Application of AC motors and drives in Steel Industries

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Abstract - This paper deals with a few major application of AC motors and drives with special controls in steel plants. Application of AC drives for electrically operated overhead crane have been discussed in details. Application of AC drives has reduced the maintenance expenses and a large amount of power is saved. AC power is also used for high frequency welding and other special applications. Large numbers of high power AC motors are used in steel industries which require control of speed to suit the process requirement. In a steel plant, power electronics plays an important role in process improvement and dimensional control of rolled products. Proper selection of drives not only saves electrical energy but also produce quality products. Advancements in the field of drives and control techniques are responsible for improvements in the quality and yield of steel products.

Index Terms: Cyclo converter for rolling stand motor, Electromagnetic stirrer, Power Factor correction, VVVF Drive for Crane.

I. INTRODUCTION

The integrated steel plants are having very large capacity motors and power electronics devices, which are used during processing of steel. The process of manufacturing steel products from iron ore involves Raw material preparation, Primary reduction, Refining, Casting, Hot and Cold rolling, Surface coating etc. Energy such as gas and electric power is required in each of these processes. The motors used in the primary area (Coke oven, Blast furnace, Steel melting shop) do not require speed regulation of high order; on the other hand motors used in finishing mills require speed regulation of high accuracy.

In most of the steel plant applications, variable speed was obtained through DC motors driven four quadrant converters. During modernization, the DC motors and drives are replaced by AC motors and drives.

Large AC power is also used for induction heating in ladle furnace during secondary refining of steel, high frequency heating during welding process in a pipe plant. Control of this power is very important for process control. These controls are done by application of power electronics.

AC drives are used mostly in primary area (Raw material handling, Sinter plant, Steel melting shop) in steel plant. Variable speed AC drives are used in soaking pits and reheat furnaces. AC motors of very high capacities (4 MW in Sinter plant and 14.4 MW in the prime mover of MG set in Plate Mill) are used in steel plants. A few applications are given in this paper.

II. AC DRIVES FOR CRANE

A. VVVF drive for crane application

Conventional AC operated EOT cranes uses slip ring induction motor whose rotor windings are connected to power resistance in 4 to 5 steps by power contactors. Reversing is done by changing the phase sequence of the stator supply through line contactors. Braking is achieved by plugging operation. A crane control system has been developed and implemented using variable voltage variable frequency drive and a programmable controller. The main advantage achieved are precise positioning of the object, reduction in electrical energy consumption by regenerative braking, increased motor life by applying low voltage at the starting and thus reducing in rush current.

A crane with following details has been taken for experimentation with adjustable frequency drive.

Capacity : Main Hoist 30 T
Auxiliary Hoist: 5 T
Current Collector: Gravity collector, Festoon with double collector arrangement.

Speed : Traveling : 80 m/min
        Traversing : 40 m/min
        Main hoist : 8 m/min
        Aux. hoist : 20 m/min

The motor details are shown in Table-1

The basic requirement of crane drives are (i) Bi directional movement of the motors, (ii) Regenerative braking facilities, (iii) Controlled acceleration to reduce the load swing, (iv) Precise positioning of the load, (v) Torque at Zero speed and (vi) Safety features.

A VVVF drive, operated in four quadrant operation and consisting of one three phase forward converter, one three phase reverse converter and one transistor based inverter unit has been developed for crane application. The inverter output is fed to the stator winding and the rotor windings are shorted at the slip ring. The reference speed is set to the speed regulator unit. The drive accepts 0 to + 10 V DC as set point for forward movement and 0 to −10 V DC for reverse movement. No pulse tacho / encoder are connected to the LT / CT motor for speed feedback. The speed feedback is taken as (1-s).n, The value of n, depends on the output frequency of the inverter.
Each motor of the crane has to sustain 20 nos of start / stop operation in an hour.

Table-1: Motor details

<table>
<thead>
<tr>
<th>Motors</th>
<th>Nos</th>
<th>Power in kW</th>
<th>Speed in RPM</th>
<th>Stator voltage</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Travel</td>
<td>2</td>
<td>23.5</td>
<td>965</td>
<td>415</td>
<td>Slip Ring</td>
</tr>
<tr>
<td>Cross Travel</td>
<td>1</td>
<td>5.5</td>
<td>965</td>
<td>415</td>
<td>Slip Ring</td>
</tr>
<tr>
<td>Main hoist</td>
<td>1</td>
<td>30</td>
<td>730</td>
<td>415</td>
<td>Slip Ring</td>
</tr>
<tr>
<td>Aux. hoist</td>
<td>1</td>
<td>10</td>
<td>736</td>
<td>415</td>
<td>Slip Ring</td>
</tr>
</tbody>
</table>

B. LT Drive capacity selected;
Motor: 23.5 kW X 2 Nos.
VVVF drive capacity: 120 kVA
Type: Four quadrant operation with regenerative facility
Converter unit: 3 Phase thyristor bridge
Inverter unit: 2 series connected power transistor with anti parallel diode.
DC link capacitor: electrolytic type
Continuous output: 150 kVA
Rated current: 165 Amps
Overload capacity: 50% for 60 sec
LT Drive steady state behavior is shown in Table-2.

C. LT Drive acceleration time
During initial trial period, the acceleration time was kept at 15 sec. After several trials it was reduced to 8 sec. It was observed that further reduction of time swings the load heavily and load starts oscillating.

D. LT drive deceleration time
During initial trial period, the acceleration time was kept at 40 sec. After several trials it was reduced to 10 sec. It was observed that further reduction of time swings the load heavily and load starts oscillating.

E. LT drive transient behavior
LT motor transient current
Position-0 to Position-1 Acceleration current 76 Amps
Position-1 to Position-2, Acceleration current 48 Amps
Position-2 to Position-3, Acceleration current 36 Amps
Position-3 to Position-4, Acceleration current 32 Amps

F. Technological Benefits
The following are the technological benefit over conventional rotor resistance control
i) Savings in electrical power as there is no loss in rotor resistance
ii) Precise positioning of the hook at very low speed operation is possible. With rotor resistance control operator has to reverse the motor a few times for positioning
iii) During braking, the drive regenerates and power is fed back to busbar through current collector
iv) All controls and safety interlocks are done in a Programmable controller and thereby the panel size is small.
v) Easy of maintenance as the faults are indicated on the display board
vi) High starting torque.

Table-2: LT drive steady state behavior

<table>
<thead>
<tr>
<th>Master Controller</th>
<th>Speed reference voltage from PLC</th>
<th>Reference frequency of drive</th>
<th>Motor Speed in RPM</th>
<th>Steady state current of both motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Left-1</td>
<td>-1.8</td>
<td>9.1 (RBY)</td>
<td>175</td>
<td>25.6</td>
</tr>
<tr>
<td>Left-2</td>
<td>-3.7</td>
<td>18.3 (RBY)</td>
<td>351</td>
<td>24.6</td>
</tr>
<tr>
<td>Left-3</td>
<td>-7.0</td>
<td>35.0 (RBY)</td>
<td>675</td>
<td>23.4</td>
</tr>
<tr>
<td>Left-4</td>
<td>-10.0</td>
<td>50.0 (RBY)</td>
<td>960</td>
<td>23.0</td>
</tr>
<tr>
<td>Right-1</td>
<td>1.8</td>
<td>9.1 (RYB)</td>
<td>174</td>
<td>25.4</td>
</tr>
<tr>
<td>Right-2</td>
<td>3.7</td>
<td>18.3 (RYB)</td>
<td>349</td>
<td>24.3</td>
</tr>
<tr>
<td>Right-3</td>
<td>7.0</td>
<td>35.0 (RYB)</td>
<td>675</td>
<td>23.1</td>
</tr>
<tr>
<td>Right-4</td>
<td>10.0</td>
<td>50.0 (RYB)</td>
<td>958</td>
<td>22.4</td>
</tr>
</tbody>
</table>

III. AC DRIVE FOR ROLLING STAND MOTOR

AC synchronous motors are used for driving the roughing stand rolls in a rolling mill. Synchronous motors are used when power requirement is very high and speed of rolling is low. The R0/V0 stand motors of Hot Strip Mill of Rourkela Steel Plant are synchronous motor. These motors are driven by cyclo converter. The capacity of R0 stand motors are 3 MW x 2 Nos, 953 Volt, 1121 Amps, 70 RPM. The capacity of V0 stand motors are 1 MW X 2 Nos at 953 volt. The cyclo converter output frequency is 5-15 Hz. The following technological benefits have been obtained from these drives;

i) Speed regulation is precise
ii) The control system is having high dynamic response
iii) The over load capacity of the drive is very high and hence the number of tripping due to over load is very less.

IV. AC DRIVE REQUIREMENT FOR LARGE MACHINES

A. Exhaustor of Sinter Plant II of Durgapur Steel Plant

The Sinter Plant-II of DSP has two exhausters to suck air through sinter machine. The suction pressure is around 1500 mm WC. The installed electrical load is 21 MW. The average energy consumption at rated capacity is 13-14 MW, out of which 8 MW is consumed in the exhausters. The power line frequency varies from 49 to 53 Hz. When the frequency is high (say 53 Hz), motor speed increases to 1060 RPM and the blade speed increases to 1442 RPM. With this speed load on the exhauster motor increases and consequently stator current increases. When the current increases above safe limit, the motor trips. Such a trip causes a delay of around 1 hour. Each synchronous motor is rated for 4670 kVA, Stator 11kV, 244 A, Rotor 78 V, 295 A, CosΦ = 0.9. During high frequency, the load on the machine is reduced by closing the damper in the suction line.

These synchronous motors are excited in such a way that it draws leading current so that the overall power factor of the plant is nearer to unity.

A variable frequency drive to suit this motor capacity shall help to control the suction by varying the supply frequency. This shall stabilize the plant.

B. Compressors of Oxygen Plant of Durgapur Steel Plant

The capacity of oxygen plant is 700 t/day. The plant consists of two numbers of air separation units each of capacity 350 t/day. There are two air compressors for 2 air separation unit. Each air compressor is driven by synchronous motor of rating 11 kV, 6 MW, 0.9 pf lead. There are three oxygen compressors, driven by synchronous motor of rating 11 kV, 1700 kW, 0.9 pf lead. There are two nitrogen compressors driven by induction motor of rating 11 kV, 1320 kW. At higher frequency above 50 Hz, the plant becomes unstable. The plant is made stable by changing vent and by this way specific power consumption increases. There is no provision for regulating the speed of the compressors at higher frequency.

Variable frequency drives to suit these motor capacities shall help to control the process by varying the supply frequency.

V. SPECIAL APPLICATION

Other than drive system, there are several special applications where power electronics is used in steel plants. A few of them are described below:

A. Electro magnetic stirrer

During casting of billets and blooms the liquid steel is stirred to improve the quality of cast product. A stirrer acts like a stator of an AC motor. It is fed by 3 phase or 2 phase power supply and a rotating magnetic field is created. The rotating magnetic field induces a torque in the liquid steel of the billet or bloom passing through the mould. The liquid steel acts like a rotor of an AC motor and rotates around the axis of the cast products in a plane perpendicular to the casting direction.

A rotating stirrer induces axial symmetrical forces creating a torque over the whole section of the liquid pool, whatever the size of the liquid pool is and even if the strand is not centered inside the stirrer. It follows that all the forces induces within the whole section of the liquid pool and consequently the full power induced inside liquid pool contributes to the stirring of the liquid steel. The frequency of the supply varies from 3-10 Hz depending on the stirrer. The principle of rotating stirrer is shown in Fig.1.

The scheme for generating the rotating magnetic field consists of converting AC power to DC power and then DC power to a variable frequency AC power. The main units are (i) Converter transformer, (ii) Diode bridge for AC to DC and (iii) Inverter bridge for DC to AC. A schematic diagram of the power line is shown in Fig 2. A stirrer system installed in continuous casting plant of DSP is having the following specification.
Converter: Input 415 V ± 10%, Output 350 V, 180 kVA, 400 A

Coil: 100 kVA at 400 A

To stirrer coil

**Fig. 2 - Power Scheme of electro magnetic stirrer**

B. **Variable voltage fixed frequency inverter for magnetic amplifier replacement**

A system has been developed for a three-phase AC to single phase AC inverter that produces a regulated AC voltage as per the reference voltage. These inverters are having several applications in steel rolling mill where the speeds of successive stands are to be proportional in steady state and in transient conditions. The system consists of a converter transformer, three-phase diode rectifier, DC link capacitors, control voltage generation scheme, a single-phase inverter and an inverter transformer. The application of such an inverter has been demonstrated in wire rod mill of Bhilai Steel Plant. The similar inverter can be used for control application in a continuous rolling mill. A single line diagram of the rectifier inverter system is shown in Fig 3.

VI. **TECHNO ECONOMIC IMPACT**

A. **Tuning of excitation of large synchronous machine for Power factor correction**

In a synchronous motor, delivering constant mechanical power when energized from a source of constant voltage and constant frequency, the stator current is a function of field excitation. At unity power factor, current drawn in the HT line is minimum. The excitation of 4 MW, 11 kV synchronous motor, used as a suction device in the sinter plant of DSP, has been tuned to achieve minimum stator current. The result shows a decrease in stator current and elimination of unwanted tripping during high frequency. A typical curve is shown in Fig 4.

VII. **CONCLUSION**

Very large capacity motors are used in steel industries. It requires various types of special drives to meet the quality requirement. Power Electronics and control system requires implementation in steel industries to sustain the customer’s quality requirement.

**Acknowledgement**

The authors are thankful to the Electro Technical Lab department of Bhilai, Durgapur & Bokaro Steel Plant and Electronics Engineering Department of Rourkela Steel Plant for extending detailed information in preparing this paper. The authors express their gratitude to the management of SAIL for the support provided in preparation of this paper.

**References**


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