Proposal for Mongolian Power Station using Joint Operation System (JOS)

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(1) What’s Joint Operation system (JOS)

What’s JOS ?

JOS optimizes the plant status for a minimization of total energy.

How ?

• Each boiler, turbine and equipment has a high efficiency operation band.
• As a practical matter, all equipment cannot be operated on the high efficiency area in the plant.

JOS can coordinate the operation point both the boiler and turbine. The operator can lead the plant to the minimization of total energy using JOS.
Actual performance of JOS

Target of JOS?

◆ The plant has a number of boiler and turbine with common header.
◆ Boiler uses some fuel for combustion.
◆ Turbine has some extraction line for process steam.

We have delivered JOS to the following plant.
- Paper manufacturing for 3 companies
  $= 3Bx7T + 16Bx9T, 3T, 6Bx7T$
- Iron manufacturing for 2 companies
  $= 3Bx4T, 5Bx5T$
- Joint Thermal Power Plant for 1 company $= 3Bx3T$

Figure 1. System diagram of paper manufacturing plant.
Functions and Features of JOS

Online real-time optimization
JOS calculates the optimal operation demand according to the mass balance of the steam and the power balance when the plant status changed.

Offline optimization
JOS can simulate the future plan to determine the running number of boilers and turbines.

Calculation of equipment operation characteristics model
JOS uses the model of boilers and turbines with the actual characteristics.

Economical operation demand
JOS calculates the total generating cost using nonlinear optimizing solver.

Automatic update the nonlinear model using identification
The model is corrected using the present plant condition.

Pattern setting of the utility power and its calendar
The operator can define when the utility power cost is decided and/or renewed by contract.

Estimation of the status
JOS estimates the actual value using mass balance because the flow sensor has an error under low flow status.

Demand control
JOS can selectively warn the operator operating the shutdown of auxiliary machine before the utility power reaches the limit of its contract at the end of a demand cycle.
JOS for Paper manufacturing

JOS Input Signals
- Boiler Input Demand
- Main Steam Flow

Controller (DCS)

JOS
- Plant Optimization Function (Economical load dispatch)
- Monitoring whole plant status Function
- Demand monitoring/control Function

JOS Output Signals
- Set point of Extraction Steam Flow
- Set point of Main Steam Flow
- MW Demand

Controller (DCS)

Figure 2. Ex. of JOS for Paper manufacturing Plant.

出典：火原協入門講座「計測と制御」
System Configuration Example

- Operation Schedule (Daily, Weekly)
- Operation Plan (Power generation, Air supply)
- Case studies
- Current demand setting
- Optimal operation balance display
- Operator
- Operation
- Offline optimization calculation
- Real-time optimization calculation
- Economical operation model
- Status assumption
- Model update
- Operation database
- Controller (DCS)
- Logs
- JOS instructions
- Current values
- Control & Monitoring
- Equipment operation characteristics model
- Operation database

JOS consists of latest personal computer.

Figure 3. Ex. of system configuration.
Figure 4. System function configuration.
How to calculate optimization

Variables are defined for calculation

Variable $X$ for JOS "Design Variable"  
Steam flow of Turbine & ext. steam, oil & coal, etc.
Feed back from demand of JOS  
MW, Steam flow of Boiler etc.
Condition for JOS  
MW demand, Steam flow demand, etc.

Equations are made from these relationship using system diagram

Equality constraint  
$H$: Mass balance of turbine, Characteristics (Flow vs. MW)
MW Demand = $\Sigma$MW + Utility power, Mass Balance around header, etc.

Inequality constraint  
$G$: MW of generator, Steam flow of boiler, etc.

Limitation of variable $X$  
Operation boundary of boiler and turbine, Utility power of contract

Object function of optimizing $F$  
Total Fuel cost and Utility power cost

Optimization using nonlinear programming method

$H=0$, $G<0$ & $F\rightarrow\min$
Answer is $X$

JOS solves $X$ so as to be minimization of $F$.

Figure 5. Solver image of JOS.
Calculation Example

Minimization for Steam flow

Characteristics of 1T

Demand

MW = 65MW
Proc. Steam = 20t/h

Initial balance

Necessary Steam = 390t/h

Optimizing

MW after optimizing

Necessary Steam = 380t/h
Ext. steam aft opt.
Necessary Steam = 378t/h

where

Design variable is X1~X4
Object function S1+S2

Figure 6. Calculation example of JOS.
(2) Proposal for Ulaanbaatar Power Station using JOS

Problem
(1) The operation is manual for Turbine/generator. \(\rightarrow\) The generating response is delay for the grid.
(2) The boiler and turbine are not coordinated. \(\rightarrow\) The plant is not stable by the mutual interference.

Improvement
In order to stabilize steam pressure/temperature, improvement of boiler control itself should be required.
(1) Stable and optimizing \(\rightarrow\) (2) Reducing an over fuel \(\rightarrow\) (3) Reducing the fuel cost and CO\(_2\) emission

Action
(1) The controller of Boilers and turbines should be improved using a proposed control method and a optimizing solver.
(2) The power plant shall be optimized to minimization of total energy using JOS.
◆ Optimizing item

**Optimizing of Boiler Control**
1. Steam Pressure setting
2. Steam Temperature setting

**Optimizing of Turbine control**
1. Improved governor controller
2. Add ALR logic
3. Optimizing Governing point

**Optimizing of Hot water production**

- **JOS**
  - (1) Boiler optimization demand
  - (2) Turbine optimization demand
  - (3) Hot water optimization demand

- Steam pressure
- Steam temperature
- Governor position
- Fuel flow, etc.

Figure 8. Optimization item.
ALR & MW Optimizing

ALR operation using optimizing solver

Figure 9. Block diagram of ALR.
◆ Turbine Optimizing (1/3)

**Specifications of Turbine Governor**

- Valve Lift (%)
- Steam Flow (%)
- Pressure Loss of GV (%)

**Case Study 1**

If Total output = 200MW by 3 generators

- 2 Generators output = 50MWx2
- 1 Generator output = 100MW

Good operating point

Figure 10. Turbine optimizing
◆ Turbine Optimizing (2/3)

**Specifications of Turbine governor**

![Graph showing specifications of turbine governor](image)

**Case Study 2**

If Total output = 200MW by 3 generators

![Graph showing case study](image)

Optimizing

Reducing turbines inlet pressure set point

Good operating point

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Case Study 3

If Total output=200MW by 3 generators

Increase turbines inlet temperature set point

Specifications of Turbine governor

Good operating point

Valve Lift (%) vs. Turbine GV Demand (%)

Steam Flow (%) vs. Turbine GV Demand (%)

Pressure Loss of GV (%) vs. Turbine GV Demand (%)
Figure 11. Block diagram of boiler demand.

※Ex. Turbine Optimizing(2/3)
Steam header pressure can be stable because each fuel controller of boiler receives from one Boiler master controller.

Figure 12. Block diagram of boiler master.
Boiler Feed Pump Inverter control & Optimizing

Super Heater → To Steam Header

Steam Drum

Feed water control valve (FWC)

BFP outlet feed water pressure

Optimizing Signal

Set point by manual

Σ

△

PI

Speed demand to Inverter

※ Differential pressure between FWC inlet and outlet shall be controlled by BFP speed.

FWC controls boiler drum level by using 1 element or 3 elements signal.

Figure 13. Block diagram of BFP inverter control.
◆ Conclusions

The Plant shall be optimized to minimization of total energy using JOS.

◆ The manager can predict total cost using offline mode.
◆ The operator can get the most economical and safety operation using online mode.

Investigation of the following characteristics,
(1) Turbine mass/heat balance
(2) Characteristics of Turbine GV
(3) Boiler mass/heat balance
(4) Fuel consumptions and cost
(4) BFP Q–H characteristics
(5) FW CV, flow, diff. Press., position, etc.
Thank you for your attention.