To Study the Tripper Movement with VFD in A Coal Handling Plant of A Coal Based Thermal Power Plant

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Abstract— The purpose of this paper to study the performance of tripper long travel movement with the use of VFD and comparison of the same with the earlier system. In a coal handling plant (CHP) of a thermal power station, trippers are vital equipments used to feed coal to coal bunkers for generation of electricity. The coal received from mines is being processed in a desired size and conveyed to coal bunkers through conveyor system, in last conveyor a equipment called tripper is installed to feed coal to different bunkers one by one with the long travel movement as per requirement. Earlier in long travel drive, the motor used was directly coupled to gear box and didn't have variation of speed as a result of that the tripper was starting with full speed as per design causing jerky operation and some time due to this, there was derailment of the tripper resulted in tedious maintenance involvement. After installation of Variable Frequency Drive (VFD) in long travel drives of tripper the starting is smooth and the power consumption by drives are reduced, also the power factor of the LT motors improved by the use of VFD which will increase the life of the motors.

Index Terms—Coal Handling Plant (CHP), Long Travel (LT), Tripper, Variable Frequency Drive (VFD).

I. INTRODUCTION

Trippers are important equipments used in coal handling plant to feed coal to the coal bunkers for generation of electricity. The arrangement of bunkers in a thermal power plant is in series so that one tripper can feed coal to all the bunkers by its movement through long travel drives.

Electricity is very much required for industries. We have to put our sincere effort to minimise the auxiliary power consumption in a power plant so that the conservation of the available resources will be done, as now we are facing acute problem of coal supply to thermal power stations used for generation of electricity. For conservation of the resources one have to take some effective measures. As a measure of cost reduction now a days VFDs[3][6] are used to run the auxiliary equipments used for power generation in a thermal power station to reduce the power consumption, where there is a speed variation in equipments is required.

Previously the movement of the tripper was done through the long travel drives without any speed control device result of that the tripper movement speed was fixed and during starting the operation of tripper was jerky some time caused derailment of tripper and choking in the system with coal. After derailment the re-railing work is very tedious and takes much time with involvement of money and material.

II. WORKING AND ADVANTAGES OF VFD

VFD is now a days common for controlling the speed of induction motors by variation of frequency. To reduce the power consumption in long travel drives of tripper at low speed, variable frequency drives (VFD)[5] is now used for controlling the speed of long travel. By use of the VFD in tripper LT drives the movement of the tripper has become smoother.
A variable frequency drive (VFD)[1], as shown in Fig.2, is an electrical variable speed drive have two parts, one is rectifier and other is inverter connected through filter elements. Since an induction motor rotates nearer to synchronous speed, the most effective way to change the motor speed is to change the frequency of the applied voltage. A VFD allows us to change the motor-speed by varying the frequency, Speed (rpm) = \( 120 \times \text{frequency (hertz) / no. of poles} \).

The VFD uses the IGBT[4], the IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor. The IGBT uses a method named “pulse width modulation” (PWM)[1][4] to simulate a current sine wave at the desired frequency to the motor.

The torque developed [12] by the induction motor is given by:-

\[
T = k_1 \cdot \phi_m \cdot I_2
\]

where: \( \phi_m = k_2 \cdot V_1/f_1 \)

\( \phi_m \): magnetising flux (Wb)

To have the flux constant the ratio of voltage to frequency should be constant

The utilisation of VFD in a system gives various advantages like[4][6]:

2. It reduces the power consumption of drives at reduced speed.
3. It improves the power factor of induction motor.
4. As efficiency of drive is high, the life of components will be more with VFD.

III. OPERATION OF LONG TRAVEL DRIVES OF TRIPPER WITHOUT SPEED CONTROL SYSTEM AND WITH VFD

a) Tripper LT Drives operation without speed control system

LT drives are used in tripper for travelling of the tripper in the track of bunker conveyor area. 02 nos. of LT drives are used in the tripper and the power supply to the all motors are from common source or we can say that the motors are connected in parallel. The motors used in the long travel drives are squirrel cage induction motor. When the movement of the tripper started by the operator the motors of the long travel drives were running at there design speed and the drives were taking current as per their rating and same time the power factor of the drives were very poor. Since the losses are more, the efficiency of the motors are very poor.

Following observation was recorded with the operation of tripper LT drives without speed control system:-

Rating of motors:- 5.5kw, 3 phase, 415V, 50Hz, 935RPM,

Travel speed of tripper is 18mtrs./min.

<table>
<thead>
<tr>
<th>S.N</th>
<th>Current Drawn (Amp)</th>
<th>Power Factor</th>
<th>Frequency (in Hz)</th>
<th>Voltage applied (in Volts)</th>
<th>Speed of tripper ( mtrs./min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.2</td>
<td>0.7</td>
<td>50</td>
<td>415</td>
<td>18</td>
</tr>
</tbody>
</table>

b) Tripper LT Drives operation with VFD:-

Table-1 observation for single motor of tripper LT

Fig.3 photographs of VFD used in tripper LT drives

By use of VFD[11] in an induction motor there is a possibilities available to run the drive at desired speed by variation of frequency. Now VFD is installed in tripper long travel drive operation for travelling of tripper in the track of bunker area ( as shown in fig.3), the power supply to both the motors are from common source through a single unit VFD or we can say that the motors are connected in parallel. As the tripper is a heavy equipment in the coal handling plant the starting of the long travel starts with jerk. By use of VFD the starting speed is controlled by variation of the frequency and hence, the starting of the drives become smooth. Also due to availability of variation of the LT speed by the VFD, the movement of the tripper is now controllable and chances of derailment are negligible. There is a reduction in power consumption of the drives at reduced speed [2] as well as the speed of the tripper is slightly more. Also both the motors are taking almost same current and running at same speed. Observations are shown in following Table-2.

Fig.3 photographs of VFD used in tripper LT drives

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### Table-2
(observation for single motor with VFD in tripper LT)

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Frequency (in Hz.)</th>
<th>Measured speed of motor (in RPM)</th>
<th>Current with VFD (in Amp.)</th>
<th>Voltage at motor terminal (V)</th>
<th>Power Factor (with use of VFD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>380</td>
<td>4.2</td>
<td>166</td>
<td>0.95</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>470</td>
<td>4.4</td>
<td>207</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>565</td>
<td>4.7</td>
<td>249</td>
<td>0.95</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>661</td>
<td>4.9</td>
<td>290</td>
<td>0.95</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>757</td>
<td>5.1</td>
<td>332</td>
<td>0.95</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>852</td>
<td>5.6</td>
<td>374</td>
<td>0.95</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>948</td>
<td>6</td>
<td>415</td>
<td>0.95</td>
</tr>
</tbody>
</table>

### IV. Calculations

Rating of Tripper LT Motor - 3 ph., 5.5kw, 415V, 935RPM, 50Hz, slip 6.5%. Speed of tripper is 18mtrs./min. 02 nos. Long Travel Drives are used.

As per the observations recorded following calculations are done:

(i) While operation of the tripper LT Motor was done without speed control system as per table-1, power consumption is calculated below:-

\[
\text{Power} = 1.732 \times \text{Voltage(V)} \times \text{Current(I)} \times \text{power factor}
\]

\[
\text{Po} = 1.732 \times 415 \times 10.2 \times 0.7 = 5.13 \text{ kw}
\]

Total power consumption by 02 motors = 5.13x2 = 10.26 kw.

(ii) As shown in Table-2, the current of the tripper L T motor is less at reduced frequency and also the power factor improved to 0.95. Hence, power drawn by the motor with different frequencies is as calculated as:-

\[
\text{Power (P)} = 1.732 \times \text{Voltage(V)} \times \text{Current (I)} \times \text{power factor x 2}
\]

\[
\% \text{saving in power} = \left( \frac{\text{Pr} - \text{P}}{\text{Pr}} \right) \times 100 / \text{Pr}
\]

\[
= \left( \frac{\sqrt{3} \times V \times I \times \cos \phi_r}{\sqrt{3} \times V \times I \times \cos \phi_f} \right) \times 100 / \sqrt{3} \times V \times I \times \cos \phi_f
\]

Where, Ir- total current of motors without speed control system which is 10.2A as above, If -total current drawn by the motors with VFD, \( \cos \phi_r \) – power factor without speed control system which is 0.7, \( \cos \phi_f \) – power factor with VFD V- voltage at motor end without VFD, \( V_f \) - voltage with VFD at motor end.

\[
\text{Pr} = 1.732 \times 415 \times 10.2 \times 0.7 \times 2
\]

= 10.26 kw

(1). at freq. 20Hz, % Saving of power

\[
= (10.26 - 1.732 \times 166 \times 4.2 \times 0.9) / 10.26 \times 100
\]

= 78.85%

(2). at freq. 25Hz, % Saving of power

\[
= (10.26 - 1.732 \times 249 \times 4.7) / 10.26 \times 100
\]

= 72.32%

(3). at freq. 30Hz, % Saving of power

\[
= (10.26 - 1.732 \times 290 \times 4.9) / 10.26 \times 100
\]

= 64.42%

(4). at freq. 35Hz, % Saving of power

\[
= (10.26 - 1.732 \times 332 \times 5.1) / 10.26 \times 100
\]

= 56.82%

(5). at freq. 40Hz, % Saving of power

\[
= (10.26 - 1.732 \times 374 \times 5.6) / 10.26 \times 100
\]

= 48.54%

(6). at freq. 45Hz, % Saving of power

\[
= (10.26 - 1.732 \times 415 \times 6) / 10.26 \times 100
\]

= 36.35%

(7). at freq. 50Hz, % Saving of power

\[
= (10.26 - 10.2 \times 6) / 10.2 \times 100
\]

= 20.17%

The above calculations are shown in Table-17 & graph in fig.4.21.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Frequency (in Hz.)</th>
<th>Current with VFD (in Amp.)</th>
<th>% saving of Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>4.2</td>
<td>78.85</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>4.4</td>
<td>72.32</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>4.7</td>
<td>64.42</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>4.9</td>
<td>56.82</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>5.1</td>
<td>48.54</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>5.6</td>
<td>36.35</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>6</td>
<td>20.17</td>
</tr>
</tbody>
</table>
(iii) The speed of tripper calculated at the measured speed is as:-

\[ \text{Speed of tripper} = \frac{\text{Measured speed}}{52} \]

The Gear Box ratio is 52:1

The speed of tripper at different frequency and measured speed is tabulated in Table-4. Fig.8 shows the graph between tripper speed Vs % saving in power.

### Table-4

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Frequency (in Hz.)</th>
<th>Speed (in RPM) at 6.5% slip</th>
<th>Measured speed of motor (in RPM)</th>
<th>Speed of tripper at measured speed of motor (in mtrs./min)</th>
<th>% saving of Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>374</td>
<td>380</td>
<td>7.3</td>
<td>78.85</td>
</tr>
<tr>
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<td>467.5</td>
<td>470</td>
<td>9</td>
<td>72.32</td>
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<td>565</td>
<td>11</td>
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</tr>
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<td>757</td>
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<td>48.54</td>
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<tr>
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<td>50</td>
<td>935</td>
<td>948</td>
<td>18.2</td>
<td>20.17</td>
</tr>
</tbody>
</table>

Fig.8 graph between tripper speed & % power saving

### V. CONCLUSIONS

As shown in the Tables-3 and Fig. 7 by the use of VFD in tripper long travel drives the current drawn by motors are very less at reduced speed. As shown in table-4 and graph-8 the power consumption at reduced speed is reduced considerable.

The VFD works as soft starter for the drives, due to which the starting of long travel drives become smoother (without any jerk), and there is minimal chances of overshooting/derailment of the tripper. Availability of equipment increased. Operation of the long travel become easier and needs less maintenance. The slip of the Induction motor also reduced by use of VFD as shown in the Table-4 measured value of the speed is more compared to rated slip speed of the motor. As the power factor of the motors are improved, the life of the motors will improve. The use of VFDs in thermal power plant equipments will help to reduce the auxiliary power consumption, which will reduce the cost of generation of electricity.

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Kind co-operation of the management as well as employees of NTPC Ltd, Korba for this academic work is highly acknowledged.

### REFERENCES


