Yokogawa Concentrated Solar Thermal Power Control System

Andrew Brodie
Yokogawa Corporation of America
Renewable Energy Solutions
“One Global Yokogawa means that whoever our customers are, and wherever they are located around the world, they will see a single Yokogawa that is reliable and worthy of trust.”

“Yokogawa is a truly global company, with 103 group companies operating in 29 countries with 20,247 employees dedicated to achieving total satisfaction with the most demanding customers worldwide.”

“A commitment made is a commitment kept.”

Isao Uchida
Chairman of the Board
Yokogawa Group
Our North American Presence

- Regional Center
- Service Center
- Service Center - Planned
- Sales Office
- R&D Center

Canada Regional Office, Calgary

Mexico Regional Office, Mex. City

Regional HQ USA, Atlanta

Houston Systems Center
Yokogawa Solar Experience

SEGS 1 and 2 Steam Plant Controls, Instruments, Data Acquisition, Tracking Controls, Wireless

Leading Collector OEM (NDA) – Tracking Controls, Field Instruments, Data Acquisition, Networking

ANU Big Dish Tracking Controls and SCADA

Daido Steel CPV Tracking Controls

Three Start-up Companies (NDA) – PV Tracking

Australian Industrial Heating (NDA) – Tracking Controls

Two Start-ups (NDA) – CSTP Tracking
- Replace Original Control Board
- Eliminate Need for Sun Sensor
- Upgrade to 0.1 degree Absolute Modbus Inclinometer with 0.01 degree resolution
- Tracking adjustment via geared on/off motor every 0.5 degrees
- Next revision due late Spring 2011 for continuous tracking hydraulic system on very large aperture experimental test loop
## Yokogawa CSP Reference Sites

<table>
<thead>
<tr>
<th>Plant</th>
<th>Type</th>
<th>EPC</th>
<th>End user</th>
<th>Power</th>
</tr>
</thead>
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<tr>
<td>PS20</td>
<td>Tower</td>
<td>Abener</td>
<td>Abengoa Solar</td>
<td>30MW</td>
</tr>
<tr>
<td>Solnova I</td>
<td>CSP</td>
<td>Abener</td>
<td>Abengoa Solar</td>
<td>50MW</td>
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<td>Solnova III</td>
<td>CSP</td>
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<td>50MW</td>
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**22 SOLAR PLANTS WITH YOKOGAWA**

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<th>Power</th>
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</table>
HXS10 SolStation – Solar Tracking Controller
HXS10 – Combines Yokogawa’s Best Technology

YS1000/DXAdvanced (Standard at FPL Nuclear Power Plants) Programmable controllers/Recorders

DARWIN (Standard DAQ at FPL Power Plants) Data Acquisition

Highly Reputed Controller Technology with 30 years history

Reliability

World No.1 Sales Recorder Technology (with highly accurate temperature measuring Know How)
HXS10 offers following advantages:

- **LOWER CAPEX**
  - *Value price through Optimized Design*
  - Significant Price advantage against general PLC solution

- **LOWER OPEX**
  - *High Reliability through low power consumption & wide operating temperature*
  - Low power consumption will help reduce internal thermal temperature of the enclosure. Reduction of internal thermal temperature will extend life of electric components used in the enclosure.
  - -20/-4 to +70/+158 C/F Operating Temperature Range

  - *High Reliability through reduction of communication load in the field*
  - Modbus Server/Client support reduces communication traffic, by reducing the number of nodes that upper layer controller directly monitors. Additionally, maintenance status information can be sent to the central SCADA without hindering vital communication related to field control.

  - **Easy Integration**
  - Distribution of user defined program to all the filed controllers can be executed by a simple bulk procedure. Open Architecture Controller can be easily integrated with Yokogawa Distributed Control System (CENTUM-VP) using the Field Gateway Server (FGS). Customer can monitor HXS10 controller from Central Control Room.
Management for a Field of Controllers
  • Automated Firmware Updates
  • Mass Deployment of Control Programs
    • Automated Parameterization
    • Automated Commissioning
    • Configuration Management
    • Open Database Design

Adjust/Maintain one by one through dedicated cable
Built to Communicate – Ethernet/RS232/RS485

Upper system (MODBUS/TCP client)

- HXS10 – Modbus TCP Client & Server and Modbus RTU Master & Slave (all simultaneously)
- Address 10 Modbus TCP Servers, 200 Client Requests, and 200 Master Requests (read/write/write immediate)
- 250 Floating Point inbound channels (CX)
- 250 Integer outbound channels (CY)
- With Independent Decimal Position for each channel (CXDP, CYDP)
HXS10 Specifications

AI(TC/mV/V/RTD): 0, 2, 4 or 6 points
   Isolated between channels, Scan measuring style
   e.g.: Temperature Heat Transfer Fluid, Sun sensor, Inclinometer,
AO: 0 or 2 points
   Non-isolated between channels, 0 to 20 or 4 to 20mA
DI: 12 points
   Non-isolated between channels, Applicable for both source current source and sink
Pulse Counter: 2 points (A, B, Z (R) channels) (10/20/40 kHz support for magnetic sensor input)
DO: 12 points
   Transistor contact (100mA/30Vdc)
   (If larger capacity is required use external relay.)
Control interval: 100/250msec (250 msec or slower for units with 4 or 6 AI)
AI measurement interval: synchronous to control interval
Program language: Function block diagram
Solar position calculation algorithm: NREL algorithm built-in (64bit calculation supported), SNTP Time Synchronization
Communication: Ethernet x 1port, Configuration port (TTL level) x 1port
   (RS232C and /or RS485 available as Option)
Power supply: 24V DC
Operating temperature: -20 to 70 °C
Dimension: approximately 226mm x 132mm x 67mm
LOC Panel – Heat Load Design

- White Enclosure with No Vents, Fans, or Filters
- 5 to 10F heat rise over ambient (36 Watts max) at 122F Ambient
- 152F max internal temperature if 132F Ambient
- All internal components rated for 158F/70C or better continuous operations
- NEMA 4 and 4X solutions
Large Global Base of Systems

As of December, 2010

TOTAL 22,435 PROJECTS

EUROPE
AUSTRIA(30)
AZERBAIJAN (1)
BELGIUM (179)
BELARUS(7)
BULGARIA (5)
CROATIA(5)
DENMARK(5)
FINLAND(1)
FRANCE (231)
GERMANY (247)
GREECE (18)
HUNGARY (63)
IRELAND(3)
ITALY(149)
KAZAKHSTAN(5)
LITHUANIA (1)
NETHERLANDS (173)
NORWAY(5)
POLAND (17)
PORTUGAL(8)
ROMANIA(12)
RUSSIA(364)
SERBIA(8)
SLOVAKIA/CZECH(103)
SLOVENIA(2)
SPAIN(162)
SWEDEN (1)
SWITZERLAND(17)
UK(79)
UKRAINE(6)

AFRICA
ALGERIA(33)
ANGOLA(13)
BOTSWANA(4)
CONGO(4)
EGYPT(48)
GABON(6)
GHANA(4)
KENYA(3)
LIBYA(4)
MOROCCO(21)
NAMIBIA(1)
NIGERIA(34)
SENEGAL(2)
SOUTH AFRICA(142)
SUDAN(2)
SWAZILAND(2)
TUNISIA(1)
UGANDA(1)

MIDDLE EAST
BAHRAIN (27)
DUBAI(1)
IRAN (93)
IRAQ(8)
JORDAN (4)
KUWAIT (11)
oman (34)
QATAR(5)
SAUDI ARABIA (203)
SYRIA(5)
TURKEY (31)
U.A.E (40)
YEMEN(7)

ASIA PACIFIC
INDIA(1,183)
MYANMAR(5)
PAKISTAN(6)
SRI
LANKA(1)
CHINA (2,044)
KOREA (892)
TAIWAN
(422)
JAPAN 
(11,496)
MALAYSIA (244)
INDONESIA(210)
PHILIPPINES (143)
SINGAPORE (181)
THAILAND (374)
VIETNAM (21)
AUSTRALIA (383)
NEW ZEALAND (2)
FIJI (6)
PAPUA NEW GUINIA(3)
NEW CALEDONIA (1)

NORTH AMERICA
CANADA (14)
USA (782)

SOUTH AMERICA
ARGENTINE (9)
BRAZIL (428)
CHILE(2)
COSTA RICA (1)
COLOMBIA (13)
CUBA (10)
EL SALVADOR(1)
MEXICO (21)
NICARAGUA(1)
PANAMA(1)
PERU (1)
TRINIDAD TOBAGO (2)
URUGUAY(1)
VENEZUELA(7)

Proprietary info goes here...
Protecting Your Investments

- Full Upward Compatibility
- Minimized Cost
- High Performance
- Evergreen and Growing

- Unique Pair & Spare reliability technology
- Seven 9’s (99.9999959) availability
- 22,435 systems installed worldwide
State-of-the-art technologies for mission-critical applications “Performance built to last”

Non-Stop Availability
- 99.99999% (Seven 9s) controller
- Integrated safety controller

Customer-Centric Openness
- Both FDT/DTM and EDDL
- Modbus, FOUNDATION fieldbus, HART, Profibus
- Siemens Turbine Controls
- Wireless

Future-Proof Evolution
- Backward compatibility and migration path
- Stable long-term supply and life-cycle services
What does 7 nines mean to a process plant?

<table>
<thead>
<tr>
<th>System Availability</th>
<th>Expected Annual Failure Time (per FCS)</th>
<th>Expected Annual Failure Time (for 10 FCSs)</th>
<th>Expected Annual Loss of Cost (for 10 FCSs)</th>
<th>System MTBF (per FCS)</th>
<th>System MTBF (for 10 FCSs)</th>
<th>Number of System Failures (12 Years)</th>
<th>Number of Shutdowns (12 Years)</th>
<th>Comparison of Loss Between Seven Nines and Four Nines (12 Years)</th>
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<tbody>
<tr>
<td>Seven nines</td>
<td>3 sec</td>
<td>31 sec</td>
<td>US$1K</td>
<td>4500 years</td>
<td>450 years</td>
<td>negligible</td>
<td>negligible</td>
<td>more than US$65M difference</td>
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<tr>
<td>Four nines</td>
<td>0.86 hour</td>
<td>8.6 hours</td>
<td>US$1M</td>
<td>4 years</td>
<td>0.4 year</td>
<td>24 times</td>
<td>4 times</td>
<td></td>
</tr>
</tbody>
</table>

What makes Yokogawa Centum VP so reliable?

9 Architectural Concepts of Centum’s High Reliability

- **Sophisticated engineering functions**
  - Prevent mistakes in application development
  - Enables upsets in upstream process to be avoided

- **Advanced test functions**
  - Prevent mistakes in application development
  - Enable virtual tests on a PC including I/O

- **Online expansion/ modification**
  - Minimizes system downtime at system expansion and modification
  - Enables control algorithms to be changed during plant operation

- **Dual-redundant system elements (for fault tolerance)**
  - Prevent a single fault from adversely affecting system operation
  - Thorough redundancy design

- **Easy-to-maintain design (for maintainability)**
  - Easy-to-troubleshoot design
  - Enriched maintenance information, auto-recovery, etc

- **Fast system response design**
  - Copes with system expansion and enhancement
  - HMIs display refresh cycle at 1 second

- **Rapid-response communication**
  - Prevents a slowdown in response when the communication load increases
  - Adopts a token-passing bus

- **Environmentally resistant design (for fault avoidance)**
  - Resistant to noise, corrosive gases, vibration, etc
  - Enables reliable operation under harsh environments

- **Measures against momentary power failure**
  - Preclude anomalies in the power supply system from causing malfunctions
  - Enable continuous operation while maintaining control
Open Architecture with Security

- Control Network (Vnet/IP)
  - IEEE 802.3ab (z) Gigabit Ethernet
  - Control Communication is secure & deterministic
    - Yokogawa manufactures the NIC (VI702) for PCs
      - Encryption, random changing keys, bandwidth partitioning.
      - Time synchronization to 1 msec
      - Switchover and Bus error recovery diagnostics
    - Redundant LANS (1 and 2)
  - Open Communication using TCP/IP (restricted to LAN 2)
- Fieldbus Networks
  - Foundation Fieldbus, Profibus DP, ISA 100 Wireless
  - Ethernet (Modbus TCP, Allen-Bradley CIP & Ethernet I/P, DeviceNet)
  - HART
- Windows MS Platforms
- Enterprise Interface
  - OLE for Process Control (OPC)
    - OPC UA
    - OPC Classic
Vnet/IP – Open and Secure

Open Communication and Highly Reliable & Real-time
Communication band-width partitioning & security on the Single High-speed Ethernet Media.

Control Communication (Vnet Protocol)

Open Communication (TCP/IP)

Yokogawa dedicated hardware – Control Firewall Card
Overall System Architecture

- **CENTUM VP HIS Engineer Station**
- **HXS10 Network Management System**
- **Operator Station (HIS)**
- **Remote I/O**

**FGS**
- Qty 4

**HXS10**
- Qty. 922

- **HRSG I/O**
- **Steam Turbine Interface**
- **Water Treatment**
- **Balance of Plant I/O**
FastTools Gateway Server (FGS)

HXS10 - LOC

Open Modbus TCP

FGS

Deterministic Vnet/IP

- FGS Faceplate block and tuning Panel for HXS10
- Native representation in HIS Operator and Engineering Stations
- Faceplate block is configurable for custom data retrieval from HXS10 to match deployed configurations
- Scan rate customization and prioritization for different data points within Faceplate block
- Custom Faceplate blocks for Weather stations, Turbine Control Systems, and Field Data Acquisition
- OPC COM/DCOM is not used for information transfer
- Redundancy option available
- Up to 64 total stations on Vnet/IP network; communication load can be shared across multiple FGS to enhance throughput speeds
"View set" enables flexible grouping of graphics, trends, and faceplates in accordance with the user roles and objectives.
Heat Recovery Steam Generator

**Feed Water**
- Feed Water Press.
- Feed Water Flow
- Feed Water Temp.
- Drum Level
- Drum Level Monitoring
- Drum Water Temp
- Drum Press
- Quality Analysis (pH, Conductivity, DeO2)

**Boiler**
- Metal Temp.
- Metal Temp. (Data Acquisition)
- Boiler Feed Pump (Vibration)
- Boiler Feed Pump (Lub. Oil & Winding Temp)
- Heater Level

**Steam**
- Steam Press.
- Steam Flow
- Steam Temp
- Spray Press.
- Spray Flow
- Spray Temp.
- Conductivity Analysis

**Flue gas**
- Furnace / Flue Gas Draft
- Furnace / Flue Gas Temp.
- Flue Gas Flow
- O2 Analysis
- NOx Analysis
- SO2 Analysis
- Dust Monitoring
Electrical Overview Graphic Interface

- Switchyard Breaker Status
  - Current
  - Power Factor
  - Power Flow
  - Trip Status
- Transformer Status
  - Tap Changer Status
  - Transformer Diagnostics
  - Breaker Status
  - Dispatch Status
- Generator Monitoring Status
  - Temperatures
  - Winding Temperature
Historical Data

OSIsoft

OR

Exaquantum

Exaopc

Operations

Proven Reliable Connection
Plant Resource Manager

• A Centralized Platform for Device Management
  Foundation Fieldbus Plant Instrumentation
  HART Plant Instrumentation
• Integrated Database for Plant Equipment Maintenance
• Condition-Based Predictive Maintenance Management
  Reliability-Centric
• Provides Maintenance History & Traceability of Plant Instrumentation
• Document Management of Field Assets
• Prioritized Alert Management

Combining predictive maintenance techniques with comprehensive analysis tools, Yokogawa’s Plant Resource Manager allows for easy and accurate assessment of the assets health in your facility. PRM incorporates multiple diagnostic technologies into a common database for comprehensive analysis of asset degradation symptoms. Unsurpassed analytical capabilities through automated diagnostics, plotting, and reporting allow you to determine asset health and condition so critical production decisions can be made for improving your business performance.
High Temperature Solar Field Instruments

- 450C/840F Digital Yewflow Vortex Meter, butt weld option for Mass Flow

- 450C/840F EJA438W with remote diaphragm seals (DFS) for Pressure

- YTA 70 operating temperatures of -40C/F to 85C/185F

- Hydrocarbon Analyzers for oil leak detection before return to boiler.
Simulation / Factory Acceptance Testing

- Factory Test with simulated I/O
- Factory Test with wireless debugging aid
- Off-line Test with FCS Simulator and HIS emulator

Diagram:

- Ethernet
- ENG
- Virtual Wiring
- Stand Alone ENG/HIS/FCS
- FCS Simulator
- HIS Emulator
- Vnet/IP
- FCS Simulated I/O
- Stand Alone

Page 31
Yokogawa Genesis Project Team

Solutions

- Project Management
- Architecture
- Solar Tracking Control Panels and DCS
- Networking
- Integration
- Solar & Power Expertise
- FAT, SAT, Commissioning
Yokogawa Genesis Project Team Leads

Yokogawa Genesis Project Manager
Assigned from pool

Executive Sponsor
Brad Byrum
VP Yokogawa
Solutions

Yokogawa Solar Solutions
Andrew Brodie

DCS
• Network
• Control
Mark Fabre

LOC Manufacturing
Jeff Summers

LOC Test and Design
James Armstrong

DCS Support
Gary Reeves

LOC Programming
Yuuichi Kikuchi

• Commissioning
• Local Support
Augie Garcia

After Sales Support
Todd Stanier

24 Hour Priority Support
Matthew Colbert

24 Hour Priority Support
Rob Sink
Our Project Implementation Process

YOKOGAWA ◆ Global Engineering Standards

• Globally standardized work execution standards and practices for all Yokogawa projects
• GES fully incorporates ISO 9001, ISO ISE 12207, and PMBOK
• Includes all project phases from order entry to site acceptance of systems
Our Project Implementation Process

**Concept Phase**
- Functional Requirements
- System Architecture
- System Defaults
- Top Down Design

**Design Phase**
- Detail Design Specifications
- Peer Review SRS
- Peer Review S/W Dev. Plan

**Implementation Phase**
- Configuration
- Coding
- Procurement
- Subsystem Integration
- Software Review
- Functional testing
- Project Documentation

**FAT Phase**
- Factory Hardware Check
- Factory Application Check
- Q.A. Audit

**SAT Phase**
- Site Installation and Verification
- Loop Checks
- Loop Tuning
- Project File Review

**Inputs**
- FRD, HDB, and S/W Dev Plan
- Instrument Data Sheets/ I/O List
- Sub-system Specifications
- Loop Drawings (P&IDs)
- Project Standards
- HMI Detailed Spec
- Control Detailed Spec

**Tasks**
- Configuration/Coding Lists
- SAT Plan Document
- Installation Verification Test Plan & Report
- Test Equipment & Instrument Calibration

**Outputs**
- Functional Requirements Document (FRD)
- Hardware Design Basis (HDB)
- Task, Anomaly, and Summary Reports

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A Complete Portfolio of After Sales Support

- Training
- Technical Assistance Center (TAC)
- Performance Enhancement & Monitoring
- Calibration and Inspection
- Repair
- Operating Inspection

“Yokogawa DCS does absolutely everything we want it to do and we are only using a fraction of its standard functionality. Yokogawa product quality is unbelievable. From day one it has never missed a single beat.”

Jack Leonard, CTR Holdings
Global network for customer support

YOKOGAWA provides 24H/365D Support Service world wide.

232 service offices

As of June, 2009
Thank you very much for your attention!