Implementation of Integrated Load management system for a Metal Industry

OVERVIEW

Metal industries require bulk power for their metal extraction and manufacturing process. Manual operation and control of this process with large amount of power imposes technical difficulties and it becomes more difficult when process stations distributed over a large geographical area. To manage such bulk power in shorter time an integrated load management system is necessary. This case study presents the real situation, principal functions, and operation of Integrated Load Management System (ILMS) for an aluminum plant with 766MW power generation and a 660,000 MTPA alumina refinery.

Implementation details

Country : India
Year of Execution : 2005 November to 2007 May
Business situation : Providing PLC based automated solution for aluminum plant
Key platform : ABB AC 800M controller, ABB 800XA SCADA, Control builder
Key Benefit :
- Faster decision making during critical event
- Shorter response time 100msec-200msec
- Lesser manual interventions
- Centralized power system monitoring and control
- Automated shift wise production management

INTRODUCTION

The client is one of the biggest aluminum producers in the country with overall aluminum smelting capacity of 342,000 MTPA, which is approximately 40% of India's overall aluminum production. The plant consists of 766MW generating station, 660,000 MTPA Alumina refinery and two co-generation plants. Overall electrical system operates at different voltage levels starting from 132KV AC to 1000V DC and the capacities of the plant equipments are large compared to normal loads. Loosing multiple generator units or loads in system often causes severe instabilities in the system and certain cases instabilities even causes blackouts in the network. Long durations are required for restoration of the power system after a blackout and recovery time for the plant to come back its normal operation causes financial losses. Hence in energy intensive plants such loss has to be avoided or minimized.

Controlling and monitoring work of the entire electricity transmission and distribution system usually require a lot of utility specific information and knowledge. Implementation of ILMS system together with a reliable fiber optic communications system assist operators to distribute electricity as efficiently, economically as allowed under all practical constraints and also protecting the system from any contingencies.

The ILMS systems together with a reliable fiber optic communications system were commissioned in May 2007 to take over the control and monitoring work of the entire electricity generation, transmission, and distribution system.
ELECTRICAL SYSTEM OVERVIEW

Figure-1 shows overall electrical arrangement of plant network where ILMS is implemented. There are two main control centers- power plant and Refinery.

I. Power plant
The main Coal-Based Power generation (CPP) facilities is situated 40KM away from the refinery which provides power for all refinery operation. There are six control rooms which control ten generators. The AVR and Governor of the generator units are controlled by the operators from their locations as per the plant demand. The power plant has its own DCS for process monitoring and turbine operation. All the generator units produce power at 11KV and before transmitting it to refinery, voltage is stepped up to 132KV using generating transformers. Details of generation in each control location is given Table-1

<table>
<thead>
<tr>
<th>CONTROL ROOM</th>
<th>GENERATOR DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 X 80 MW</td>
</tr>
<tr>
<td>2</td>
<td>1 X 76 MW</td>
</tr>
<tr>
<td>3</td>
<td>2 X 68 MW</td>
</tr>
<tr>
<td>4</td>
<td>2 X 74MW</td>
</tr>
<tr>
<td>5</td>
<td>1 X 68MW</td>
</tr>
<tr>
<td>6</td>
<td>2 X 74MW</td>
</tr>
</tbody>
</table>

Table-1: generation details for cpp

The primary power transmission between power plant and load centers are achieved through long distance transmission lines at 132KV. There are ten transmission lines in place to evacuate power to load centers, which are connected in such a way that plant can operate in N-1 contingencies. In addition to this, plant has connections to state grid to support normal operation or when power plant undergoes any maintenance. During grid connected operation, the power draw from or to the grid is limited based on the contractual Maximum demand agreement.

II. Plant load models
Plant loads are classified into process loads, normal loads and critical loads. Metal extraction Process loads are the main loads in the plant and consumes majority of power produced. The refinery have three load centers in which process load size comparatively higher than normal loads, the load sizes varies from 10MW to 40MW. Aluminum extraction process is an electrolysis process, Depending upon aluminum smelting requirements there will be 1000-2000 electrolysis cells connected in parallel and fed from a common 1000V DC bus. The DC power is derived from, 132KV bus, which is stepped down to 800-1000V DC by a combination of special type transformers and rectifier units called rectiformers. The load current can
be controlled by changing tap positions of rectifier or by changing firing angle of rectifier circuits. In addition to these process loads there are 70 more feeders which support other operations in the system and some of these are critical feeders.

In all together power plant and loads keeps complex electrical network interconnection and operations.

**SYSTEM REQUIREMENTS**

At present plants are operated manually and production targets are met by the operator through manual monitoring of process parameters. During critical events, the plant has to relay on the experience of the operator to save the plant, in many case, events are so fast which will not give enough time for the operator to take any decision. Also during critical situation many data have to be interchanged between power plants and refinery for better operation. Losing of critical information can induce further instability in the system. Hence the utility require complete Integrated Load Management System (ILMS) for protecting the plant during any contingencies.

Major requirement of the system are as follows:

- Distributed Asset Monitoring and Control
- Secure Load shedding schemes
- Generator shedding scheme
- Active and reactive sharing of generators
- Spinning reserve management
- Import/Export control
- Production management-Potline control
- Islanding and restoration assistance
- Equipment overloading protection

**a. System requirement when plant operated with grid**

When plant connected to grid, the ILMS will maintain the power import to grid or export form the grid within its preferred limits. The plant has two operational contract limits

- Power import limit: 40MW for 30 minutes window time(Maximum Demand)
- Power export limit: 60MW

Violation of above limits will cause financial penalties to the plant or it can cause overloading of the equipment. While operating ILMS, must not allow any of the networks equipment (transformers, transmission lines) not to be overloaded and must ensure that ILMS control action shall have minimal impact on the production process. To ensure proper ILMS operation, the control objective shall be suitably interlocked with capacity limits of the equipments.

**b. System requirement when operated in islands**

When plants operated in islands, the primary objective of ILMS shall be to maintain system voltage at 132KV±2KV and frequency at 50Hz ±0.5Hz. In addition to this there shall be different supporting modes like Normal, Loading, and Syncing modes for different plant operations. At power plant, generators and transformers are operated in tandem, so capability limits of generating units shall not be violated during any kind operation.

**c. Overloading control**

Number of transmission lines runs from power plant to load center is more than one, hence transmission line tower carries multiple transmission lines. The geographical area in which transmission lines runs are prone to frequent lightening and thunder storm. During stormy days lightening causes tripping of multiple transmission lines. Due to sudden loss of transmission lines, other transmission lines in the network will be overloaded. When implemented ILMS shall suitably control generation as well as loads to reduce over load.
d. Potline control
There are 11 pot lines in the plant which are operated by rectiformer or by thyristor controlled devices. Operator continuously monitors pot line currents and regulates transformer taps/set points to maintain output current to predefined value. The proposed ILMS must automatically maintain the load currents values as per production targets on hourly, in shift and daily basis with a possible tolerance of 0.05KA.

SOLUTION
To meet above customer requirements, Kalkitech has done initial design and pre-sales support to OEM. The scope of the project included; system architecture, controller performance evaluation and conceptual design, HMI development, IO-engineering, implementation of Integrated Load Management Functions in IEC61131-3 programming tool, testing, factory acceptance test, site acceptance test and final hand-over at site.

The ILMS hardware system consists of following:
- Plant wide redundant fiber optic I/O link
- 2000 S800 -I/O
- Seven AC 800M of distributed controllers
- Redundant 800XA HMI server for data storing and archiving
- 10 Operator Stations located control rooms
- Transducers panel consisting Active power, Reactive Power, Voltage and Frequency transducers.
- GPS based time synchronizing using SNTP protocol
- Interfaces to Process DCS for pot line control.

SYSTEM ARCHITECTURE
The New ILMS system is distributed open system architecture with state of the art technology characterized by easy upgrade ability and extensibility.
III. ABB REF Relays
Fast switching relays with configurable outputs. The relay used for detecting under frequency condition and to initiates tripping of loads.

IV. HMI Server
The Servers (800XA) for the ILMS systems are located at aluminum refinery and power plant. Multiple user interface terminals with multiple Display units are provided in each control room for the control center operators to control and monitor the power system. The full graphic capability of the new systems is exploited to enhance user interface. Color schemes are devised to convey vital information such as voltage level, or whether a circuit is de-energized or energized, to the users.

The principal functions of HMIs are:
• Enables operator remotely monitor and control the Company’s power system
• Alarm processing processes the data collected and alert the Control Center Operators immediately if an alarm condition is detected.
• Tagging and Interlock Checking functions help to prevent inadvertent errors and ensure the safety of all persons working with the electricity network as well as supply reliability.
• Data archiving and trending

Typical HMI screens developed is shown in the figure-4

Figure- 4 ILMS GUI for the power plant

a. Software integration
The system has Load shedding, Generator shedding and Load management module to meet entire customer requirements. The total implementation comes under system protection scheme. Initiation of control actions will be managed by the contingency manager which will identify the contingencies and initiates one or more modules to operate automatically. Below section will give details of modules implemented.

b. Load shedding schemes
Disturbances in the power balance that require load shedding are usually caused by loss of generated power or network change. The loss is in almost every case caused by the trip of a (critical-) circuit breaker and disconnecting generation from the load. Fast Load shedding (FLS) initiates power balance calculations on the trip of a critical breaker. The module calculates the load to be shed and compared to the priority load table. FLS function will issue shed commands to all loads with the lowest priority and the calculated priority.

Based on the status of tiebreaker / bus couplers there can be a different number of electrical networks that work independently. FLS will make the calculation for
each individual electrical network that contains a load busbar (a busbar to which generation and loads are connected). Load shedding Feeder priorities can be done on line and FLS can handle up to 50 priorities. Each load can be temporarily inhibited from the load shedding system. Figure-5 shows the typical load shedding flow for load shedding scheme.

d. Generator shedding
When the system operated is islanded, then the sudden loss of the bulk loads will cause over frequency in the network, the situation is also called “load throw”. If this load throw is more than that of single generator unit then it can cause cascaded tripping of generators units in the system. To avoid such contingency, ILMS monitors power imbalance and breaker disconnect status of loads and issues generator trip to stabilize the system. ILMS uses reverse logics of load shedding to achieve the generator shedding. Assignment of priorities can be done online and can handle up to 20 priorities. Each load can be temporarily inhibited from the generator shedding system.

e. Turbine control
The ILMS Automatic generator control module is interfaced with local turbine control panel (UCP) for controlling generator units. ILMS provides different operating modes to operator for monitoring and control. During emergency condition the units selected to operate in ILMS receives remote override command and operates the units as per requirements. A self-explanatory diagram is provided in Fig 6.0
ILMS provides the following modes to control the governor:

- **Manual control**
  This is the droop mode where the operator can increase or decrease the power output with raise/lower keys.

- **Manual set-point control**
  This is the MW mode where the operator enters a set point for active power.

- **Auto Mode**
  This is the Auto mode where the generators are controlled in groups to achieve a common goal. In this mode, the generator units participate in bus bar frequency control while islanded, and maintains active power set point when connected with grid. In addition to above an overload reduction function also part this mode, in this mode module monitors overloading of busbar/transmission lines and reduces the power output of generators. A special generator grouping algorithms are built, which will group the generators based on the power flows in bus couplers.

- **Reactive power control**
  The operational principle for reactive power control is analogous to active power control, that is, load sharing using the automatic voltage control of the AVR. This principle is based on maintaining the bus voltage at 132kV using one generator, where the other generator(s) follow(s) the reactive power working point of the voltage generator. ILMS monitors voltage feedback and set points entered by the operator and difference is converted to reactive sharing using a closed loop PID controller.
  The implementation gives better utilization generator reactive power production and sharing of reactive power in proportional manner with improved system stability. The system also checks the reactive capability limits and overshoots are limited by blocking controls action

**Load control**

During critical situation increasing power output of generators are limited due to process constraints. So ILMS will control pot lines and reduces the power requirements instead of overloading generators. ILMS monitors import set points, maximum demands and frequencies and gives tap lower or lower set points to pot lines.

**ACHIEVEMENTS**

With the implementation of ILMS in December 2007, plants have successfully sustained major outage conditions. Implementation of ILMS system together with a reliable fiber optic communications system controls and monitors the plant for any contingencies. As ILMS implemented with automatic real time trigger detection, load shedding and generation shedding protects the plant under different contingencies.
At present many of the controls are implemented considering security constraints. The ILMS is not having any financial or plant efficiency constraints while load managing application. A power plant performance evaluation/economic dispatch system can be implemented to optimize plant operations which can result improvement in financial objectives of the plant. The further improvements of existing solution to the end customer can consider performance optimization tools for power plant operations.