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Performance Review of Long Travel Drives of Stacker/Reclaimer in A Coal Based Thermal Power Station After Installation of VFD

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***Abstract*— In a coal based thermal power station stacker/reclaimers (S/R) are the most needful and important equipment used to stack the excess coal received from mines in coal yard in a coal handling plant for utilisation in future, and reclamation of the stacked coal is done during emergency condition when coal supply from mines stopped due to various reasons. For stacking and reclamation of the coal from coal yard stacker/reclaimer has to travel to full length of the yard on the track . For traveling of the S/R in the track Six nos. of Long Travel (LT) drives are used. The motors used in the drives are slip ring induction motors. Initially the control of the initial torque for long travel drives were done with the use of resistance box. Resistance box is used to inject the resistance in rotor conductor to improve the initial torque of the long travel drive of S/R. Now a days Variable Frequency Drive (VFD) is used in the long travel drives for controlling the travel speed of the S/R. By use of VFD in LT drives of S/R resulted in smooth starting of the LT drives and reduction of the running current of LT drives (less power consumption at low speed by variation of frequency, maintaining v/f constant).**

***Keywords*— Coal Handling Plant, Energy Saving, Long Travel, Stacker/Reclaimer,, Resistance Box, Slip Ring Induction Motor, Thermal power station, Variable Frequency Drive (VFD)..**

I. INTRODUCTION

Electricity is essential for growth and development of the industries. India is a developing country and the demand of electricity in the country will be more and more, we have to put our sincere efforts to reduce the cost of generation of the electricity. One of the solutions for this is by reducing the auxiliary power consumption in the power station.

Now a days we are facing acute problem of coal supply to thermal power stations used for generation of electricity. For reduction in the cost of power generation the auxiliary power consumption, & repair and maintenance cost of the station should be reduced. For conservation of the conventional resources we have to take some corrective and effective measures.

As a measure of cost reduction now a days VFDs are used to run the auxiliary equipment (used for power generation in a coal based thermal power station) to reduce the power consumption, where there is a speed variation in equipment is required and which is being done by means of other conventional methods of control without saving the energy.

The Stacker/Reclaimer is the biggest equipment as shown in Fig.-1 used in coal handling plant of a coal based thermal power station for stacking of the excess coal received from the mines in the coal yard and the same coal have to be reclaimed during emergency conditions when the coal supply stopped by the mines. For stacking and reclamation of the coal in the coal yard, the stacker/reclaimer have to travel in the track for about 600mtrs length. To travel in the length, 06 nos. long travel drives as shown in Fig.-2 are used. During stacking and reclamation of coal the operators have to control the speed of the travel as per requirement of the job. As S/R is a heavy machine requires high initial torque. For obtaining high initial torque resistance is being injected in the rotor circuit through slip ring from the resistance box. But there was no saving in energy because the long travel drives were running with full currents as per their ratings.

Fig.1 photograph of stacker/reclaimer [13]

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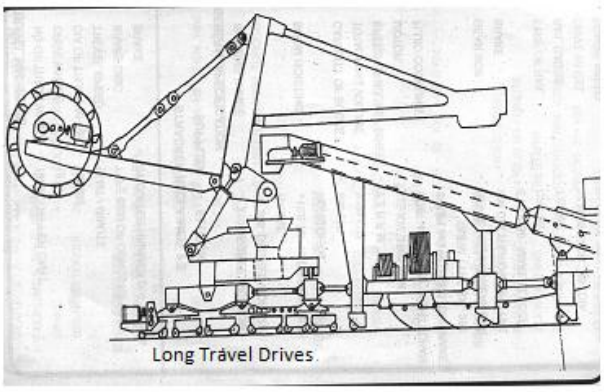

Fig.2 schematic diagram of stacker/reclaimer & LT drives [13]

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 stacker/reclaimer at low speed, variable frequency drives (VFD) are now used for controlling the speed of long travel. By use of the VFD in stacker/reclaimer LT drives, the operation of the drives become smoother.

II. Operation And Advantages Of VFD

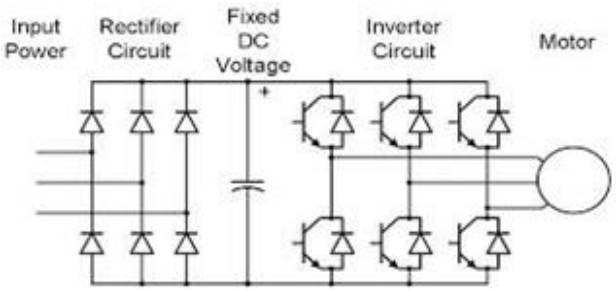

Fig.3 VFD schematic diagram[13]

The induction motors are the extensively used in the power plant for various auxiliaries which are operating at fixed speed as per the supply frequency. Alternating current given to the stator windings of an induction motor produces a magnetic field that rotates at synchronous speed. This speed may be calculated by dividing line frequency by the number of magnetic pole pairs in the motor winding i.e. Speed (rpm) = frequency (hertz) x 120 / no. of poles. The rotor of an induction motor attempts to follow this rotating magnetic field, and, under load, the rotor speed slightly slips behind the rotating field. This slip speed generates an induced current, and the resulting magnetic field in the rotor produces torque.

The torque developed[12] by the induction motor follows the equation below:

$T = k1 . m . I2$

where: $m = k2 .V1/f1$

m : magnetising flux (Wb)

T : torque available on the shaft (Nm)

I2 : rotor current (A) à depends on the load!

V1 : stator voltage (V)

k1 & k2 : constants à depend on the material and on the machine design.

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

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 variable frequency drive (VFD), as shown in Fig.3, is an electrical variable speed. When the system needs to work at reduced speed for long time at reduced load it wastes energy. A VFD allows us to adjust the motor-speed capability and match it with motor-output load. This is how it saves energy. Varying the frequency output of the VFD controls motor speed: Speed (rpm) = frequency (hertz) x 120 / 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 utilisation of VFD in a system gives various advantages like[4][6]:-

1. Soft starting features for a longer life of electrical and mechanical equipment
2. It reduces the power consumption of drives at reduced speed.
3. It improves the power factor of induction motor.
4. It improves the electrical efficiency of induction motor.
5. The operation of drive system is smooth.

III. Operation Of Long Travel Drives Of S/R With Resistance Box And VFD.

a) LT Drives operation with Resistance Box[13] :-

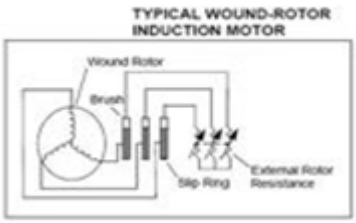

Fig.4 connection diagram of slip ring induction motor[13]

LT drives are used in stacker/reclaimer for traveling of the stacker/reclaimer in the track of S/R in coal yard area. 06 nos. of LT drives are used in the stacker/reclaimer and the power supply to the all motors are from common source, or we can say that the motors are connected in parallel.

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The motors used in the long travel drives are slip ring induction motors (as shown in fig.4). By adding external resistance, in the slip ring induction motor, makes the rotor resistance high when starting, thus the rotor current is low and the starting torque is maximum. Also the slip necessary to generate maximum torque is directly proportional to the rotor resistance. Since the rotor resistance is high, the slip is more, thus it's possible to achieve "pull-out" torque even at low speeds.

As the motor reaches its base speed (full rated speed), after the removal of external resistance and under normal running conditions, it behaves in the same way as a squirrel cage induction motor. Resistance box (as shown in fig.5) was used for the injection of the resistance in the rotor circuit. By operation of the long travel drives with resistance box there was no saving in the power consumption. The drives were taking current as per their rating and same time the power factor of the drives were very poor.

Fig.5 picture of resistance box[13]

There are some disadvantages in this method of speed control. As the rotor resistance is increased, the "I^2* R" losses also increases which in turn decreases the operating efficiency of the motor. It can be interpreted as, the loss is directly proportional to reduction in speed. Since the losses are more, this method of speed reduction is not beneficial.

b) LT Drives operation with VFD:-

Fig.6 photographs of VFD used in stacker/reclaimer LT drives, rating of VFD is 55kw,115A,415V.[13]

By use of VFD in an induction motor there is a possibilities available to run the drive at desired speed by variation of frequency i.e. from 0 to 50Hz. Now VFD is installed in stacker/reclaimer long travel drive operation for traveling of stacker/reclaimer in the coal yard area.(as shown in Fig.6), the power supply to the all motors are from common source through a single unit VFD or we can say that the motors are connected in parallel As the S/R 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 position the stacker/reclaimer is now controllable for stacking and reclamation of the coal. Power consumption of the drives at reduced speed drastically reduced as well as slip of the motor is also reduced. All the motors are taking almost same current and running at same speed. Observations are shown in following Table-1.

Table-1
For single motor

S.N.	Frequency (in Hz.)	Current with VFD (in Amp.)	Measured voltage (in V)	Power Factor (with use of VFD)
1	30	7	249	0.9
2	35	8.2	290	0.9
3	40	8.7	332	0.9
4	45	9.3	374	0.9
5	50	10.1	415	0.9

IV. CALCULATIONS

Rating of stacker/reclaimer LT Motor - 3 ph., 7.5kw, 415V, 972RPM, 50Hz. 06 nos. Long Travel Drives are used.

As per the observations of Table-1 following calculations are done:-

i. While operation of the stacker/reclaimer LT Motor was done with the resistance box, the power factor measured is 0.6 and current taken by a single drive is 18 Amps at 415V supply and frequency 50Hz. Hence, power consumption with these parameters:-

Active Power = √3xVoltage(V) x Current(I) x CosΦ

Pa = 1.732x415x18x0.6 = 7.76 kw

Total Active power consumption by 06 motors = 7.76x6
= 46.56 kw

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Reactive power = √3xVoltage(V) x Current(I) x SinΦx 6

Pr = 1.732x415x18x0.8x6

= 62.10kvar

ii. As shown in Table-1, the current of the paddle feeder is less at reduced frequency and also the power factor improved to 0.9. Hence, power drawn by the motor with different frequencies is as calculated below:-

Active Power (Pa) = √3xVoltage(V) x Current(I) x CosΦr x 6

Reactive power(Pr) = √3xVoltage(V) x Current(I) x SinΦx 6

% saving in Reactive power = (Pr-Prf)*100/Pr

where, Pr- total reactive power of motors with resistance box which is 62.10kvar as above, Prf-total reactive power drawn by the motors with VFD at different frequencies.

(1). at freq. 30Hz, Prf1 = 1.732x249x7x0.42x6
= 7.64 kvar
% Saving of reactive power = (62.10-7.64)*100/62.10
= 87.69%

(2). at freq. 35Hz, Prf2 = 1.732x290x8.2x0.42x6
= 10.37 kvar
% Saving of reactive power = (62.10-10.37)*100/62.10
= 83.30%

(3). at freq. 40Hz, Prf3 = 1.732x332x8.7x0.42x6
= 12.72 kvar
% Saving of reactive power = (62.10-12.72)*100/62.10
= 79.51%

(4). at freq. 45Hz, Prf4 = 1.732x374x9.3x0.42x6
= 15.21 kvar
% Saving of reactive power = (62.10-15.21)*100/62.10
= 75.50%

(5). at freq. 50Hz, Prf5 = 1.732x415x10.1x0.42x6
= 18.29 kvar
% Saving of reactive power = (62.10-18.29)*100/62.10
= 70.55%

The above observation is shown in Table-2 & fig.6&7.

Table-2

S. N.	Frequency (in Hz.)	Current with VFD (in Amp.)	Power Factor (with use of VFD)	ReactivePower drawn Prf in kvar	% saving of reactive Power
1	30	7	0.9	7.64	87.69
2	35	8.2	0.9	10.37	83.3
3	40	8.7	0.9	12.72	79.51
4	45	9.3	0.9	15.21	75.5
5	50	10.1	0.9	18.29	70.55

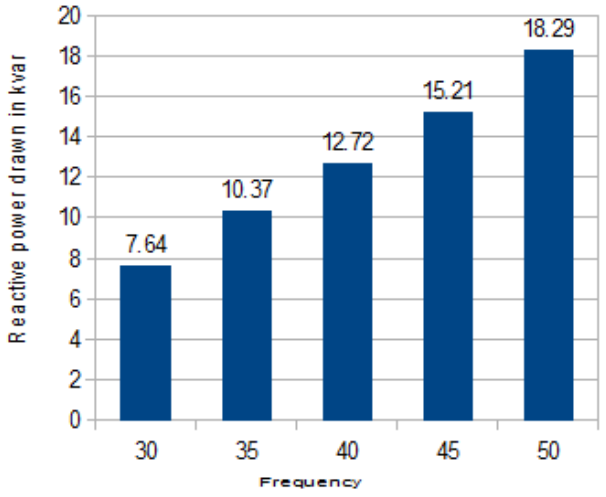

Fig.6 graph between freq. reactive power drawn

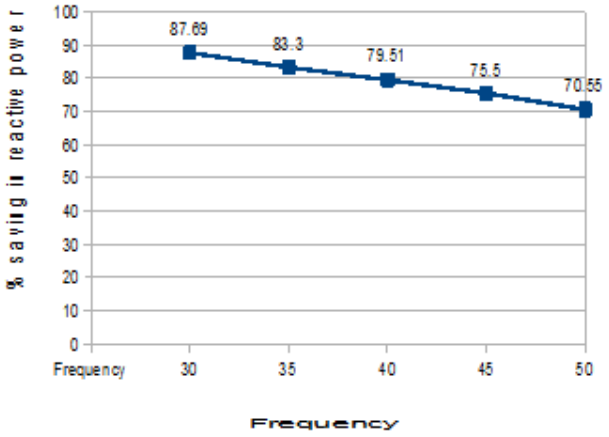

Fig.7 graph between freq. & % saving in reactive power

V. CONCLUSIONS

As shown in the Tables-1 & 2 and Fig.6 & 7 by the use of VFD in stacker/reclaimer long travel drives the current consumption at reduced speed is reduced very much and hence, energy saving. The VFD works as soft starter for the drives and hence, the starting of long travel drives become smoother without any jerk and hence, the life of associated components of the drives will be more compare to operation of drives with resistance box. Operation of the long travel become easier and needs less maintenance. The reactive power consumption of the Induction motor also reduced by use of VFD as shown in the Table-1 hence, the electrical efficiency of the motor has increased because most of the power is utilized to drive the motors. From the above observations we can say that by use of VFD in auxiliary equipment in a coal based thermal power station will be helpful in reduction of auxiliary power consumption.

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