HELE - High Efficiency Low Emission

Yokogawa
FGD Optimization System
Flue Gas Desulfurization

27th Sep, 2016
Yokogawa Electric Corporation
Agenda

- Introduction to Yokogawa
- Flue Gas Desulphurization plant in Japan
- Yokogawa optimization software system
Introduction to Yokogawa
## Corporate Information

### 100 years of history for control and measurement business

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>Established as an electric meter research institute in Tokyo.</td>
</tr>
<tr>
<td>1917</td>
<td>Produced Japan’s first electric meter.</td>
</tr>
<tr>
<td>1924</td>
<td>Released Japan’s first portable magnetic oscillograph.</td>
</tr>
<tr>
<td>1950</td>
<td>Developed Japan’s first electronic recorder.</td>
</tr>
<tr>
<td>1975</td>
<td>Released the world’s first distributed control system (DCS).</td>
</tr>
<tr>
<td>1984</td>
<td>Released analog LSI test system.</td>
</tr>
<tr>
<td>1988</td>
<td>Entered the high-frequency measuring instrument business with digital oscilloscope.</td>
</tr>
<tr>
<td>2015</td>
<td>100th Anniversary</td>
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</tbody>
</table>

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**Co-innovating tomorrow**
Products & Solution portfolio

Corporate Management (ERP*)
Integrated business operation systems

Production Management (MES*)
Systems for advanced control, simulation, production management, and scheduling

Advanced Process Control & Operational Work Assistance

Production & Operation Management System

Real-time Production Organizer

Asset Management

Plant Information management System

Production Control Systems

Field Instruments
Field instruments, sensors, measuring instruments, analyzers and other equipment

* ERP = Enterprise Resource Planning
* MES = Manufacturing Execution System

Co-innovating tomorrow

Field Instruments
Field instruments, sensors, measuring instruments, analyzers and other equipment

Distributed Control System (DCS)

Network Based Control System

Safety Instrumented System

Differential Pressure Transmitter

Magnetic Flowmeter

Digital Vortex Flowmeter

Tunable Diode Laser Analyzer

Ultrasonic Flowmeter

Process Gas Chromatograph

Advanced Valve Positioner

Temperature Transmitter

* ERP = Enterprise Resource Planning
* MES = Manufacturing Execution System
DCS Installation Map

EUROPE
- AUSTRIA (30)
- AZERBAIJAN (1)
- BELGIUM (222)
- BELARUS (17)
- BULGARIA (5)
- CROATIA (5)
- DENMARK (6)
- FINLAND (3)
- FRANCE (251)
- GERMANY (283)
- GREECE (21)
- HUNGARY (69)
- IRELAND (4)
- ITALY (153)
- KAZAKHSTAN (17)
- LITHUANIA (1)
- NETHERLANDS (193)
- NORWAY (10)
- POLAND (24)
- PORTUGAL (8)
- ROMANIA (12)
- RUSSIA (799)
- SERBIA (12)
- SLOVAKIA/CZECH (115)
- SLOVENIA (2)
- SPAIN (163)
- SWEDEN (2)
- SWITZERLAND (18)
- TURKMENISTAN (12)
- UK (106)
- UKRAINE (8)
- TURKEY (37)
- SCOTLAND (1)

AFRICA
- ALGERIA (50)
- ANGOLA (16)
- BOTSWANA (4)
- CONGO (14)
- EGYPT (64)
- GABON (10)
- GHANA (6)
- KENYA (3)
- LIBYA (5)
- MOROCCO (24)
- MOZAMBIQUE (1)
- NAMIBIA (1)
- NIGERIA (50)
- SENEGAL (3)
- SOUTH AFRICA (160)
- SUDAN (6)
- SWAZILAND (2)
- TUNISIA (2)
- UGANDA (4)
- Tanzania (1)

MIDDLE EAST
- BAHRAIN (37)
- DUBAI (1)
- IRAN (106)
- IRAQ (17)
- JORDAN (5)
- KUWAIT (16)
-oman (61)
- QATAR (15)
- SAUDI ARABIA (315)
- SYRIA (6)
- U.A.E (69)
- YEMEN (11)

OCEANIA
- AUSTRALIA (409)
- NEW ZEALAND (2)
- 新喀里多尼亚 (1)
- Papua New Guinea (4)
- Fiji (6)

CENTUM is Well-accepted Widely in the Market

As of Jun. 2016

TOTAL:
26,575 UNITS

NORTH AMERICA
- CANADA (24)
- USA (944)

SOUTH AMERICA
- ARGENTINE (12)
- BRAZIL (594)
- BOLIVIA (1)
- CHILE (4)
- COSTA RICA (1)
- COLOMBIA (17)
- CUBA (14)
- EL SALVADOR (1)
- MEXICO (49)
- NICARAGUA (1)
- PANAMA (2)
- PERU (1)
- TRINIDAD TOBAGO (2)
- URUGUAY (2)
- VENEZUELA (11)
FGD plant installation history

Installation of FGD Plant

- No. of FGD plant
- Total processing capacity

No. of plant

- Total capacity ($10^6 \text{m}^3 \text{N/h}$)

- The number of installation
- Installed for Oil fired
- Installed for Coal fired

1970 - 2010
### Yokogawa’s DCS share for FGD in Japan: 60%

<table>
<thead>
<tr>
<th>Electric Utility</th>
<th>Power Station</th>
<th>Unit</th>
<th>Generation Capacity</th>
<th>FGD Plant Supplier</th>
<th>Operation Date</th>
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<tbody>
<tr>
<td>Kansai Electric</td>
<td>Maizuru</td>
<td>1</td>
<td>900MW</td>
<td>CCEC</td>
<td>Jul-04</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>700MW</td>
<td></td>
<td></td>
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<tr>
<td>Kyushu Electric</td>
<td>Reihoku</td>
<td>1</td>
<td>700MW</td>
<td>IHI</td>
<td>Jun-03</td>
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<tr>
<td></td>
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<td>2</td>
<td>700MW</td>
<td>IHI</td>
<td>Jul-95</td>
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<tr>
<td>Chubu Electric</td>
<td>Hekinan</td>
<td>1</td>
<td>700MW</td>
<td>MHI</td>
<td>Oct-91</td>
</tr>
<tr>
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<td>KHI</td>
<td>Jun-92</td>
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<td>3</td>
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<td>MHI/CCEC</td>
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<td>4</td>
<td>1,000MW</td>
<td>KHI/BHK</td>
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<td>5</td>
<td>1,000MW</td>
<td>KHI/BHK</td>
<td>Mar-02</td>
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<tr>
<td>Hokuriku Electric</td>
<td>Nanao Ohta</td>
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<td>500MW</td>
<td>CCEC</td>
<td>Mar-95</td>
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<tr>
<td></td>
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<td>2</td>
<td>700MW</td>
<td>CCEC</td>
<td>Jul-98</td>
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<tr>
<td></td>
<td>Tsuruga</td>
<td>1</td>
<td>500MW</td>
<td>IHI</td>
<td>Jan-91</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>700MW</td>
<td>IHI</td>
<td>Oct-00</td>
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<tr>
<td>Shikoku Electric</td>
<td>Tachibana-wan</td>
<td>1</td>
<td>700MW</td>
<td>MHI</td>
<td>Jul-00</td>
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<tr>
<td>Chugoku Electric</td>
<td>Misumi</td>
<td>1</td>
<td>1,000MW</td>
<td>MHI</td>
<td>Jul-98</td>
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<tr>
<td>Hokkaido Electric</td>
<td>Tomato Atsuma</td>
<td>2</td>
<td>600MW</td>
<td>MHI</td>
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<td>4</td>
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<td>MHI</td>
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<td>Electric Power Development</td>
<td>Tachibana-wan</td>
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<td>1,050MW</td>
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<td>1,050MW</td>
<td>BHK</td>
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<td>Matsuura</td>
<td>1</td>
<td>1,000MW</td>
<td>Hitachi</td>
<td>Jan-91</td>
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<td>Matsushima</td>
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<td>500MW</td>
<td>Sumitomo Machine</td>
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<td>500MW</td>
<td>Hitachi</td>
<td>Jun-81</td>
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<td></td>
<td>Takehara</td>
<td>3</td>
<td>700MW</td>
<td>IHI</td>
<td>Mar-83</td>
</tr>
</tbody>
</table>

Above is some reference projects only. The share is for utility companies.
Yokogawa FGD Optimization System

Flue Gas Desulfurization
Benefits of APC

**Specification or limit**

- BEFORE APC
- APC ONLINE
- SETPOINT MOVED CLOSER TO LIMIT

**Operator target**

**Base Case**

**Stabilise**

**Benefits**

Standard deviation of controlled variable
Flue Gas Desulfurization

**Flue Gas**
- Furnace / Flue Gas Draft
- Furnace / Flue Gas Temp.
- Flue Gas Flow
- O2 Analysis
- NOx Analysis
- SO2 Analysis
- Dust Monitoring

**Combustion Air**
- Air Press.
- Air Flow
- Air Temp.
- O2 Analysis
- Forced Draft Fan (Vibration)
- Forced Draft Fan (Lub. Oil & Winding Temp)
Flue gas desulphurization types

<table>
<thead>
<tr>
<th>Process</th>
<th>Absorbent</th>
<th>Byproduct</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seawater Scrubbing</td>
<td>Seawater</td>
<td>dissolved in seawater</td>
<td>max. 97%</td>
</tr>
<tr>
<td>Lime/Limestone scrubbing</td>
<td>Ca(OH)$_2$/CaCO$_3$</td>
<td>gypsum (saleable)</td>
<td>max. 98%</td>
</tr>
<tr>
<td>Semi-dry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray absorption</td>
<td>Ca(OH)$_2$</td>
<td>useable for landfill</td>
<td>max. 95%</td>
</tr>
<tr>
<td>Fluid bed CFB/GSA process</td>
<td>CaCO$_3$</td>
<td>useable for landfill</td>
<td>max. 95%</td>
</tr>
<tr>
<td>Dry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry injection LIFAC</td>
<td>CaCO$_3$</td>
<td>useable for landfill</td>
<td>max. 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>max. 60%*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>max. 80%**</td>
</tr>
</tbody>
</table>

* With humidification, ** With product recycling
Limestone Scrubbing – Flow Diagram

To control outlet SO2 within regulation limit

Recirculation pump x 4-6

Chemical reactions

\[ \text{CaCO}_3 + \text{SO}_2 + 2 \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \rightarrow \text{CaSO}_4 + 2\text{H}_2\text{O} + \text{CO}_2 \]
Result

Actual data of 700MW coal fired unit in Japan

Optimization OFF: 8 hours

Optimization ON: 8 hours

- Coal type changed to high sulfur coal
- No. of Pump reduced from 5 to 3
- Outlet SO2 is below target
Actual data of Boiler load 0 to 700MW
700MW coal fired unit in Japan

Outlet SO2 set point: 19 ppm
Outlet SO2 regulation: 25 ppm
2days
Optimization Control Scheme

Advanced control: Optimization

MPC: Model based Prediction by Exasmoc

Process value prediction By Exarqe

ERC: Enhanced Regulatory Control

FGD normal control by DCS

- Optimized Slurry flow calculation
- Optimized pH calculation
- SO2 value prediction
- CaCO3 value prediction
- pH bias prediction
- No. of Pump control
- Slurry flow set point calculation
- pH set point calculation
- FF control for abnormal cases
- Slurry flow control
- pH control

Optimization can be added to existing system
Optimization and DCS control scheme

**Optimization Function**

- Outlet SO2 PV
- pH value
- Slurry flow
- Outlet SO2 set point
- Recirculation pump selection
- MWD
- Inlet SO2 PV
- Flue gas flow

Predictive Control

- Model
- Slurry flow bias
- SO2/ CaCO3 Prediction
- pH- Total SOx F(x)
- Total SOx Bias
- Total SOx
- Pump inc/dec
- pH set point
- Slurry flow bias
- Slurry flow

**Conventional Control by DCS**

- Optimize lime stone slurry flow
- pH Control
- Lime stone slurry flow
1. Control SO2 lower than regulation limit
   • Primary objective of FGD plant

2. Optimize number of operating recirculation pumps
   • Conventional: No. of pumps are not controlled well
   • To reduce house load

3. Optimize lime stone slurry flow control
   • By advanced and predictive control

4. Adjusted to various types of coal (Mixed)
   • Even if coal changed, mixed, automatically optimized
5. Adjusted to plant aging
   • Adjusted to spray nozzle plugging, pump performance deterioration

6. Predict CaCO3 value
   • Prevent over-injection of limestone
   • Once over-injected, plant must be stopped for clean-up

7. Adjusted to load change
   • Optimization range: 15% to 100%

8. Automatic pump start/stop
   • Operators do not need to start/stop manually
System Configuration

APC server can connect to variety of OPC compliant DCS platforms and control systems. APC Client can be run on DCS consoles as rich or thin client.
Benefits of FGD Optimization System

**Benefits**

- **Operation cost savings for FGD pump load**
  - 600k - 800k Euro/ unit/ year cost saving
    - 700MW, Base load, 300 days/ year, 7 cent Euro/kW (cost)

- **Operation cost savings for limestone**

- **Optimization for various types of coal**

**Actual data of power plant in Japan**

References of 2x 700MW coal fired (in operation)
To be used for 2x 1000MW coal fired plants (next year)
Thank you for your attention.