Hybrid DC-DC-AC Main Drive for ILVA, Taranto Finishing Mill

Michael A DeCarli
TM GE Automation Systems, LLC
2060 Cook Drive
Salem, VA 24153, USA
Tel: 540-283-2118
Fax: 540-283-2395
E-mail: **Michael.DeCarli@TMEIC-GE.com**

Brent Jones
TM GE Automation Systems, LLC
2060 Cook Drive
Salem, VA 24153, USA
Tel: 540-283-2121
Fax: 540-283-2395
E-mail: **Brent.Jones@TMEIC-GE.com**

Antonio Giordano
Electrical Manager, ILVA HSM #1
Taranto, Puglia, ITALY
Tel: +390994813896
E-mail: **Tna1Ele.Taranto@rivagroup.com**

Keywords: Induction Motor, Finishing Mill, Tandem Motor, DC Motor

INTRODUCTION

In 2006 the ILVA #1 Hot Strip Mill in Taranto, Italy undertook a project to upgrade the existing Finishing Mill main drives. The drive systems for Finishing Mill Stands F2 and F3 were each upgraded by replacing one armature of the existing three-armature DC motor with a new higher capacity AC Induction motor. The new drive systems were successfully commissioned in 2009. This upgrade philosophy is a conservative, and potentially lower cost alternative to the traditional practice of simultaneously replacing all tandem armatures with a single large AC main drive motor.

UPGRADE OVERVIEW

The existing layout of the six-stand Finish Mill at ILVA HSM #1 in Taranto, Italy consisted of three-armature DC motors on stands F1-F5 and a two-armature DC motor on F6. The 17 armatures were all identical, rated 2,630 HP, 700 V, 3000 A. Each stand motor had a stub shaft with one pedestal bearing, and each armature had one pedestal bearing. Thus, F1 – F5 motors had three armatures with four pedestal bearings and a combined rating of 7890 HP. The F6 motor had two armatures with three pedestal bearings and a combined rating of 5260 HP.

The goal of this re-powering project was to increase the horsepower of the Finishing Mill enabling ILVA to run a more diverse product range. The upgrade was intended to be accomplished in multiple phases. The first phase of the re-powering increased the HP of stands F2, F3, and F6. Subsequent phases will upgrade the HP of the remaining stands and allow ILVA to replace all the DC motors with AC Motors. Stands F2 and F3 were selected to be upgraded first because they are set up to take the largest draft during rolling and would benefit the most from having more power available. Stand F6 was upgraded because it was possible to increase the HP of this stand without purchasing any new motors.

The power of Stands F2 and F3 was increased by replacing the front 2,630 HP DC armatures with 4,000 kW (5,362 HP) AC motors. These new motors were designed to fit the existing DC motor base, operate coupled to the remaining two DC armatures, and increase the power of these two FM stands. The shaft of the AC motors was designed to transmit twice the output torque of each new AC motor. This shaft design would allow ILVA to eventually replace the two remaining DC armatures on each stand with a second induction motor in the future. New heavier pedestal bearings were supplied to accommodate the increased motor weight and shaft size. The modification of stands F2 and F3 can be seen in Figure 1.

The upgrade of Stand F6 was straightforward. The foundation and motor base were already configured for a three-armature main drive. One of the customer's existing spare DC armatures was installed at Stand F6 to convert it from a two-armature to a three-armature configuration. A new single larger DC power supply was installed to support the increased power demand of the F6 stand. This conversion was made possible because the AC upgrade to stands F2 and F3 enabled ILVA to have 2 additional spare DC motors.

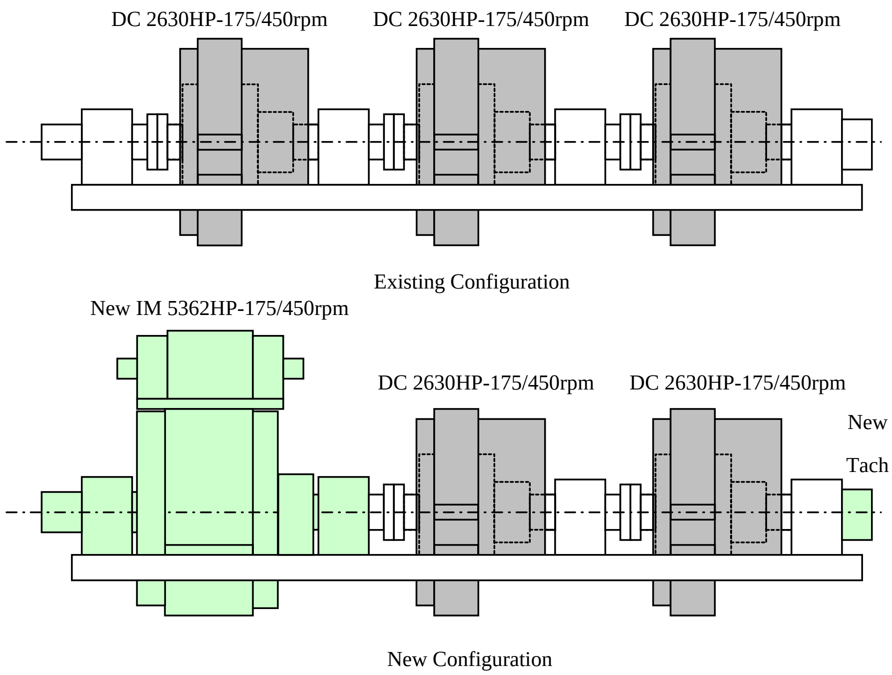

Figure 1: Original and Final Tandem Motor Configurations for F2 and F3

New IEGT PWM AC Main drive equipment was installed in the existing DC Thyristor Electrical Room, with new transformers mounted outdoors. A new 66 kV feeder was installed for each new AC drive. Additional 10 kV switchgear was installed to supply two new power centers, one for the new F6 motor field exciters and one for the new AC drive cooling water system. A new motor control center was installed to support the additional auxiliary loads associated with the new motors and drives. This equipment was designed to support both Phase 1 and Phase 2 of the mill re-power.

The AC motor is controlled as a torque follower of the remaining two DC armatures. This control scheme minimizes the impact on the existing control system for the Finishing Mill and does not affect speed coordination between the main drives of the Finishing Mill stands. The faster response of the AC drives compared to the Thyristor Power Supplies (TPS) makes the AC drive a suitable torque or current follower. The remaining two armatures for each stand continued to be fed by the existing TPS, using a new tachometer for speed feedback.

Phase 2 of this upgrade will duplicate the strategy used for the upgrade of Stands F2 and F3, upgrading the power of Stands F4 and F5. A summary of the original and upgraded main drive ratings is shown in Table 1.

Original Motor Configuration

Stand	First Motor	Second Motor	Third Motor	Total Power
F1	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F2	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F3	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F4	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F5	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F6	DC 2630 HP	DC 2630 HP	None	5260 HP

New Motor Configuration (including Phase 2)

Stand	First Motor	Second Motor	Third Motor	Total Power
F1	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP
F2	IM 5362 HP	DC 2630 HP	DC 2630 HP	10622 HP
F3	IM 5362 HP	DC 2630 HP	DC 2630 HP	10622 HP
F4 *	IM 5362 HP	DC 2630 HP	DC 2630 HP	10622 HP
F5 *	IM 5362 HP	DC 2630 HP	DC 2630 HP	10622 HP
F6	DC 2630 HP	DC 2630 HP	DC 2630 HP	7896 HP

*Future - Phase 2

Table 1: Original and Final Tandem Motor Power Comparison

When both phases of the upgrade are complete, the total power of F1 and F6 will be 7,890 HP each, and of F2 – F5 will be 10,620 HP each. The DC armatures removed from the four upgraded stands will be used as spares.

APPLICATION CONSIDERATIONS

Motor Type

A synchronous motor was originally considered for this application, because most modern hot strip mills feature synchronous motors as the main drives for the Finishing Mill. However, the space available to install the new motor was restricted by the existing foundation and remaining DC armatures. The rotor diameter required for the new motor rating would fit the existing space regardless of motor type, but the motor length was the critical restriction. Both types of AC motor designs were carefully studied, and it was decided that there was insufficient space for the collector ring assembly required by a synchronous motor. Therefore an induction motor was selected for this installation because the required motor length would be shorter for the same desired rating. Additionally, the motor manufacturer had a great deal of experience making induction motors near this rating of 5362HP, 175/450 RPM since it is similar to the ratings of motors used in cold mill applications. These factors made an induction motor the preferred choice for this project.

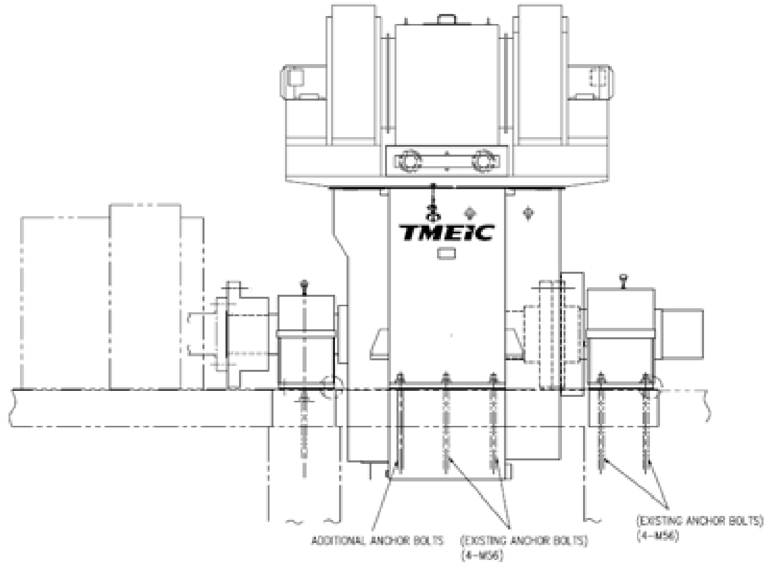

Figure 2: Induction Motor Designed for DC motor Base & Foundation

Torque Amplification Factor

Because the new motor is directly coupled to an existing drive system, and the new motor shaft would deliver the combined tandem motor output torque to the load, it was necessary to study the mechanical system to confirm that no significant mechanical resonance would occur during operation.

$$\frac{Torque_{Peak}}{Torque_{Applied}} = TAF$$

Equation 1: Definition of Torque Amplification Factor

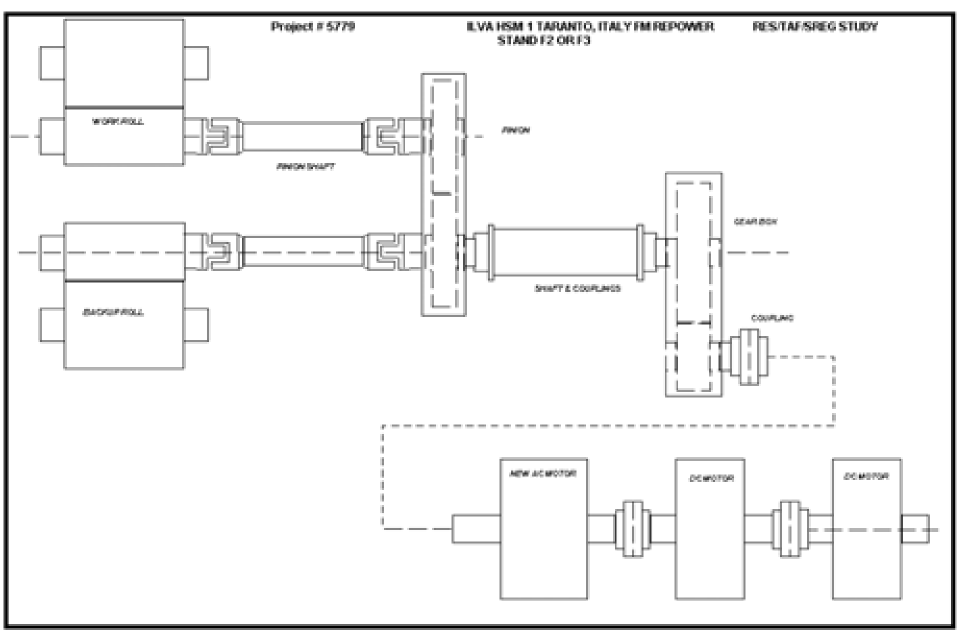

Figure 3: Physical System Studied for TAF Analysis

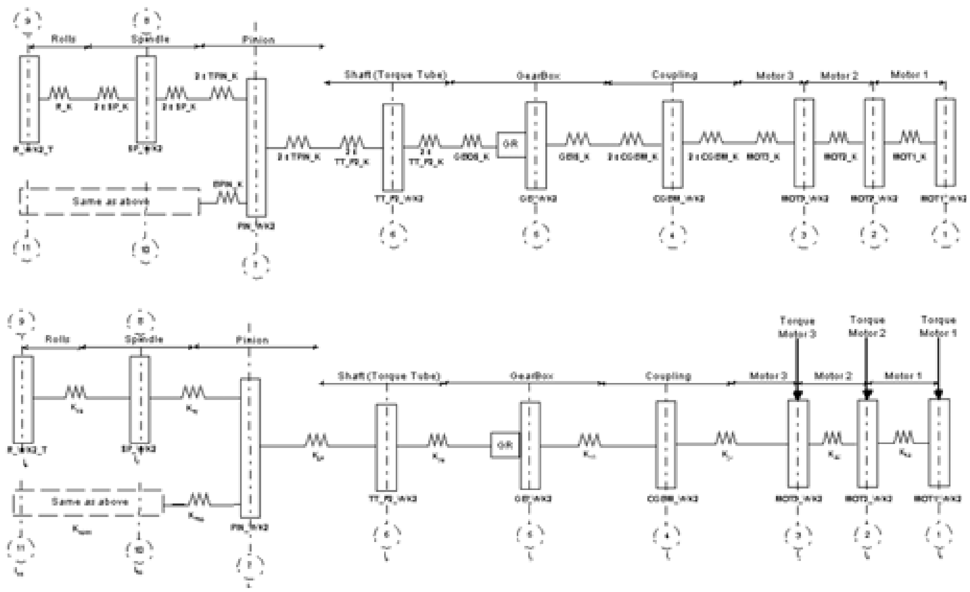

Figure 4: Model Representation for TAF Analysis

	Stand F2			Stand F3		
	EXISTING 3 DC MOTORS	1 INDUCTION MOTOR, 2 DC MOTORS	FUTURE 2 INDUCTION MOTORS	EXISTING 3 DC MOTORS	1 INDUCTION MOTOR, 2 DC MOTORS	FUTURE 2 INDUCTION MOTORS
MOTOR 1 TO MOTOR 2	1.1	1.3	1.2	1.4	1.4	1.5
MOTOR 2 TO MOTOR 3	1.5	1.5	N/A	1.7	1.7	N/A
MOTOR 3 TO COUPLING	1.8	1.9	1.7	1.9	2.0	1.9
COUPLING TO GEARBOX	1.8	1.9	1.7	1.9	2.0	1.9
GEARBOX TO SHAFT	1.9	1.9	1.9	1.7	1.7	1.7
SHAFT TO PINION	1.9	1.9	1.9	1.7	1.7	1.7
PINION TO TOP SPINDLE	1.9	1.9	2.0	1.7	1.7	1.9
TOP SPINDLE TO TOP ROLL	1.9	1.9	2.0	1.7	1.7	1.9
PINION TO BOTTOM SPINDLE	1.9	1.9	1.9	1.7	1.7	1.7
BOTTOM SPINDLE TO BOTTOM ROLL	1.9	1.9	1.9	1.7	1.7	1.7

Table 2: Calculated Torque Amplification Factor

The calculated TAF values are show in Table 2, above. Although in some cases the TAF of the new drive system would exceed the existing TAF, the calculated TAF values were considered to be acceptable. The new motors were designed with consideration for the calculated TAF values.

Construction and Installation

The existing bases were modified by installing additional anchor bolts to support the increase in power. One extra anchor bolt was added to each side of each existing base. Figure 2 illustrates the location of the additional anchor bolts. Because the bottom of the motor foundation was accessible, a hole was drilled all the way through the existing motor foundation and the new anchor bolt was inserted into this new hole and attached to a steel plate at the underside of the motor foundation.

The length of the opening in the existing base was also lengthened by approximately 2” to remove interference between the base and the stator covers of the new motor. Figure 5 shows the installed view of the F2 tandem motors.

Figure 5: F2 DC-DC-AC tandem motors

Motor Auxiliary Systems

The existing DC motors for F2 and F3 were converted from three armatures in parallel to two armatures in parallel. Existing buswork for the front motor was removed and replaced with new 3 phase AC cable.

The existing front DC motor was a Drip-Proof, Separately Ventilated (DPSV) machine, while the new motors are Totally Enclosed Water-to-Air Cooled (TEWAC). This required some changes to the plant auxiliary systems. The existing cooling air ducts under the front motor were sealed off because no cooling air was required for the new TEWAC motor. The AC motors utilize plant water to cool the motor internal air through an air-to-water heat exchanger installed on top of the motor.

The new AC drive cabinets are cooled directly by an integrated, self-contained de-ionized water cooling loop. This de-ionized loop is cooled by plant water through a water to water heat exchanger. Often multiple main drives are cooled by a common de-ionized water cooling loop, but in this case there was no space available for a central cooling water skid, so the cooling water equipment was close coupled to each drive cabinet lineup as shown in Figure 6.

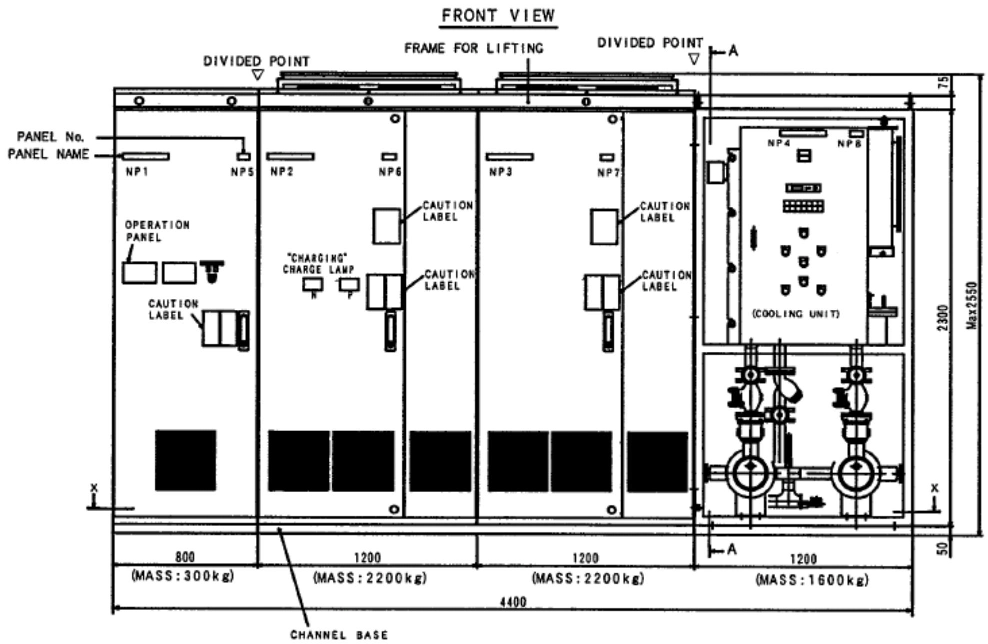

Figure 6: AC Main Drive Outline

The existing bearing lubrication system was re-used with only minor piping modifications to supply the bearings for the new motors.

Drive System

An important consideration when implementing this new drive system was how to successfully integrate the new AC Drive into the existing system with older generation DC drives. After thorough analysis it was decided to configure the new AC drive to run as a slave (torque follower) with a torque reference from the digital front end of one of the DC drives acting as the master. The DC drive was chosen to be the master due to its slower response time. The new AC Drive has a maximum torque current response of 600 radians per second while the DC drives are limited to 300 radians per second. A diagram of the modified main drive control scheme is shown in Figure 7.

Additionally, keeping the DC drive as the master controller minimized disturbances to the existing control system which reduced both the cost and risk associated with the project. Sequencing logic in the existing mill controllers was modified to accept inputs from the new motors and drives.

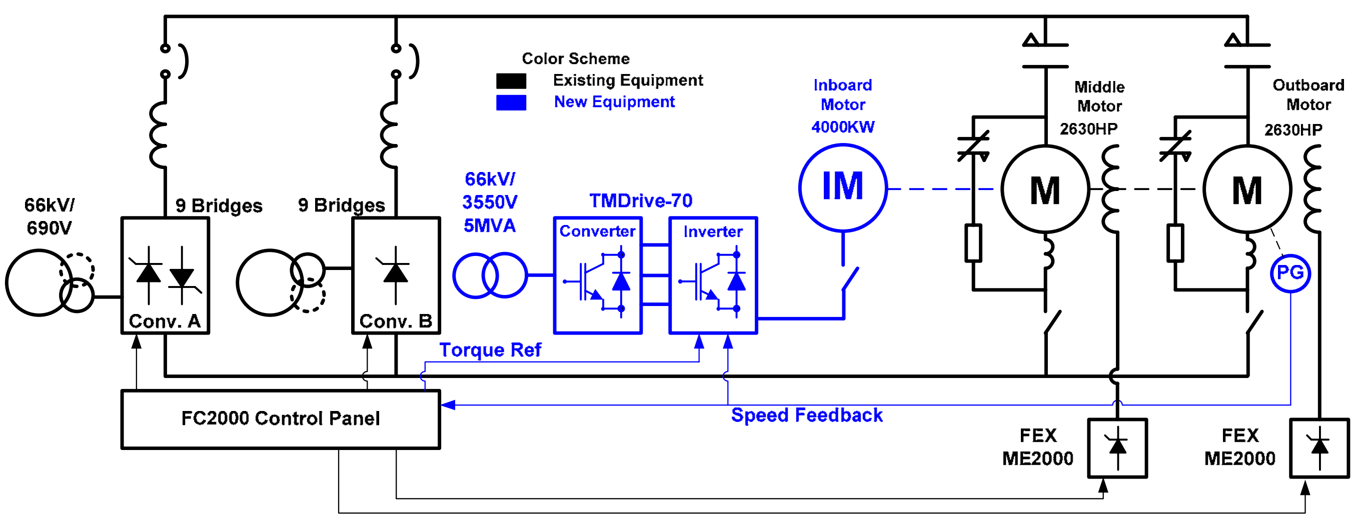

Figure 7: Control Scheme Diagram

One feature of the existing DC motor control scheme that was required to be maintained in the new system was the ability to operate the mill stand with any single motor out of service. In the previous configuration, any single DC armature could be removed from service and the stand would operate with power reduced to 5260HP. In the new configuration, either DC armature or the AC motor can be removed from service and the worst case result is the same 5260HP that was available with the DC motor scenario. However, due to the simplicity and reduced maintenance of the AC Induction motor, it is unlikely that the mill will operate with the AC motor out of service. In this case with either DC armature out of service the stand power will be reduced from 10,620 HP to 7,990 HP which is still more power than was available with three DC armatures.

Another feature of the new drive system is overall improvement in system efficiency compared to the existing DC motor drive system. The new IEGT PWM AC drive efficiency is rated at >98.5%. This is an improvement of approximately 5% compared to the efficiency of the DC thyristor converters which had been used with the DC motors. The new Induction motor efficiency is roughly 94% at rated load, compared to typical DC motor efficiency of 80%. Although it is believed that the energy savings generated by this upgrade was substantial, energy savings was not used as a justification for this project and the benefits have not been rigorously analyzed.

PROJECT EXECUTION OVERVIEW

Project Schedule

During the routine annual shutdown of 2008, the F6 stand was upgraded with the third armature and new DC drive. Preliminary work was also done to prepare for the later installation of the AC drives in 2009. New feeders were added to the mill electrical distribution system for the new drives and motors, new drive isolation transformers were installed outdoors, and new AC drives were installed in the existing TPS room of the mill and during this shutdown.

Because of unusually low orders in 2008, ILVA decided to shut down the #1 HSM in December, 2008. The inboard DC armatures of Stands F2 and F3 were removed by ILVA before the end of 2008. In January 2009, work began to install the new AC motors and commission the drive system.

In May 2009, the new drive system of Stands F2 and F3 had been exercised as much as possible without rolling metal through these stands, and the commissioning was declared complete. A benefit of the difficult economic times is that ILVA has been able to complete the majority of this phase of the re-powering without additional downtime and lost production. TMEIC GE will return to ILVA’s #1 HSM for a period of production support after the mill is restarted in 2010.

SUMMARY

The front DC armatures of two three-armature Finishing Mill main drives were replaced by larger capacity AC Induction motors to increase the power of those Finishing Mill Stands with minimal disturbance to the existing DC armatures, DC drives, and mill automation system. Under special conditions like those at Ilva, this modernization philosophy has significant potential for the upgrade of other mills featuring tandem DC armatures which are facing obsolescence or power limitation issues. With proper engineering analysis to verify the feasibility of this solution, it is a conservative alternative to the traditional practice of simultaneously replacing all tandem armatures with a single large AC main drive motor.

REFERENCES

1. H. Hosoda, S. Kodama, and R. Tessendorf. “Large PWM Inverters for Rolling Mills”, Iron & Steel Technology, Vol.5, No.1, January 2008
2. R. Tessendorf. “Synchronous and Induction Motors for Main Drive Applications”, Submitted for Publication in Iron & Steel Technology, February, 2010