The XDC800 Hardware Platform-Based Xinhua Digital Electro-Hydraulic Control System DEH-V for Steam Turbines

SHANGHAI XINHUA CONTROL TECHNOLOGY (GROUP) CO., LTD.
In the 1960s, China has already kept abreast of international developments in the research on technologies for steam turbine electro-hydraulic speed control systems and put into operation the first set of turbine oil electro-hydraulic governing system in Changchun in 1965; in the mid-1970s, the first set of power station steam turbine analog electro-hydraulic control system AEH utilizing high-pressure fire-resistant oil was successfully developed in the country.

Upon entry into the 1980s, the country began to introduce the large 300MW and 600MW thermal power equipment manufacturing technology. In 1981, China introduced the 300MW and 600MW thermal power equipment manufacturing technologies from Westinghouse and Combustion Engineering Corporation of the United States of America, but not the manufacturing technologies for the turbine control system DEH and so had to rely on imports. As a technical expert who had dedicated himself in this very field for decades-Mr. Li Peizhi-resolutely decided to take the tough job of localizing the steam turbine control system (DEH) for the 300MW and 600MW large thermal power units, taking the lead in the efforts to bring about breakthrough in technologies of digital electro-hydraulic control systems for steam turbines. Hence, a cross-industry and cross-regional research and production association under a collective ownership-China Electro-hydraulic Control Technology Development Center, later renamed Xinhua Control Technology Joint Development Center, was set up in March 1985, specializing in the development of steam turbine DEH control system.

Early in 1965, members of Xinhua Control Technology Joint Development Center already successfully developed electro-hydraulic governing system for turbine low-pressure turbine oil and then successfully launched electro-hydraulic governing system for steam turbine high-pressure fire-resistant oil in 1976. Therefore, as it has already possessed technology for and experience in the design and use of power station steam turbine control systems in the process of introduction, Xinhua Control Technology Joint Development Center quickly and completely mastered technologies for the design of DEH systems for the 300MW and 600MW steam turbines and successfully developed the DEH, MEH and DAS systems with independent intellectual property rights within a short period of two years after it was founded.

The company, by virtue of its core technology, the steam turbine electro-hydraulic control system DEH for thermal power plants, gradually built up advantages in the power station DEH field. The important position of DEH in the automation of power stations has notably raised the status of the company in the power plant automation industry. In 1988, Xinhua Control Technology Joint Development Center, on the basis of the DEH technology, set up a Sino-foreign joint venture company-Xinhua Power Station Control Engineering Co., Ltd. Developed through introduction, digestion, and innovation, the first homebred and fully functional DEH-III system, together with the 300MW turbo-generator unit produced by Shanghai Steam Turbine Factory, was put into use in Hanchuan power plant in January 1990. Compared with the Westinghouse W2500 minicomputer stand-alone-configured DEH-II used for the evaluation units in Shiheng Power Plant and Pingyu Power Plant, this set of system represents a huge step forward and has reached the Westinghouse DEH-III level.

The operational practice of this set of system shows that the localized, optimized design of the DEH-III for the 300MW unit is successful and can fully replace imports; in December 1990, the former Ministry of Machinery and Ministry of Energy held a technical assessment meeting, at which experts concluded that the DEH-III system in China was used for the very first time, that the development was successful, and that this signified that the Chinese steam turbine control technology had reached a whole new level.

Since then DEH has been put into mass production to meet the demand for a complementary product of the 300MW unit and exported to Pakistan as a complementary product of the 320MW unit, showing the Chinese brand DEH system with zero fault
performance. In January 1996, DEH-III for the 600MW unit was handed over to the power plant upon its passage through 168 hours of trial operation in Harbin third power plant.

At the same time, Xinhua Control Technology Joint Development Center, the later Shanghai Xinhua Control Technology (Group) Co.,Ltd, continued the development of DEH and DAS technology and integrated the DEH and DAS systems into the Xinhua control system-XDPS-400 distributed processing system in 1994.

With the development of computer technology and the ever-increasing demands for power plant used control equipment, by applying a design concept called distributed control system, in 1996 Xinhua upgraded DEH-III to DEH-IIIA, a distributed and digital electric hydraulic control system. DEH-IIIA is a real time control system based on decentralized control for steam turbine-generator units in power stations. Its hydraulic part utilizes high-pressure fire-resistant oil electro-hydraulic servo control system EH. The Electro-hydraulic control system consisting of DEH-IIIA and EH achieves real-time control on turbine speed and load by controlling the openings of main throttle valves and of governing valves of the steam turbine.

With the expansion in the application and functions of the DEH-IIIA system, a steam turbine island control system is formed, with functions covering DEH, MEH, BPC, ETS, TSI, and SCS (steam turbine part) system etc; this system and the boiler control system together constitute the power plant thermal engineering control system. The first set of steam turbine island control system was put into operation in 1999.

From its founding in 1985 to 2009, Xinhua Control Technology Group Co.,Ltd had undertaken a total of more than 1300 sets of steam turbine control systems DEH and MEH.

According to professional survey organizations employed by foreign peers, Xinhua products enjoyed a market share of more than 90% in DEH for thermal power units and of more than 72% in DCS for thermal power units in years 2003 through 2004.

At that time, Xinhua Group had eight subsidiaries. In March 31, 2005, Xinhua Group transferred to General Electric Company GE of the United States of America its controlling interest of Xinhua Control Engineering Co.,Ltd, a Sino-foreign joint venture (a system integration engineering company) engaged in power plant distributed control engineering business, due to willingness of the then foreign shareholder. After GE gained controlling power in Xinhua Control Engineering Co.,Ltd, Xinhua group retained its own R&D team, engineering team and two production bases, and had R&D and production sites of nearly 50,000 sqm and more than 600 employees. It retained a large number of technical backbone talents engaged in power plant DEH and DCS business because GE had its own DEH-Mark V and Mark VI. Only 2 years later, DEH-V, which Xinhua XDC800 is taken as its base platform, was launched based on a large number of applications of XDPS400 and DEH-III. DEH-V is an upgraded version of DEH-IIIA, which covers the most advanced digital control technology and servo control technology available today, integrates control, monitoring and protection functions, and further enhances the reliability and practicability seen in the traditional steam turbine DEH system beyond DEH-IIIA, leading to more reasonable structure.

In January 2011, XDC800 platform-based DEH and ETS passed the SIL3 certification issued by the National Center for Industrial Automation Instrumentation Product Quality Supervision and Inspection.

Starting from 2010, Xinhua Group resumed providing clients form power industry with DEH-V, XDC800 and relevant automation control system products and solutions such as DEH and DCS with Xinhua Brand along with unique and all-around services from Xinhua..

President, Shanghai Xinhua Control Technology (Group) Co.,Ltd
Professor-level Senior Engineer
Shanghai Working Role Model
China Excellent Private Technological Entrepreneur
Shanghai Excellent Technological Entrepreneur
Hong Kong Redbud Cup Excellent Entrepreneur
July 2011
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Xinhua Steam Turbine Digital Control System DEH-V

In order to keep pace with the ever-demanding automation performance of turbine-generator units running in large power grids, the digital control system DEH has been widely used in steam turbine generator units and so the DEH system has become a node in a distributed control system DCS in a power plant. Whilst digital control systems DEH are widely used in large steam turbines, digital control technology is also used in 200MW, 125MW, 100MW, 50MW units and below, as well as in steam reheating or steam extraction units.

A real-time control system for steam turbine generator units, the turbine digital control system DEH is a regulating controller for the turbine under starting, shutdown, and normal operation conditions as well as accident conditions. With digital control techniques used to control the opening of the main valve and the adjustment valve, real-time control on rotational speed, load, and pressure steam turbine-generator units can be achieved.

Xinhua turbine digital control system DEH-V is an upgraded product launched by Xinhua Group based on its experience in the development, design, and industrialization process for DEH and the operation of DEH-III and DEH-IIIA for the turbine generator units in power stations, representing another achievement of Xinhua Group resulting from its constant efforts toward innovation. DEH-V covers the most advanced digital control technology and servo control technology available today, integrates control, monitoring and protection functions, and further enhances the reliability and practicability seen in the traditional steam turbine DEH system beyond DEH-IIIA, leading to more reasonable structure.

Xinhua steam turbine digital control system DEH-V is composed of two parts: steam turbine digital control system DEH-V and the electro-hydraulic servo control system EH.

Xinhua steam turbine digital control system DEH-V utilizes the hardware and software for Xinhua digital control system XDC series. The hardware is composed of decentralized processing unit XCU, engineer stations, operator stations and I/O cards of the XDC series. The software uses the XDC series OnXDC graphical configuration software and visual programming software.

The electro-hydraulic servo control system EH is an important part of a steam turbine digital control system. Xinhua EH is divided into two types of hydraulic control systems that respectively use high-pressure and low-pressure turbine oil as liquid actuating medium.
1. Xinhua Steam Turbine Digital Control System DEH-V

Steam turbine digital control system DEH-V utilizes hierarchical design, leading to a clear layered structure: network, human-machine interface, process control, servo control drive and onsite valve actuating devices, each level completing its independent functions separately. The process control part of DEH-V accomplishes real-time control on turbine rotational speed and load; the drive part of the Servo control completes closed loop servo control on oil motivators and steam valves; the actuator generates push the valve movement dynamics; human-machine interface to complete the real-time display, alarm and various operations; network communications between the control system of steam turbine and power plant management network.
1.1 Hardware platform of Xinhua Steam Turbine digital DEH-V control system—an advanced process control system XDC800 for the whole production process

An upgraded version of XDPS-400, Xinhua Control System XDC800 is a fully distributed, networked comprehensive automation control system that integrates computer, network, database and automatic control technology as a whole and incorporates Industrial Ethernet and field bus and makes full use of the Internet.

Hardware modules at various layers of the XDC800 system adopt intelligent configuration. The use of an embedded software operating system (WinCE) and embedded software programming results in a compact program structure, more concise code, and high efficiency in implementation, good safety and high reliability.

- The management and control integration design concept
- Advanced process control system for the whole production process
- Xinhua controller XCU consisting of the high performance 32-bit CPU processor as the core
- Turbine-control-specific intelligent I/O module with fully redundant input and output
- I/O with separated modular structure replacing XDPS card structure, with no need to configure terminal cabinets
- System architecture with data stream technology and no servers
- Integration and fusion of industrial Ethernet and field bus
- Web technology-based network operation, with the browser window displaying real-time information and data to achieve remote transmission of files and data
- Visualizable graph configuration and visualizable algorithm in configuration software
- Control and management integration
- The process control technology of rapid data processing, which reduces the disk space and improves the historical data query speed
- It contains process control, logic control and batch control and is therefore adapted to the user’s real demand for control
The XDC800 has been appraised as a "national key new product" by five ministries of the nation including Ministry of Science and Technology.

The XDC800 industrial process control technology was conferred the second prize of science and technology in Shanghai City.

The XDC800 have passed a good variety of international certifications standards such as CE/EMC, FCC, and TÜV.

The XDC800 platform-based DEH, FSSS, and ETS have passed the SIL3 certification.

In 2009, organized and sponsored by Shanghai Pudong New Area Committee of science and technology, an assessment of "Xinhua digital control system (XDC800)" of Shanghai Xinhua Control Technology (Group) Co., Ltd was conducted and attending experts agreed that XDC800 is an innovative product developed by Xinhua Group with independent intellectual property rights; as this product utilizes data stream technology, has a system architecture with no server and makes use of Web technology, it solves problems in DCS system network architecture, real-timeliness, reliability, network communication bottleneck and remote transmission, and has reached the internationally advanced level. The evaluation opinions are as follows:
Expert Review Comments on Xinhua XDC800 Digital Control System

On August 6, 2009, chaired by Pudong Area Committee of Science and Technology, the Committee of Experts conducted review on “Xinhua digital control system (XDC800)” product developed by Shanghai Xinhua Control Technology (Group) Co.,Ltd. The Committee of Experts listened carefully to the product presentation, reviewed the technical report, test report, user report, novelty level search report and its own intellectual property rights certificates and other documents; after careful discussion, review comments are as follows:

1. XDC800 is an innovative product with independent intellectual property rights developed by Xinhua Group; the product utilizes a data diverting technology, a system architecture with no server, and the Web technology, and through level retrieval, its functions have in fact reached an advanced level in terms of the DCS system network architecture, system real-timeliness, reliability, network communication and remote transmission.

2. Key Technologies Used in and Major Innovations of XDC800:
   (A) The network structure reasonably diverts real-time data and non real-time data, ensuring the real-timeliness of the system;
   (B) The hierarchical, modular and standardized framework design idea, not only improves reliability of the system, but also allows for seamless connection with other systems (including field bus);
   (C) The new, separated I/O module structure is convenient for constructing large-scale industrial control system;
   (D) The serverless mode of a distributive real-time data technology, improves reliability of the system and data sharing;
   (E) Visual graphic configuration programming technology, virtual technology, and Web technology have been used, resulting in easy applications;
   (F) Efficient process control history data processing technology has been used.

3. The product can be widely used in industrial process automation control systems for environmental protection, electric power, petrochemical, cement, papermaking, municipal works, iron and steel, etc. Its wide applications have important practical significance for enterprises in their production efficiency improvement, energy saving and consumption reduction, emission reduction and efficiency enhancement.

   In sum up, the overall technology of the system has entered into advanced ranks for the industrial control sector, demonstrated superior control performance in general process control system, and has a wide application prospect.

   It is suggested that Xinhua Group further improve the application level for the product according to the characteristics of various sectors.

Director of the Committee of Review Experts (Signature):

Pudong New Area Science and Technology Commission (Seal)
1.2 Hardware structure of steam turbine digital control system DEH-V

Xinhua DEH-V (Digital Control System for Steam Turbine) is launched by Xinhua Group on the basis of the development, design, industrialization of DEH and operational practice of DEH-III and DEH-III A for turbine-generator units; DEH-V takes Xinhua XDC800 as its base platform. DEH-V is an upgraded DEH-III A, which covers the most advanced and current digital control technology and servo control technology, integrates control, monitoring and protection functions, and further enhances the reliability and practicability seen in the traditional steam turbine DEH system beyond DEH-III A, leading to more reasonable structure.

DEH-V covers the feed water pump turbine control system MEH, power plant bypass control system TBC, and steam turbine protection system ETS and turbine supervisory instrument TSI, comprising the control system for the power plant Turbine Island.

DEH-V composed of XDC800 is a typical steam turbine control system DCS systems. The structure of DEH-V system is as follows,

1.2.1 Hardware composition

The hardware system of a DEH-V system is composed of control panels, engineer stations, operator stations and corresponding networks.

The control panel is composed of Xinhua controller XCU with redundant configuration of turbine-specific speed measurement module xSD, servo control module xSV and various I/O functional modules. I/O input modules for control panel collects field I/O signals, which are processed in accordance with the designed DEH control strategies and outputted through a servo control module; field control actuators or valves are controlled through EH system.

DEH-V consists of two sets the XCU with redundant configuration to achieve basic control, turbine rotor stress calculations and automatic turbine control ATC functions.

The engineer station and operator station composed of industrial PC machines are a human-machine interface. The engineer station ENG is used for the control strategy configuration, software loading, system maintenance and management and other functions. Typically a DEH-V system is configured with an engineer station.
The operator station OPS is used for steam turbine monitoring and operation; it is a window through which operators monitor operational conditions of the production process to ensure stable operation of the production process. It displays production processes, process flow diagrams, and trend graphs through the operation of operators.

The structure of the DEH-V system has been designed with control-layer network and field-layer network. Control-layer network XDCNET is used for real time data transmission between a distributed control unit and the human-machine interface (HMI). In order to ensure the real-timeliness and certainty in system data transmission, the network at this layer consists of three networks, A, B, and C. XCU and HMI devices are directly hung on networks A and B to transmit system real time data in a redundant manner, while at the same time HMI devices are connected network C to confine files, historical data, image data etc that do not require real-time transmission to network C. The field-layer network IONET, which has a redundant configuration, is used for data transmission between XCUs and speed measurement modules, servo control modules and I/O modules.

With triple redundancy ESD technology, OPC is composed of dedicated independent hardware and software configured with two out of three logic to achieve over-speed control protection so as to ensure safe operation of the steam turbine.

1.2.2 Xinhua controller XCU

Xinhua controller XCU is the host part of DEH-V. Redundant IONET bus is used to realize communication with and control over I/O, while at the same time, achieving networking of XCU through XDCNET network. Software configuration is completed on the engineer station and after configuration is completed, it is loaded in XCU and can be modified both online and offline. The steam turbine is configured with two sets of redundant XCUs, which serve as hot standby for each other.

The characteristics of Xinhua controller XCU:

- **Distribution functions**
  The XCU functions relatively independently; it transmits information via a communication network to realize information sharing. A system structure with decentralized functions will improve availability of the system as well as separating system risks, and thereby improving reliability of the system.

- **Redundant configuration**
  The redundant configuration of XCU; the high-speed data network connecting XCU and HMI has a redundant configuration. The use of redundancy techniques improves reliability of the system and prolongs failure-free operation time.

- **Intuitive, simple visual graphic configuration software**
  In line with international IEC61131-3 programmable control algorithm, it can complete design and programming with all the control strategies at one time.

- **Multi-task operating system**
  Multi-task embedded operating system with configurable multi-loop processing capabilities enables a single controller to control objects with different requirements.
Online configuration and simulation
XCU supports online configuration, including parameter setting, simulation, algorithm, online modifications to strategies without re-compiling and downloading the whole control algorithms, making it greatly convenient for users to maintain the configuration and debug the system.

The powerful functional module
The algorithm function module of XCU is very concise and practical; a variety of ad-hoc modules and user-defined modules are available and can meet all kinds of process control and optimization control requirements.

Self-recovery when power is on
The power-on process for XCU does not require manual intervention; it can automatically enter into the normal working condition.

Hot-plugging
XCU allows online hot-plugging, making maintenance and replacement very convenient.

1.2.3 IO modules
DEH-V system entirely uses the XDC800 series intelligent modules to achieve specific signal processing functions. A module is composed of CPU, isolators, A/D or D/A, amplifiers, over-voltage/over-current protection, AI transmitter power supply, and DI query voltage, module communication etc, which are used to indicate sticking process. DEH-V system modules mainly include:
- The speed measurement module xSD
- The servo control module xSV
- The analog input module xAI
- The analog output module xAO
- The digital input module xDI
- The digital output module xDO
- The loop control module xLC
- The logic protection module xLP

1.2.3.1 Turbine digital control system-specific modules.
(1) Speed measurement module xSD
XSD is a special and intelligent over-speeding monitoring and protection module for steam turbine control systems.

XSD module utilizes the RDC8830 16-bit embedded CPU; it has characteristics such as fast speed, strong data processing ability, and good compatibility with PC machine instructions. Therefore, it has relatively strong software development means. Its maximum addressable
space is its memory, 1Mbyte and 64K for I/O; it performs functions such as three 16-bit counters/timers, multi-level interruption, and 8 priority levels.

When the program memory FLASH ROM (AMD 29F040) is concerned, FLASH ROM solidifies a 32K execution program for EMON86 V3.21 and PI; regarding the 1M RAM with 621024 byte for the data memory, this RAM is mainly used for program operation and data calculation.

xSD module is not only used for detecting the rotational speed of the turbine, judging the over-speed protection and control, but also has a load prediction function and a power-load balancing function. It can realize online operation over-speed protection test. The xSD module completes judgment and execution of fast speed to ensure that the speed-up is no more than 7% when steam turbine is shedding off load.

At the same time, in order to ensure that the steam turbine speed control and over-speed protection system is reliable, the DEH-V system is equipped with 6 independent xSD modules, wherein 3 pieces of triple redundant speed numbers are used for steam turbine speed control, and the other 3 pieces of 3 redundant speed-in are used to carry out 2 out of 3 judgment for the purpose of over-speed protection (OPC) so as to prevent to a maximal extent over-speed protection mal-operation and rejection of operation.

- **Technical indicators of the xSD module:**
  - 4-channel speed measurement: 0 ~ 10KHz, the minimum input voltage: 100mV; time for measuring speed < 20ms;
  - 8-channel digital input;
  - 4-channel digital output;

- **Main characteristics of the xSD module:**
  - High performance and high reliability design
  - Photoelectric isolation for input/output, with isolation voltage ≥1500V
  - Low power consumption design < 2.5W.
  - It supports hot-plugging
  - LED indicators for running state

- The xSD measuring precision: 1R/min
(2) Steam turbine servo valve drive module xSV

The XSV module, designed for DEH-V system to realize servo valve PI control, is used for turbine valve servo drive control. The XSV module corresponds to the electro-hydraulic servo valve to achieve separate control over valve oil motivators and valve management functions.

The XSV module uses high input impedance instrument amplifiers and 16bitAD to achieve signal sampling; at the front end, electronic analog switch channels are used, while at the back end isolation amplifiers are used to achieve isolation between external signals and internal CPU. High performance AMD188 CPU completes a variety of signal sampling, processing, servo valve PID control, valve feedback intelligent judgment and selection, and achieves the communication with upper computers.

XSV, together with xSV-TB, receives signal s from 2 displacement sensors (LVDT), including 2-channel 0 ~ 20mA signals, 2-channel + 40mA servo current output, 2-channel of 0 ~ 20mA current output, 8-channel digital input, and 1-channel digital outputs.

### Technical indexes of xSV:

- 1 PID control loop
- 8-channel analog input, 0 ~ 5V input range, sampling error < 0.1%
- 2 -way analog outputs, 0 ~ 20mA, error < 0.2%
- 7-channel stem node digital input
- 1-channel relay contact output, 1A/30VDC
- The isolation between signals and communication bus is more than 3000VP-P

### Major properties of xSV:

- High reliability design
- 16-bit A/D, 100k/s conversion rate
- High performance 16-bit CPU.
- The isolation between signals and communication bus is more than 3000VP-P
- LED indication of Running state and signal state

1.2.3.2 Universal modules

Turbine control-specific modules and the universal I/O modules work together to achieve the turbine speed control and load control functions.

Properties of the DEH-V system I/O universal modules:

#### The specifications

- XAI: input 8
- XDI: input 16
- XAO: output 8
- XDO: output 16
- XLC: 4-channel AI; 1-channel AO; 4-channel DI; 4-channel DO
- XLP: 24-channel DI; 6-channel DO

#### Electrical properties

- AD: 16-bit
- Analog input measurement precision: 0.05%; for voltage and current; 0.1% for thermal resistance and thermocouple
- Analog output precision: 0.1%
- Inter-channel isolation voltage 400Vp-p
- The resolution of SOE 1ms
- Power supply 24VDC (+ 25%) 0.1A (max)

#### Exterior Dimensions

- Width: 50mm,
- Depth: 116mm
- Height: 130mm

#### The requirements for ambient working conditions

- Working temperature: 20°C ~ 60°C
- Storage temperature: 40°C ~ 85°C
- Relative humidity: 90% (no condensation)
1.3 Human Machine Interface Station HMI

The engineer station (ENG) and operator station (OPS) are the human-machine interface stations (HMI) of DEH-V. HMI uses industrial PCs that run Windows XP operating system, and is equipped with color display of high external resolution, laser printers, and CD drives. The human-machine interface of DEH-V system is rich and colorful, and is very convenient to operate, whilst the engineer station can be used as a standby station for the operator station.

<table>
<thead>
<tr>
<th>Host Computer</th>
<th>PC Workstation/Industrial control computer</th>
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<tbody>
<tr>
<td>Operating system</td>
<td>WINDOWS XP</td>
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<td>Chinesizing capability</td>
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<td>Graphical resolution (depending on configuration software)</td>
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<td>Software</td>
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<td>Online real-time configuration</td>
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<td>Fully off-line configuration</td>
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<td></td>
<td>Automatic document update</td>
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</tbody>
</table>
1.4 Graphic Configuration and Visual Programming Software OnXDC

OnXDC is a visual graphical configuration and programming software with independent intellectual property rights that runs on the human-machine interface HMI and Xinhua controller XCU, including the xHMI interface visual graphic configuration software and xCU graphic configuration programming software. XHMI has a strong image display function and convenient, intuitive, and visualized graph generating functions; xCU graphic configuration programming software is featured with abundant control algorithms.

OnXDC main program interface:
Advanced monitoring system: the all-Chinese window operation platform contributes to an efficient and convenient operation, computer training and easy maintenance.

Operation guide, online testing, and process constraining mechanism strengthen accident analysis and operation guide for the entire DCS.

All graphic and open configuration leads to what is seen is what is obtained: this is in line with the international IEC1131-3 design principles; there are various generic modules that can construct various state spaces and fuzzy control algorithms, leading to strong online Chinese annotation functions.

It can truly achieve on-line configuration and online modification functions, with no need to compile and download, thus ensuring the continuity of the production process.

Distributed real time database

It possesses virtual XCU, online and offline simulation functions.

Powerful system online self-diagnosis functions.

Seamless connection between MIS and DCS, efficient integration guaranteed.

1.4.1 HMI software

The operator station (OPS) of the DEH-V system, featured with multi-window displaying, is to monitor real time operation conditions of turbine-generator units through flow charts, bar graphs, trend charts, single points, overview, and grouped displays and other forms. By checking the working conditions of DEH-V system through self-inspection, the system provides real-time alarm, alarm history, historical trends, and SOE records.

The engineer station (ENG) provides powerful programming and management tools: system configuration, database, graphics generation, control logic configuration generation, report generation, and historical records. Graphics generation software can achieve 3D graphics for a variety of complex processes; report software can be configured to generate periodic reports, triggering-type statements, and SOE recall-based statements. For historical records, analog, digital and historical values for analog at a global point can be collected.
1.4.2 XCU software

DEH-V real-time control system software includes turbine control software and ATC software. Basic control software runs on a pair of redundant XCUs and achieves collection, judgment and closed loop control of major control variables such as turbine speed, load, and pressure, as well as testing of valves, valve management, over-speed test, frequency modulation and other basic functions; ATC software also runs on a pair of redundant XCUs, executing sequence logic control functions for unit auto start to achieve acquisition and judgment of temperature, pressure, and flow of the steam turbine, generator and auxiliary machines and to conduct rotor stress calculation and lifetime accumulation.

OPC over-speed protection software usually resides in the xSD module.
2. Electro-hydraulic Servo Control System EH

2.1 High-pressure fire-resistant oil system

High-pressure fire-resistant oil system mainly consists of oil supply, actuating mechanism and emergency Trip system.
(1) Oil supply
EH oil supply system consisting of fire-resistant oil supply devices, reproduction devices and oil pipeline drive a servo actuator through the 14.5MPa constant pressure provided by a variable pump, while the internal independent oil filtering system and cooling system make EH oil work under qualified conditions, and ensure that the actuator is running safely, reliably, and correctly. The oil supply system has sufficient capacity and can satisfy the needs for oil usage by DEH, MEH and BPC hydraulic control system, that is, the three systems DEH, MEH, and BPC can share one oil tank.
The Shanghai Turbine 1000MW supercritical steam turbine has 9 steam valves on both the left and the right sides: 2 high pressure main valves, 2 high pressure governing valves, 2 medium-pressure main throttle valves, and 2 intermediate-pressure governing valves and 1 supplementary steam valve. The Opening and closing of the main steam valve is controlled by an electromagnetic valve; the oil motivator for the main steam valve is of a two-position type, so that the valve is either in the fully open or in the fully closed position. While the adjusting valve and steam supply valve are controlled by the servo valve in any position; its closure is achieved through the servo valve or the corresponding solenoid valve.

The hydraulic control system comprises 9 actuating mechanisms. The 4 switch-type actuators controlled by the electromagnetic valve control the opening of 2 high pressure main valves and 2 reheat main valves. 4 servo-type actuators respectively control the openness of 2 high pressure adjustment valves and 2 reheat valves; they can have the valves controlled in any required position according to orders from the computer. There is an oil motor for the air supply valve.

The hydraulic control system for the 900MW supercritical steam turbine comprises 9 actuating mechanisms. Except for the differences in Interface size and cylinder diameters, action principles are the same as those of the hydraulic control systems for the 1000MW steam turbine.

The hydraulic control system for the 600MW imported-type turbine comprises 12 actuating mechanisms. The 2 switch-type actuators controlled by the electromagnetic valve respectively control the opening of 2 reheat main valves. 10 servo-type actuators respectively control the valve openness of 2 high pressure adjustment valves, 4 high pressure adjusting valves, and 4 reheat adjustment valves; they can have the valves controlled in any required position according to orders from the computer.

The hydraulic control system for the 300MW imported-type turbine comprises 12 actuating mechanisms. The 2 switch-type actuators controlled by the electromagnetic valve respectively control the opening of 2 reheat main valves. 10 servo-type actuators respectively control the valve openness of 2 high pressure main steam valves, 6 high pressure adjusting valves, and 2 reheat adjustment valves; they can have the valves controlled in any required position according to orders from the computer.

The hydraulic control system for the 200MW domestically produced turbine also comprises 12 actuating mechanisms. The 4 switch-type actuators controlled by the electromagnetic valve respectively control the opening of 2 main steam valves and 2 reheat main valves. 8 servo-type actuators respectively control the valve openness of 4 high pressure adjusting valves and 4 reheat adjustment valves; they can have the valves controlled in any required position according to orders from the computer.

The hydraulic control system for the 100MW domestically produced turbine also comprises 5 actuating mechanisms. The 1 switch-type actuators controlled by the electromagnetic valve control the opening of 1 main steam valve. 4 servo-type actuators respectively control the valve openness of 4 high pressure adjusting valves; they can have the valves controlled in any required position according to orders from the computer.
(3) The Emergency Trip System

When the unit is under emergency conditions or the operating parameters exceed limit values, the ETS (Emergency Trip System) device will give out an emergency stop signal. AST electromagnetic valve actuates, the EH safety oil pressure is released, the steam valves are all rapidly closed under the manipulation of a spring force, and the unit shuts down automatically. The 4 AST electromagnetic valves mutually form a serial-parallel structure and OPC electromagnetic valves form a parallel mechanism to ensure safety of the trip system.

ETS system and DEH system are closely linked in that the ETS system completes protection actions through the EH component and the oil pipeline. After the ETS protection system actuates, it must lead to an interlock of all the links of DEH. In addition to being sent to AST electromagnetic valves to quickly close the main valve, the tripping signals from ETS system are also sent to the DEH controller and the valve driving card at the same time to clear command signals.
2.2 Low-pressure Turbine Oil System

Low pressure steam turbine hydraulic control system uses the low pressure turbine oil system as a driving force for actuators to drive turbine steam valves and as a conventionally-equipped device for its turbine oil, oil motivator, gas distribution mechanism and security system.

A key part of the low pressure turbine oil DEH system is the electro-hydraulic converter. What Xinhua is using is a turbine oil DEH system that uses a torque motor valve type structure and the DDV (Direct Drive Servo Valve) servo valve as the electro-hydraulic interface.
3. DEH-V Reliability Design

- **Redundant Control**
  - Redundant Xinhua controller XCU and double modular fault-tolerant software design
  - Redundant high-speed data networks
  - Redundant I/O stations and XCU communications
  - Redundancy for Important signals and redundancy for I/O modules
  - Two out of three for basic speed control channels
  - Two out of three for over-speed control and over-speed protection OPC rotational speed channel
  - Two-way valve oil actuator position feedback LVDT
  - Dual AC power supply
  - Redundant power supply for I/O modules

- **Two-out-of-Three principle for important signals**
  Field signals for which the two-out-of-three treatment is used are read in through three separate I/O modules, with each I/O module installed in a different communication channel. The two-out-of-three signals include:
  - Main steam pressure
  - First stage steam pressure
  - Turbine rotational speed
  - Over-speed control and over-speed protection OPC rotational speed signal
  - Power of the generator
  - Steam turbine trip
  - Oil switch

- **Measures enhancing hardware reliability**
  - Derated use of components and strict screening for aging
  - 24 hours test under high temperature
  - Simulation of power plant operating conditions for copying machine debugging

- **Visualizable graphical configuration software security check**
  - Application software is open to users
  - Software process check through HMI station
  - System configuration, software download, and online inspection and maintenance on the engineer station
  - Security check for modifications to downloading of software
■ Friendly human-machine interface
Chinese-mode software platform
Graphical human-machine interface
Intuitive and convenient on-site parameter tuning and monitoring operation with keyboard, mouse, and CRT
All the information on the steam turbine-generator available via flow charts, displays, alarms, and reports

■ Anti-interference measures
Digital photoelectric isolation and jitter elimination treatment
Analog isolation and digital filter

■ Self-diagnosis, self-recovery
Diagnosis to the module channel level
Screen-display of diagnostic information
Hot-plugging, on-line replacement

■ Simulated debugging and electro-hydraulic linkage
Simulation tests and electro-hydraulic linkage tests with full functionality under all working conditions in the simulated power plant operation environment
Continuous assessment for 6 months to verify reliability of hardware and validity of software

■ Reliable EH system
Variable constant pressure fire-resistant oil system
Redundant configuration for pumps, motors and control components
Oil pump outlet and return oil filter, air filter, and fire-resistant oil regeneration device
4. Functions of DEH-V

- **Turbine start-up control**
  - Turbine latch
  - High pressure cylinder start-up, medium pressure cylinder start-up, high/intermediate pressure cylinder joint start-up
  - ATC start-up
  - Operator start-up.

- **The speed control**
  - Automatic speed control
  - Friction tests
  - Warming-up control
  - Automatic fast over-critical speed
  - Automatic synchronization control

- **Load control**
  - Automatic taking on initial load.
  - Automatic adjustment of unit load
  - Load limitation
  - Hot load control for and decoupling of extraction steam and heat supply units
  - Main steam pressure control and limitation

- **Valve management**

- **Over-speed protection**
  - Over-speed protection test, mechanical over-speed protection test
  - Over-speed protection OPC
  - Load rejection prediction and power imbalance control

- **Low vacuum protection and limitation**

- **Involvement in primary FM and secondary FM**

- **Coordinating with generator unit CCS system to realize coordinated control over the unit**

- **Rapid load reducing RUNBACK**

- **Communication interfaces**
  - The automatic synchronization, boiler control, and automatic dispatch interface
  - Communication interface with DCS
  - Standard communication interface

- **Self-diagnosis**
5. Characteristics of DEH-V

- DEH-V can be extended to constitute a power station steam turbine Island control system. Its covers DEH (turbine control system), MEH (feed water pump turbine control system), (BPC) bypass valve control system, ETs (steam turbine emergency trip system), SCS (steam turbine auxiliary equipment control system), (TSI) steam turbine and feed water pump turbine supervisory instrument.

- Distributed control, fully redundant configuration, and Ethernet communication.

- It is equipped with interface for connection with the DCS system and large screen displays.

- The operator station and engineer station with WINDOWS software platform.

- DEH-V has six channels for velocimetry, of which three speed cards are used for basic control, and the other three for OPC.

- Triple redundancy technology is used for speed control and protection OPC.

- The over-speed control and protection (OPC) of DEH-V, including 103% OPC over-speed control and 110% OPC over-speed protection, and 110% ETS over-speed protection. It separates OPC and basic control and is an independent set of hardware and software; OPC speed measurement channel is an independent two out of three, in addition, 110% ETS over-speed protection is also available.

- Basic control: Operator Automatic Control OA, CCS control, ADS control, ATC control, OA and ATC Integrated control.

- ATC automatic start-stop control, ATC control, automatic synchronization.

- Multivariable, multi-level feedback control loop, to ensure dynamic responses and static properties and to participate in primary and secondary FM in power grid.

- Redundant XCU for basic control, including speed control, power control, and steam pressure control.

- Redundant XCU for ATC and stress control.

- Double configuration for channels for valve servo actuator position feedback signals (LVDT), elimination of potential safety hazard due to the fault caused by regulating valves when the LVDT is configured with a single channel.

- The intelligent valve servo drive card, servo valve actuator and computer servo control loop formed via valves on a one-to-one basis.

- Valve management, valve linearization, and conversion between single valves and sequence valves.

- For steam turbine valve tests, there are two modes: full stroke test and loosening test.

- Buffer technology for EH servo actuator oil motivators enables collision between the valve and the valve seat to be avoided in case of rapid closure of the valves.

- The EH system is equipped with an independent oil filtering system to allow for on-line oil circulation and oil quality control.

- Well-equipped EH system electro-hydraulic linkage test chamber and steam turbine, boiler, and power grid simulators, for fully functional and closed-loop simulation operation examinations.
6. DEH and ETS have passed the SIL3 certifications
7. Technical Performances of the DEH-V System

- **Speed control:**
  - Range: Turning-3600 rp/m
  - Precision: ±1 rp/m

- **The load control:**
  - Range: initial load-110% rated load
  - Precision: 0.5%

- **Droop:** 5% (3%-6% adjustable); local droop: stepless adjustable, ranging from 3% to 20000%

- **The delay rate:** ≤0.06%

- **Speed overshooting:** speed overshooting at load rejection < 7%

- **Reliability:**
  - computer MTBF > 150000 hours
  - EH MTBF > 50000 hours
8. Application Areas

- Various types of steam turbine control systems for thermal power stations: steam reheat unit, steam extraction, condensing unit, dorsal pressure unit, feed water pump turbine;
- Steam turbine control systems for nuclear power station
- The various grades of turbine unit control: control on feed water pump turbine, 25MW, 50MW, 100MW, 125MW, 130MW, 200MW, 300MW, 325MW, 330MW, 600MW and on turbine units with even larger capacities (including nuclear power steam turbine control);
- Industrial steam turbine control system: for turbines driving compressors, fans and pumps
- Hydraulic turbine control for hydraulic power station.
9. Technological advantages of Xinhua Group

Xinhua Group is China’s earliest manufacturer of DEH, EH, and DCS and has enjoyed high popularity in the domestic market for DEH, EH, and DCS. By independently developing control systems with entirely independent intellectual property rights, Xinhua Group has made enormous contributions to our country for the localization of DEH, EH, and DCS systems.

DEH-V system is a new generation of network-based digital control systems developed by Xinhua Group based on design, research and development experience and operation practice gained through China’s first set of AEH system in 1975 and its first set of DEH system in 1990.

The multi-layer and redundant structure of the DEH-V system ensures reliability of the steam turbine control system. With hardware designed with high reliability and embedded specialized control algorithms, redundant Ethernet communication network, and IE browser-mode interface, the system is suitable for control of large, medium and small turbine-generator units, an advanced steam turbine control system for power plants.

Xinhua Group is the only manufacturer in the world that produces both DEH and EH at the same time; each set of DEH and EH leaves the factory only after they have been debugged to ensure smooth start-up and operation of steam turbines.

(1) SIL3 certification

XDC800 platform-based DEH and ETS have passed the SIL3 certification.

(2) System design

- The hardware and software integration design: reducing spare parts and improving their maintainability.
- The redundancy design-communication network, controller, I/O module and power supply are all redundantly configured to ensure long-term reliable operation of the system.
- The open system: ready for seamless connection with other systems and plant-level supervisory information system SIS.
- Strong expansibility: the original hardware, equipment or software can be conveniently extended to expand their functionality so as to achieve integrated control on DEH, MEH, BPC and ETS for the Steam Turbine Island.
- High reliability: complete high temperature aging, and impact testing equipment and a high degree of redundancy, and the decentralized design lay a foundation for a system with high reliability.

(3) The system network

- The double-looped, redundant, and fault-tolerant highway has transmission rate up to 100Mbps and 640,000 bit/sec radio broadcast, leading to high real-time performance.
- High speed information network: effective triage between real-time data and non real-time data information ensures that real-time load remains constant to lower load rates on trunk networks, at the same time serving as a network channel for on-line maintenance for the system.
- The high speed I/O bus designed with redundancy has transmission rate up to 10Mbps and strong ability to take on stations; it is convenient for maintenance.
(4) Reliable hardware
- As all modules have been produced using SMT (surface mount technology), they have incorporated advanced technology, require low power consumption, and have high reliability.
- The operation station and process station are connected directly, with no server devices such as gateway in between to avoid communication bottlenecks.
- 1: 1 redundancy for XCU (controller), power supply, and communication network; and 1: N redundancy for human-machine interface station HMI (engineer station, operator station)
- XCU (controller), I/O and power supply can be charged hot-swappable and maintained on-line.
- All modules can be diagnosed to the module level.
- The module has passed the electromagnetic compatibility certification.

(5) Visual graphic configuration and programming software
- Advanced monitoring system: the all-Chinese window operation platform contributes to an efficient and convenient operation, computer training and easy maintenance.
- Operation guide, online testing, and process constraining mechanism strengthen accident analysis and operation guide for the entire DEH.
- All graphic and open configuration leads to what is seen is what is obtained: this is in line with the international IEC1131-3 design principles; there are various generic modules that can construct various state spaces and fuzzy control algorithms, leading to strong online Chinese annotation functions.
- It can truly achieve on-line configuration and online modification functions and possess virtual XCU, online and offline simulation functions.
- Powerful system online self-diagnosis functions.
- Seamlessly connection between and efficient integration of MIS and DCS systems.

(6) Training
- The simulated closed-loop joint adjustment; a unique full simulation system, which enables simulated closed-loop joint adjustment to be completed within the factory through simulation by DEH of real objects.
- Training for personnel that is in line with engineering design and debugging is available: classroom training, operational training, maintenance training and field training.

(7) Engineering ability
- There are 624 sets of Xinhua DEH control systems applied to various grades of steam turbines; 308 sets of MEH systems for feed water pump turbines; 74 sets of bypass control BPS systems; and 145 sets of steam turbine emergency trip ETS system.
- In the power industry and waste heat power generation industry, more than 600 sets of turbine DEH systems have been successfully put into operation. The company has a wealth of engineering design, commissioning, and operation capabilities.
- The visualizable graphic configuration software as well as the core technologies for the design and manufacture of various types of hardware, coupled with the advantages in professional application, engineering experience and technological advantages, enables the company to provide a variety of specialized solutions and professional services for steam turbines for thermal power stations, steam turbines for nuclear power stations, heat supply units, condenser units, steam extraction units, feed water pump turbines, and compressor turbines.

(8) Spare parts
- A specialized electronics production company, which possesses the capabilities to supply DEH systems on a long-term basis, provides free software upgrades, and has strong advantages in system maintenance and in prices of spare parts.
10. Cited Norms and Standards

(1) General standards

- The National Fire Protection Association (NFPA) of America
  ANSI/NFPA 70: National Electrical Codes

- The American Institute of Electrical and Electronics Engineers (IEEE)
  EIA RS-232-C: The Interface between Data terminal Equipment and Data Communication Equipment Using Serial Binary Data for Data Exchange

- The Instrument Society of America (ISA)
  ISA IPTS 68: Thermocouple Conversion Table
  ISA RP55.1: Digital Processing Computer Hardware Test

- The Scientific Instrument Manufacturers Association (SAMA) of America
  SAMA PMS 22.1: Functionally Graphical Representation of Instrumentation and Control Systems

- The National Electric Manufacturers Association (NEMA) of America
  ANSI/NEMA ICS4: Terminal Rows for Industrial Control Equipment and Systems
  ANSI/NEMA ICS6: Industrial Control Equipment and System Shells
  ANSI/NEMA ICS2: Standards for Industrial Control Device, Controllers and Components

- The United States of America Underwriters Laboratories (UL)
  UL 1413: Prevention of Television Cathode Ray Tube Implosion
  UL 44: Safety Standards for Rubber Wires and Cables

- The International Electro-technical Commission (IEC)
  IEC TC529 Basic Safety Standards: Classification of Shell Protection Grades
  AWS American Welding Society
  ICEA Insulated Cable Engineers Association
  NEPB Environmental Protection Bureau of America
  NEC National Electric Code of America
  HEI Heat Exchange Association
  ISO International Organization for Standardization
  TCP/IP Network Communication Protocol
IEEE 802 LAN Standards
China Standards GB
G-RK-95-51 Technical Specifications for Decentralized Control Systems of Thermal Power Plants
G-RK-98-54 Technical Specifications for Steam Turbine Control Systems of Thermal Power Plants
ANSI/ASME TDP-1-1985 Power Plant Steam Turbine Water Inlet protection Measures
DL/T 609-1996 Operation Guidelines for 300MW-level Steam Turbines

(2) Network communication
IEEE802.3/IEEE802.3n Power Station Electronic Engineers Association Ethernet Working Group
IEC61158 Technical Standards for Field Bus
IEC61850 Substation Communication System

(3) Software Engineering
GB/T 11457-95 Software Engineer Station
IEC-1131-3 Standards for Graphics in the Programmable Logic Control Language
GB/T15532-95 Specifications for Software Unit Test
GB/T12504-90 Specifications for Software Quality assurance
GB/T16680-96 Specifications for Software File Management
(4) EH high-pressure fire-resistant oil electro-hydraulic servo system

GB/T786.1-93 Graphical Symbols for Hydraulic Drive
GB3452.1-92 O-Shaped Rubber Seal for Hydraulic Drive Dimensions and Tolerances
NAS1638 Standards of American Institute of Aeronautics and Astronautics for Hydraulic Oil Contamination Levels
GB/T14041.1-4, ISO2941-3 Standards for Filter Structure Performance Tests
CCC/QD0277-2001 Specifications for Design of Oil Motivators

HB5024-89 Standards for Steel Castings for Use by Ministry of Aerospace Industry of the People's Republic of China in Aircraft

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