THE NEW POWER DISTRIBUTION SUPERVISORY SYSTEM OF ARCELORMITTAL TUBARÃO[1]

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Abstract

This paper presents implementation aspects of the new supervisory system Power TG, from ArcelorMittal Tubarão power distribution system. In 1983, with a production capacity of 3 million tons of steel per year and a power generation capacity of 144 MW, the power distribution system was originally not automated. In 1997, with its year production expanded to 4,5 million tons and with a power capacity of 290 MW, the substations were digitalized and the digital supervisory system ALSPA was installed, centralizing the operation. In the 2007 expansion to 7,5 million tons/year and the power generation capacity expanded to 433 MW, a power surplus of 120 MW started to be sold to the power market, demanding the power system co-operation with the National System Operation, ONS. Hence, the new Level 2 supervisory system Power TG was installed to face the new challenges with its system control interfaces, main managerial information monitoring, historical database and communication with PROCOM systems. The system nowadays exceeds the initial expectations, since it provides flexibility, safety and reliability to the complex power grid operation.

Key words: Automation; Level 2; Power distribution system; Power TG

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1 INTRODUCTION

In the modern steelmaking process, one of the major strategic points consist on the utilities systems, consisting on the provision of vital inputs: electrical power, fuel gases, process steam, air fractioning gases such as argon, oxygen and nitrogen, and water treatment and pumping. Those systems are widely distributed and present in each ArcelorMittal Tubarão productive process, from raw material handling (coal, iron ores, etc) to the final product (steel slabs, steel hot strips and logistic facilities).
The Power Distribution System was conceived to allow the efficient and reliable management, projected under a philosophy focused to the power systems integrated control, to reduce the potential losses from electrical occurrences from the inside grid and from the interconnected Escelsa/Furnas power grid.
This paper is focused on the Supervisory Control System from the ArcelorMittal Tubarão Power Grid. It is going to be done a contextualization from the power grid inside the history of ArcelorMittal Tubarão, and its evolution until 2008.

2 POWER MODEL HISTORY

The evolution of ArcelorMittal Tubarão Power Model has got 4 crucial moments that represented landmarks to the expansion of the generation/load grid and to the technological evolution of its control and management.

2.1 Startup – 3,0 MT/year

In 1983, the company, then called CST – Companhia Siderúrgica de Tubarão – began its operations with a production capacity of 3,0 million tons of steel per year. It was a company joined to the Siderbrás state group. It is highlighted that in this period there was only one Blast Furnace, a conventional slab casting system with reheating furnace and ingot casting.
The power generation matrix was composed by 2 thermal plants, that use the gases that come from steelmaking process (COG – Coke Gas and BFG – Blast Furnace Gas). Each one has a power capacity of 68 MW, performing a grid with 136 MW power capacity. The own generation capacity supported 90% of the demand. The Power Grid was composed by 6 Substations. In 1992, the company was privatized, and new investments for production increase took place in 1996, with the #1 Continuous Casting replacing the conventional ingot casting to aggregate value to the produced steel slabs.

2.2 1998 – 4,5 MT/year

In 1998, there was the first significant production expansion to 4,5 million tons of steel per year, with the implementation of the Second Blast Furnace (Figure 1) and the Second Continuous Casting.

Figure 1 – Blast Furnace 2

With this production expansion, it was installed a third Power Plant with 75 MW of capacity, and a Top Pressure Recovery Turbine in Blast Furnace 1, with a generation capacity of 16 MW. Hence, the generation grid has grown to 227 MW, being able to provide 100% of the company load. In 2002, there was a great improvement on the aggregated value of the company's production with the startup of the HSM – Hot Strip Mill (Figure 2).

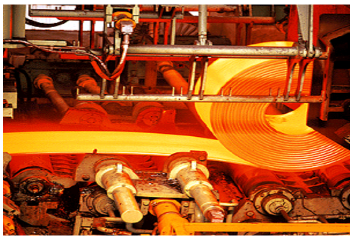

Figure 2 – Part of the HSM process – Coil Box

The Power Distribution system by that year had 10 Distribution Substations. The company started to show a results generation capacity that allowed it to aim other production improvements, that came indeed.

2.3 2004 – 5,0 MT/year

In 2004, there was a production optimization to 5 million tons of steel per year without the building of new productive unities, where the aim was to improve the productivity of the operating plants. In a visionary project, it was built a system to save the LDG – the LD Furnace Gas, generated from the steel refining at LD Furnace and with a high calorific power. This gas started to be used at the boiler of a fourth Power Plant, with a 75 MW capacity. The power grid has then jumped to 302 MW.

2.4. 2007 – 7,5 MT/year

In 2007, it was concluded another important expansion step, to 7,5 million tons of steel per year, highlighting the building of the third Blast Furnace, the third LD Furnace, the third Continuous Casting, a new Lime Plant and the new Heat Recovery Coke Plant with 2 new Power Plants with a capacity of 98 MW each. The Power Grid expansion has lead it to 15 power distribution substations. The power grid reached the generation capacity of 472 MW, the equivalent of 120% of the installed load. With this configuration, the company started to sell energy and, due to the dispatched power levels, it has reached the category of 'dispatched generator'. Since then, the Power Grid has been remotely co-operated by the National System Operator, ONS.

3 HISTORY OF THE SUPERVISORY CONTROL SYSTEM

The evolution of the Power Grid supervisory control system followed, alongside of its path, both the production expansion and the supervision and control technology availability and competitiveness. There are three great moments, one at the Company startup, one at the digitalization of the Power Distribution and the other at the supervisory fitness to the production expansion to 7.5 million tons/year.

3.1 Original Configuration

At the Company startup in 1983, there was no automated system to centralize the operation of the Power Grid, neither a cost-effective digital technology available to do so. For this reason, each one of the 6 original Substations had its own command and control table, with synoptic panels used by operators, always in the field, whenever it was necessary to perform maneuvers and system load balances. At those times, the protection system of the Power Grid was composed by analogical relays with individual protection functions.
The system had only one Receiving Substation, that joined together the two first Power Plants and the first transmission line to Furnas/Escelsa, to buy the lacking power to complete the load balance of the plant (Figure 3).

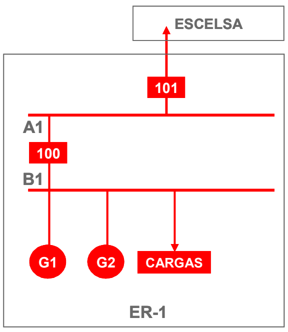

Figure 3 – Original Power Grid simplified one-line diagram by the plant startup

3.2 Power System Digitalization

In 1997, the Company was able to expand its production and innovate its productive processes. With the advent of the Blast Furnace 2, the third Air Fractioning plant and the third Power Plant, and counting on with technologies of Optical Fiber, Digital Communication Network Protocols, Programmable Logic Controllers, Advanced Supervision and Control Systems, and Power Distribution Networks Control Systems, it was the right time to modernize the Company's power system. At that year it had happened the digitalization of the Substations with the replacement of synoptic and control panels by PLCs, fiber optic networks and the Supervisory and Control System SSC ALSPA, which allowed the remote control and operation of all Substations from the Energy Center. The ALSPA system, based on the OpenVMS operating system platform, had the appropriate performance as an answer for the needs of robustness and reliability. The power system expansion placed an additional challenge: besides the central control of the system, the original Substations upgrade should be compatible to the new Substations. This was the reason for the adoption of an electrical protection system standard (GE Multilin), a PLC standard (GE Fanuc) and a digital communication system standard (FDDI with TCP/IP). The Power Grid, then with two Receiving Substations (Figure 4), became completely digitalized, what represented the acquiring of an important new competitive advantage for the Company.

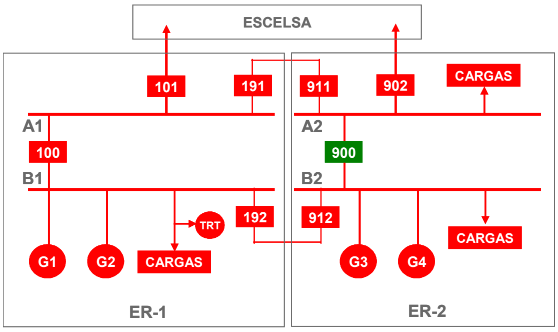

Figure 4 – Power Grid simplified one-line diagram after the 5 MT/year expansion

This advantage became visible when the new production expansion to 7,5 million tons per year was started: increasing from 10 to 15 Substations, from 2 to 3 Receiving Substations, and from 4 to 6 Power Plants (Figure 5), the system increased significantly its complexity, staying its operation already able to be adjusted to the digital communication network expansion, excepting the supervisory system.

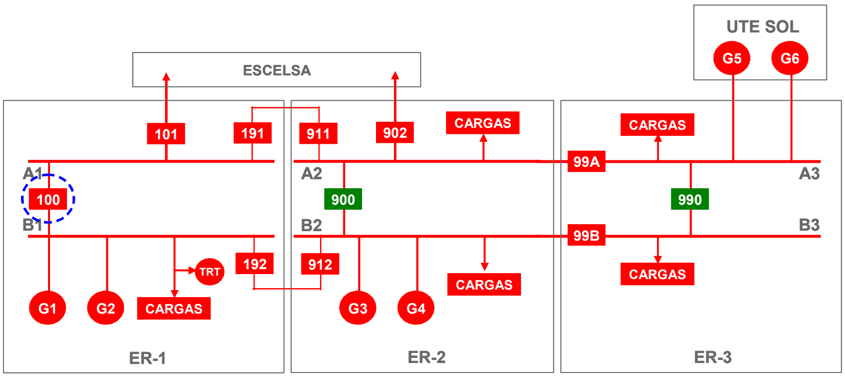

Figure 5 – Power Grid simplified one-line diagram after the 7,5 MT/year expansion

4 SUPERVISORY CONTROL SYSTEM ADVANTAGES

The Supervisory Control System has brought improvements to the system operation:

- Remote and standardized operation of all Substation by the Energy Center: reduced as the quantity of operators in the field as the probability of human failure during the routine or special activities over the Power Grid elements (ties, buses, circuit breakers, interconnections, etc). It is also highlighted the alternative option of local operation at the Substation via panel, representing an operational alternative in case of any abnormality that restrains the remote operation.
- Power Grid, Fuel gases and water treatment information centralized at the same operational environment: provided a single supervision control center of Utilities, increasing the synergy among those systems.
- Compatibility, similarity and standardization of all electrical components for Control Measurement and Protection (digital relays): allowed the centralized supervision of the control network of digital electrical protection system, and the installation of the central load shed system, crucial for minimizing impacts

over the Power System caused by internally generated events (ex: unpredicted shutdown of a Power Plant) or externally generated ones (ex: undervoltages from the Furnas/Escelsa grid).

- Operational management improvement: allowed the generation of better decision making support information at the supervision level (fast and reliable information) and at the managerial level (information retaining, data treatment and analysis ability):
  - Daily and monthly reports: report generation with reliable data ensuring high reliability to the information provided to the supervisor at the system operation routine and to the periodic information provided to the manager at the management and planning routines.
  - Power balance: allows to establish priorities at the power distribution and to make maneuvers to prevent the exceed of technical, legal or contractual constraints, and a better generation and load equalizing among the three Receiving Substations.
  - Historical database: allows the data analysis a posteriori to investigate problem causes, besides allowing the survey of historical data about the system operation.
  - Trend graphics: allows critical operational information from the Power Grid to be monitored during the short term to its close control, besides the operational decision making during emergency situations.
  - Events and occurrences register (SOE PLC's): allow the survey of protection events that came from Power System unexpected conditions in order to find the root causes, heal problems and improve the system robustness.

5 THE NEED OF CHANGING THE SUPERVISORY SYSTEM

The robustness of SSC-ALSPA/OpenVMS brought a technical problem that showed up when the tasks of the 7,5 MT/year expansion took place: the system had low flexibility to expand as the number of communication points with the Power Grid control system digital network, as the number of control variables.

6 POWER TG SYSTEM CHARACTERISTICS

The fundamental characteristics of Power TG are as follows.

- Windows Client-Server Architecture: Power TG works in Windows servers, communicating through network with client stations in real-time.
- Real-time and object-oriented database: The information received or sent to PLCs or PROCOM systems are stored in a real-time database, managed by the Server application.
- High performance and efficiency: the Server application performs data receiving and sending readings each 4 seconds to all system interfaces, what makes it fast enough to show the information to the control stations in real-time, and to send the operator commands to the Power Grid PLC's in high velocity.
- High availability (over 99,98%): the robustness from the system architecture makes it highly resistant to software problems and able to cope with its critical mission of supervising the Power System.

- Flexibility, scalability, friendly graphic interface: Power TG can be continuously customized without greater difficulties to fit to modifications or new operational needs. Its capacity of database expansion – if adequately supported by the eventually necessary hardware improvements – makes it ready for future expansions and/or modifications at the Power Grid.
- Trend Graphics: the new system allows the building of customized trend graphics according to the operational needs. An example is the energy (MWh) dispatch to the interconnected system, which is supposed to remain inside a range of maximum and minimum values at each 15 minutes, and through its following it is possible to make operational decisions.
- Alarm filtering (by priority, Substation, Not Recognized ones, etc): The alarms are classified in order to let the operator to view quickly the events with higher priority. It helps on reducing the problem diagnosis time and its solving.
- Scalability (the system presently has got around 25 thousand points): Power TG is able to accept more communication and control points to be aggregated as long as it becomes necessary.
- Maintenance of screens and real-time database: The operator interface screens can be continuously changed and improved, as long as the operational need appears.
- Failure redundancy (hot standby): The server system consists of two redundant servers, in a manner that, if the supervising server fails for any reason, the hot standby server assumes automatically the supervision, reducing the operational disturbs.
- Communication protocols flexibility: Power TG communicates with Substations PLC's through TCP/IP protocol, with PROCOM systems through OPC protocol, and with ONP communication link through ICCP protocol, all of them in real-time.
- Data portability: Data from real-time database can be converted to different formats, according to the communication system: to the digital communication with PLC's (Level 1 automation), or to ONS or the PROCOM systems (Level 2 automation). The real-time or the historical data can also be exported to convertible formats onto MS-Office tables, for event data analysis.

7 SYSTEM TOPOLOGY

The system has a Level 1 topology, for communication with PLC's, and a Level 2 topology, for communication with servers, console stations and others.

7.1. Level 1 Topology

The Level 1 architecture, according to Figure 6, consists on 3 main groups of PLC's: Load shed system PLC's connected via FDDI ring among themselves and with the SRCG, load and generation shed server; Power Distribution System Supervisory Control PLC's, connected to the Load Shed system and to Power TG; and SOE – Sequence Of Events – system PLC's, also connected to the Load Shed and to Power TG. The insulation of Load shed ring provides the safety needed to the fast load or generation shedding during events in the Power Grid.

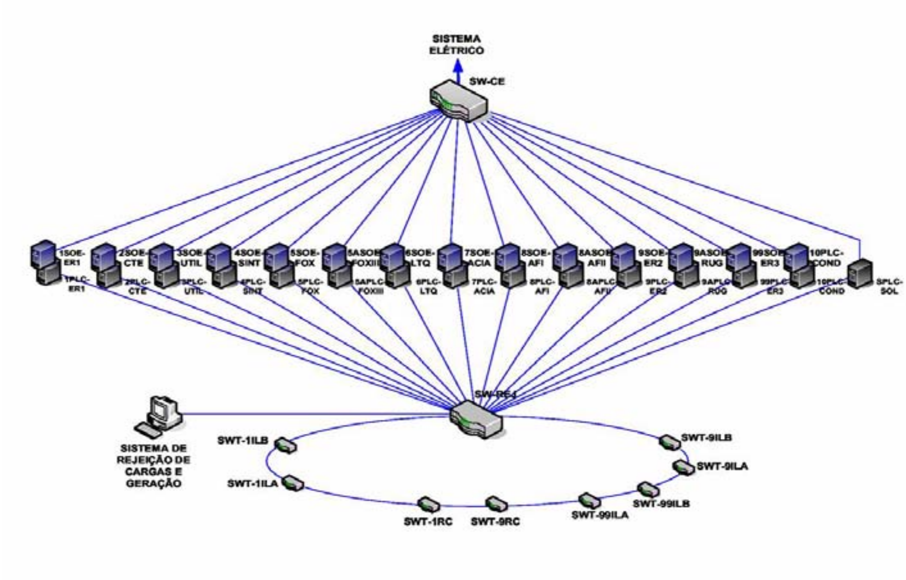

Figure 6 – Level 1 topology

7.2. Level 2 Topology

The level 2 topology consists, according to Figure 7, on the interconnection among Servers 1, 2 and Historic, the two Console stations, the switch from the Substations PLC's network, the DTS station, the switch from PROCOM system, and the ICCP server.

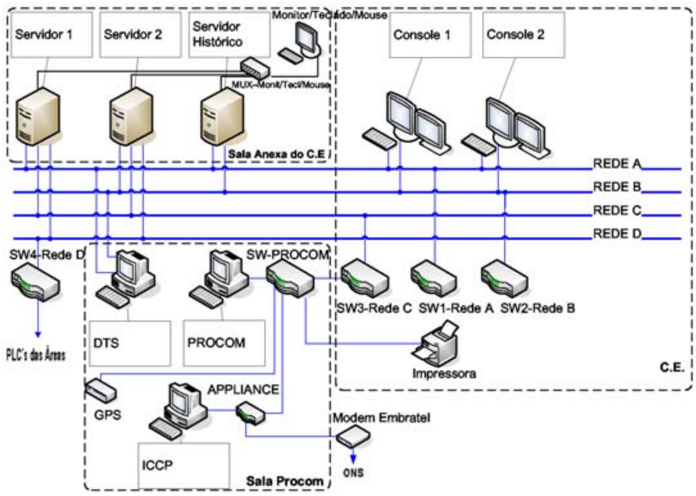

Figure 7 – Level 2 topology

8 INTEGRATED SYSTEMS

The integrated systems from Power TG perform important complementary functions that aggregate funcionalities to the system.

8.1 Basic Functions

- Alarms list: Power TG updates continuously an alarm list of events generated by the Substation PLC's for control, SOE or Load Shed, as well as internal alarms or communication systems (ICCP, PROCOM).
- Alarm filter: Power TG filters the alarms by category, by substation, by recognized or not ones, and by other types of filter.
- Events search: The system allows the search of the origin of events with registered alarm in the system, through its information addressing and data filtering.
- Print screens: In order to allow the information interchange between the operational, supervision, management and technical support levels, there is a screen printing resource to collect evidences of any type of problem.
- Server redundancy: The hot standby method is possible because of the existence of two real-time redundant servers, that communicate both with all the systems involved.
- Remote command: The maneuver operations of the systems connected on Level 1 can be done by the operator at his operation desk at Energy Center.

8.2 Optional Issues

- Historical database: The Historic server stores longer lasting data(depending on the data density, even for months), allowing the later data collecting for information analysis about events or others, whenever necessary.
- Remote Access: The Siemens technical support, through internet secure communication link, can remotely access the server to perform improvements, configuration adjustments or modifications requested by the Company.
- Control functions: The system offers advanced control functions that allow the monitoring of the managerial items from the system control, such as the Demand Control and Power Factor Control among other items.
- Reports: The system allows specific filtered data collecting for report making, besides allowing the on-line monitoring of the main managerial data related to the Power Grid operation.

8.3 Applications

- Scripts: By the use of proprietary language scripts, the database structures, communication interfaces or interface screens can be built or modified.
- Communication protocols: For the Level 1 communication among Substations PLC's, servers, console stations and switches, the TCP/IP protocol is used. The communication with ONS is performed via an ICCP protocol server. The data interchange with PROCOM systems is supported by OPC protocol.
- Configuring system: The Siemens Builder environment is the system used to configure various Power TG parameters even during the system update, without causing impact over the supervisory operation.
- Screen Editor: Siemens IPE is an application that allows the edition and customization of the system screens whenever it is needed, preventing the system to become out-of-date and hence gradually lose functionality.

- Database Editor: Siemens Builder allows the edition of the real-time and historical database, allowing their progressive fitness to the operational needs or to solve preexisting bugs on the database.
- Data exporting and migration: Power TG provides an ODBC communication interface that allows the data mining tools to collect specific stored data from the Historic server.

8.4 Data Management

- Real-time database: the database performs a scan of every data communication points (received or sent) each 4 seconds, providing a high velocity on the update of data exhibited on the operator screens and also for the operational commands sent to the Substations PLC's.
- RTUCS: Remote Terminal Unit Communication Systems are data concentration functions performed by Servers 1 and 2 when they are supervising the Power Grid: they aggregate in one only database the data from the entire Power Grid, process them and exhibit them at the Console stations.
- API: Application Program Interfaces are communication drives used by Power TG to change data with PROCOM systems, providing a stable way to data communication.
- ICCP: The communication with ONS, mandatory at the 'Dispatched Generator' category from the Company's Power Grid, is done through the ICCP communication server connected to the Embratel router.
- SQL Server: The historical databases are built over an SQL Server environment, at the Historic server, providing versatility and portability due to its wide format and data interchange compatibility.

8.5 ONS Communication System

ONS coordinates the country's entire generation and power transmission grid, and manages the hydroelectric dams reservoir levels. To do so, it is necessary information from all the dispatched generation companies (companies that send more than 30 MW to the system). This online communication link is provided at the Company by the ICCP server. Besides the online real-time information, reports containing the daily, monthly and yearly generation programs and the programmed generator maintenance overhauls are sent through Internet to ONS. This procedure is regulated by a contract clause for dispatching power to the interconnected power grid.

8.6 Utilities PROCOM

Developed over the OpenVMS system architecture, the Utilities PROCOM provides the information integration from the supervisory control systems from the Utilities areas (Power System, Fuel Gases, Water Treatment, Power Plants and Air Fractioning Plants) to sum up the balances (operational or managerial reports), communication with corporative systems (Production and Costs bulletin) and integration with other company's PROCOM systems. It is hence an important tool for management and strategic planning.

8.7 Historic Server

The Historic server has the same hardware architecture of 1 and 2 real-time servers. Its capacity or data collecting and storage from more than 8.700 data points is due to the SQL Server 2000 system, which communicates continuously with the present supervising real-time Power TG server, and an adequately dimensioned hard disk for the medium-term (a few months) data storage. Through ODBC protocol, it is possible to extract data from the server for further analysis.

9 MAIN CONTROLS

Power TG provides an effective control and managerial information (see Table 1) monitoring during the regular operation of the Power Grid.

Table 1 – Main managerial control data from the Power Grid

Control Items		Values	Period	How?
Demand	Buy	20 MW HF 15 MW HP	15 min.	- To elevate the generation or to cut loads - To elevate the generation or to cut loads
	Sell	124 MW	15 min.	- To reduce generation
Power Factor	Capacitive	> 0,92	06 ~24h	- To elevate the reactive power generation
	Inductive	> 0,92	00 ~06h	- To reduce the reactive power generation
Flow A x B (100)	Assuming	< 10 MW	Constant	- To transfer buses or to reject loads
Flow B x A (100)	Rejecting	< 35 MW	Constant	- To reject TRT

9.1 Bus Control

This control aims to balance the amount of generated power with the connected loads at the generation buses of each Receiving Substation. It is necessary to prevent, during a interconnection circuit breaker opening, the excessive steam rejection at the Power Plants or an overload under-frequency, both able to cause a Power Grid blackout.

9.2 Demand Control

This control aims to prevent the consumed or generated demand from the Power Grid to exceed the contracted values during specified periods, ‘Off-the-Peak Hour’ and ‘Peak Hour’ (18:00 to 21:00 regularly or 19:00 to 22:00 during Daylight Saving Time). This demand is summed up each 15 minutes (Figure 8).

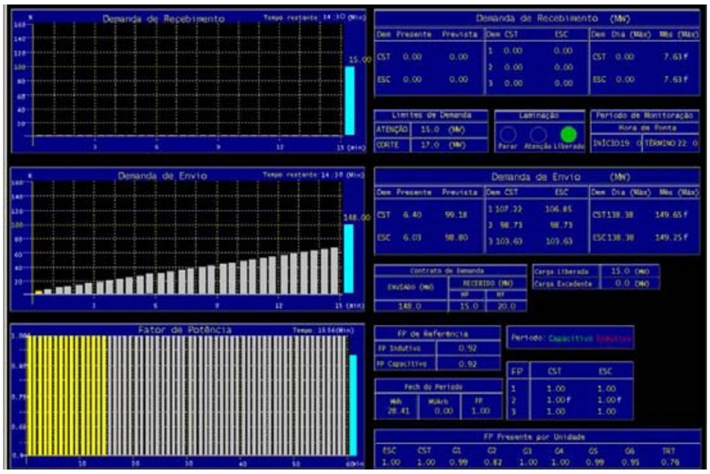

Figure 8 – Demand Control screen

9.3 Power Factor Control

This control aims to control the PF – Power Factor hourly from the Power Grid interconnection to the Escelsa/Furnas system. The PF is controlled for each entire hour (00:00 - 01:00 – 02:00, …). The FP regulation is performed by acting over the internal reactive power generation.

9.4 Gross Generation, Escelsa Dispatch and HSM Load Graphic Trends

Those graphics allow the online monitoring of the overall generation (MWh), dispatched power and the HSM load (Figure 9). Those items are crucial in order to have an effective Power Grid supervision along the day.

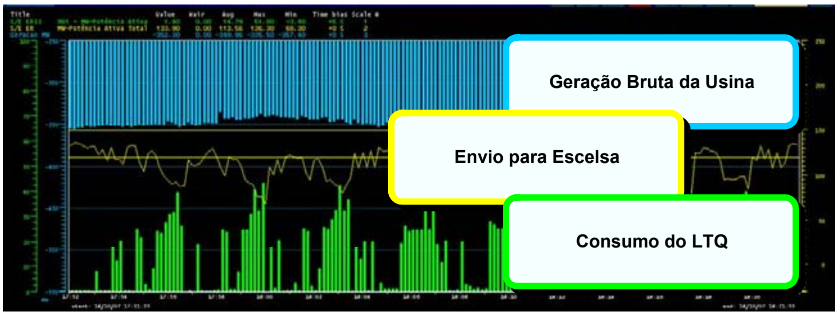

Figure 9 – Gross Generation, Power Dispatch and HSM Load Trends

10 ADDITIONAL INFORMATION ABOUT ARCELORMITTAL TUBARÃO POWER GENERATION

The ArcelorMittal Tubarão power generation capacity in 2008 was of 433 MW, and for comparison, the local concessionary Escelsa had the installed generation capacity of 230 MW (that means, 203 MW lower). The average Espirito Santo State load is between 1,200 and 1,400 MW.
ArcelorMittal Tubarão is self-sustaining on electric power and nowadays is sell the exceeding to Tractebel, an energy company from Florianópolis/SC, using the interconnected transmission system of Escelsa/Furnas/ONS to dispatch the exceeding power. The use of steelmaking by-produced flammable gases (BFG, COG and LDG) at the Power Plants contributes to reducing the atmospheric emissions,

once this generated electrical power is not generated by direct burning fossil fuels in other power plants or spending more water at the hydro plants alongside the country generation grid. Besides that, it benefits the public power system once it makes the State power grid more robust, with a bigger generation matrix.

11 CONCLUSION

During the production expansion to 7,5 million tons of steel per year, the ArcelorMittal Tubarão Power Grid configuration has changed its characteristics, increasing its criticality not only for the Company but also for the Brazilian power grid as a whole, involving then more stakeholders on its operational stability.
The adoption of the new supervisory control system represented the adequate evolution to this paradigm change, once that aggregates the necessary functionalities. After two years of development, factory testing, field commissioning, user training, pending items solving and improvements on the go, Power TG has exceeded the operational performance expectations, providing more flexibility to the users and helping the preservation and improvement of Power Grid operational stability and reliability, both crucial for the next ArcelorMittal Tubarão evolutionary steps to come.