
- The increases in discharge flow rate, the discharge pump power consumption increases.
- The increase in discharge flow rate the pump efficiency first increasing linearly than decreases.
- NPSH Required: The minimum pressure required at the suction port of the pump to keep the pump from cavitating.

4. VARIABLE FREQUENCY DRIVE IN A BOILER FEED PUMP

![Figure 3. VFD Unit with load](image)

Variable frequency drive is also called variable speed drive(VSD), frequency inverter or AC drive etc. It is an electric device to change utility power source to variable frequency to control AC motor in variable speed operation. The variable frequency drive (VFD) converts the supply frequency and voltage to the required frequency and voltage to drive a motor. Hence, VFD converts the supply frequency and voltage to the frequency and voltage required to drive a motor at a desired speed other than its rated speed.
The synchronous speed of an induction motor is given by the equation as:

\[ N_S = \frac{120 \times f}{P} \]

Where, \( N_S \) = synchronous speed of motor,
\( f \) = frequency of current, in Hz
\( P \) = No. of poles in motor winding.

Motor speed (RPM) is dependent upon frequency.
Varying frequency output of the VFD controls motor speed:

**Example:**

Speed, \( N_S \) = Frequency (hertz) \times \frac{120}{\text{no. of poles}}

2-poles motor at different frequencies
- 3600 rpm = 60 hertz \times \frac{120}{2} = 3600
- 3000 rpm = 50 hertz \times \frac{120}{2} = 3000
- 2400 rpm = 40 hertz \times \frac{120}{2} = 2400

The actual running speed is always lesser by 2 to 6% of its synchronous speed.

5. BOILER FEED PUMP FLOW CONTROL METHOD

![Power vs Flow](image)

**Figure 4.** Boiler feed pump flow control curve

Following are the boiler feed control method in boiler house.

- **On / Off control:** In this system the pump starts and stops as per the water level in the water drum.

- **Feed control valve:** In this system boiler drum level is controlled by feed control valve, which is automatically operated by boiler pressure head.

- **VSD Only:** In this system, The boiler drum level is controlled by variable frequency drive, which controls the pump flow rate of the boiler feed pump with constant pressure head. The design discharge pressure must be maintained constant to ensure the water gets to its intended location. As compared to above two methods VSD is efficient controlling and power saving.

- **Feed control valve and VSD:** In this system both feed control valve and VSD are used, to control the flow rate with constant head pressure.

6. INSTALLATION POSSIBILITY OF VFD IN BOILER FEED PUMP

![Installation Possibility](image)

**Figure 5.** Installation possibility of VFD in BFP
• Pump operates only at the speed that is required, that is optimum speed of pump.
• Pump speed reduces up to only pinched valve, there is boiler feed pump changed capacity of flow with constant pressure head.
• No pressure loss across the pinched valve.
• High energy conservation at pinch point.

7. ENERGY SAVING WITH VFD IN BOILER FEED PUMP

The fixed speed motor load application such as the boiler feed pump supplies direct AC power. The energy saving is obtained by variable speed drive by using pump affinity laws.

By using a Variable Frequency Drive (VFD) to slow down a pump motor speed from 100% to 80% can save 50% of energy. Reducing pump speed not only reduces energy consumption but also reduces noise and vibration. “A pump or a fan running at half speed consumes only one-eighth of the power compared to one running at full speed.”

7.1 VFD affinity Laws for pump

The affinity laws for pumps/fans are used in plant, hydraulics and HVAC to express the relationship between variables involved in pump or fan performance (such as head, volumetric flow rate, shaft speed and power). They apply to pumps, fans, and hydraulic turbines. In these rotary implements, the affinity laws apply both to centrifugal and axial flows.

7.1.1 With impeller diameter (D) held constant:

Law 1.a. Flow is proportional to shaft speed:

\[ \frac{Q_1}{Q_2} = \left( \frac{N_1}{N_2} \right) \]

Law 1.b. Pressure or Head is proportional to the square of shaft speed:

\[ \frac{H_1}{H_2} = \left( \frac{N_1}{N_2} \right)^2 \]
Law 1.c. Power is proportional to the cube of shaft speed:

\[ \frac{P_1}{P_2} = \left( \frac{N_1}{N_2} \right)^3 \]

Where,
- \( Q \) is the volumetric flow rate (CFM),
- \( D \) is the impeller diameter (mm),
- \( N \) is the shaft rotational speed (rpm),
- \( H \) is the pressure or head developed by the fan/pump (m WC), and
- \( P \) is the shaft power (KW).

### 7.2.2 Calculations
- To assess the performance of BFP, the following parameter were observed in the control room at Sikka Thermal Power Plant, Jamnagar and the power measurement were measured using portable online power analyzer.
- The performance parameters are tabulated below:
- Types of discharge control: Throttle control valve

#### Table no.1 Boiler feed pump data

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Design</th>
<th>Actual Measured</th>
</tr>
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<tr>
<td>Units load</td>
<td>MW</td>
<td>120</td>
<td>85 Min Coal Rating(MCR)</td>
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<td>Frequency</td>
<td>Hz</td>
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<td>Speed</td>
<td>RPM</td>
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<tr>
<td>Flow</td>
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<tr>
<td>Total head</td>
<td>m WC</td>
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<td>1605</td>
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<td>Power consumption</td>
<td>KW</td>
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<tr>
<td>Motor input</td>
<td>KW</td>
<td>1800</td>
<td>1444</td>
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- Energy saving by Installing VFD in BFP 1
- Assume that total working hours per year = 7200 Hrs (24 hr shift/day * 300 day)

#### Table no.2 Mathematical formulation

<table>
<thead>
<tr>
<th>Pump Operating speed %</th>
<th>Pressure Head (m of WC)</th>
<th>Flow TPH</th>
<th>Power consumption without VFD in kw</th>
<th>Power consumption with VFD in kw</th>
<th>Energy consumption without VFD kwh</th>
<th>Energy consumption with VFD kwh/yr</th>
<th>Energy saving in kwh/yr</th>
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</table>
Figure 8. Flow rate in TPH v/s Pump operating speed in %

Figure 9. Pressure head Power v/s Pump operating speed in %

Figure 10. Power without and with VFD v/s Pump operating speed %
From above graph, 
- We can analysis that there is slight decrease in operating speed minor pressure head drop occurs and negligible effect on flow rate.
- The slight decrease rotation speed causes only a small decrease in the pump efficiency compared to operation with fixed revolution and allows a reduction in energy consumption in a wide range of loads.

8. OVERALL RESULTS
- The average energy saving using VSD per year is 1811844 KWh/yr.
- Considering per KWh charge of Rs. 3.5
- The energy saving per year of Rs. 6341454 can be achieved.
- Cost of installation VFD =1,44,00000 Rs
- Payback period = Total installation cost of VFD/ Cost of energy saving per year
- Payback period= 2.2 years

9. CONCLUSION
- VFD can be installed in boiler feed pump. It can reduce the power consumption by 25% by reducing the 10% operating speed of pump and thereby saves the energy cost.
- The installation of VFD is not only resulted in energy and cost savings but also avoids operational problems of the plant.
- Reducing pump speed not only reduces energy consumption but also reduces noise, vibration.

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