DEH-V

Turbine Digital Electro-Hydraulic Control System

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1 Functions of DEH-V

DEH-V Turbine Digital Electro-Hydraulic Control System (DEH) is the main production of Xinhua Control Engineering Co, Ltd. It is a DCS technology based & state-of-art system, having powerfull functions and high reliability. It is for the control various turbines mostly suitable for the unit capacities from 50MW up to 600MW. It emerging about the following functions:

1) Turbine Speed Control
To control turbine speed from impulse starting to synchronizing, and maintain in the rated speed after load rejection

2) Automatic Synchronizing Control (AS)
After the turbine reaches its operating speed (eg 3000 RPM), DEH regulates the turbine speed to a synchronizing speed based on the input signals from a synchronizing device, and makes the turbine ready for synchronizing

3) Load Control
After synchronization of the unit, DEH regulates the governor valves (GV) to control the load of the unit.

4) Frequency Regulation
If required, DEH can take the turbine to participate in primary frequency regulation of power grid. Operator can adjust the speed droop If the unit is not required to primary frequency regulation, the operator can easily switch off the function by pressing the function push button.

5) Coordinated Control
DEH can receive load requirement from CCS subsystem of DCS and then regulation the turbine-generator megawatt output In the case, the unit is operating in the turbine-boiler coordinated control mode.

6) Runback
DEH provided three different rates and limits of fast decreasing load in the occasion of the unit accessory equipment failure The parameters for runback can be modified on site.

7) Main Steam Pressure Control (TPC)
DE well provided pressure low protection and pressure regulation functions.

8) Multi-valve (sequence valve) Control
DEH can regulatiothe strokes of all the governor valves, which is the so-called valve administration function. With this function, operator can switch the turbine to single valve control mode and

multi-valve control mode operation, ie throttle governing and ray governing.

9) Valve tested
All valves and their control loops can be checked on line.

10) OPC Control
Turbine over-speed protection and over-speed protection testing.

11) Turbine Automatic Control (ATC)
In this operating mode, the whole start up process of turbine proceeds automatic. DEH monitors running parameters during turbine start up process, calculated the heat stress of the turbine rotor, and automatically set up the target speed, speed-up rate and load-up rate based upon the calculation results The rotor heat stress can be controlled within detailed limits and the turbine lifetime can be prolonged this way. Based upon the ATC logic, DEH automatically bring the turbine through turning gear, impulse starting, warming up, transport of valves, synchronizing till completion of start up after the operator, the operator gives the goal load, then ATC control turbine to the goal automatically, according to the turbine stress and running parameters and states of the unit.

12) Match the Start-up modes for various turbine
DEH-V can satisfy the turbine's start-up modes, for example using HP start up or IP start-up modle.

13) Manual Control
DEH-V provides manual control function as a backup control mode in case of DEH main control device failure.

14) Redundancy
Sufficient redundancy is adopted in the DEH design, such as supers processors , power supplies and factors modules and hydraulic devices.

15) Communication with other system
A gateway is provided as an interface to DCS for data communication in case of different DCS hardware used for boiler control (if the same hardware is used for both turbine control and boiler control, i e. XDPS-400, a distributed processing system manufactured by Xin Hua Control Engineering Co., Ltd., then the gateway is not necessary.

2 System Structure

The DEH-V consists of the following hardware components:

1) Control Cabinets

Cabinet No.01: Basic control cabinet, housing one redundant DPU (processor) and 3 I/Ostations, including valve control and OPC.

Cabinet No.02: Terminal cabinet for basic control.

Cabinet No.03: ATC control and supervision cabinet, housing one redundant DPU and 2 data acquisition stations

Cabinet No. 04: ATC terminal cabinet.

ATC Cabinets in assembly in front of the turbine capacity exceeds 200MW.

2) Operator Station (OPU)

One operator station often an IPC, 21 "color CRT (or LCD), printer, etc. The operator station uses a windows environment and high-resolution graphics to perform operation functions. The operator station drivers operators with process data, system diagrams, control flow diagrams, alarms, trends, bar charts, historical data storage and retrievals It is the man-machine interface (MMI) of DEH-VThe

3) Engineer Station (ENG)

One engine station normally the same hardware of the OPU, maybe a smaller color CRT (LCD), color ink jet printer The engineer station uses a windows environment and high-resolution graphics to perform engineering, operation, maintenance functions. Application software of all devices in the DEH-V may be developed, loaded and maintained. It can function as either an engineer station or an operator station.

4) Manual Operation Panel (user selectable, we suggest not required)

Manual operation is a backup control mode of DEH-VThdThe operator can operate (raise or lower) the valves in case of DPU failure or OPU failure.

5) Electro-Hydraulic Device (EH)

Including:	EH fluid supply system	1
	Throttle valve HP actuator	according to
	Governor valve HP actuator:	according to
	Main stop valve IP actuator	according to
	Governor valve IP actuator	according to

EH blocks of over-speed protection (OPC) and emergency trip (AST)

3. DEH-V Software

Four software packages are provided along with DEH-V, ie operator software, engineer software, ATC software (optional) and basic control software.

1) Engineer Software

Engineer station runs on the engineer software based upon Windows platform and communicates with other drop devices in DEH-V via data highway. It runs following software:

The created application software can be downloaded on-line or off-line to the operator station and DPU's. All configured algorithms are automatically stored in flash memory (RAM) in DPU. On the engineer station we can access all real time signals and system data.

2) Operator Software

Operator station runs on the operator software based upon Windows platform. The operator software includes communication drive, display, print out, operation processing and log blocks. The display block performs various displays functions, such as, graphics, bar charts, valve groups, trends, etc. The print out block provides graphic prints, curves prints, retrieval prints, log prints and schedule prints. The operation-processing block performs display processing, parameter arrangement, mouse operating and operating commands, and sends the control commands to the basic control DPU for turbine control.

3) Control Software

It provides I / Oscanning, control strategies, communication drive, commands processing, tracking and transfer between master processor and back up processor. All these software blocks share the data in local real time database, and interact to fulfill the control tasks.

The tracking and transfer software can transfer the control mode from primary processor to the back up processor bumplessly when the primary processor fails.

ATC software provides the algorithms for the calculation of rotor heat stress.

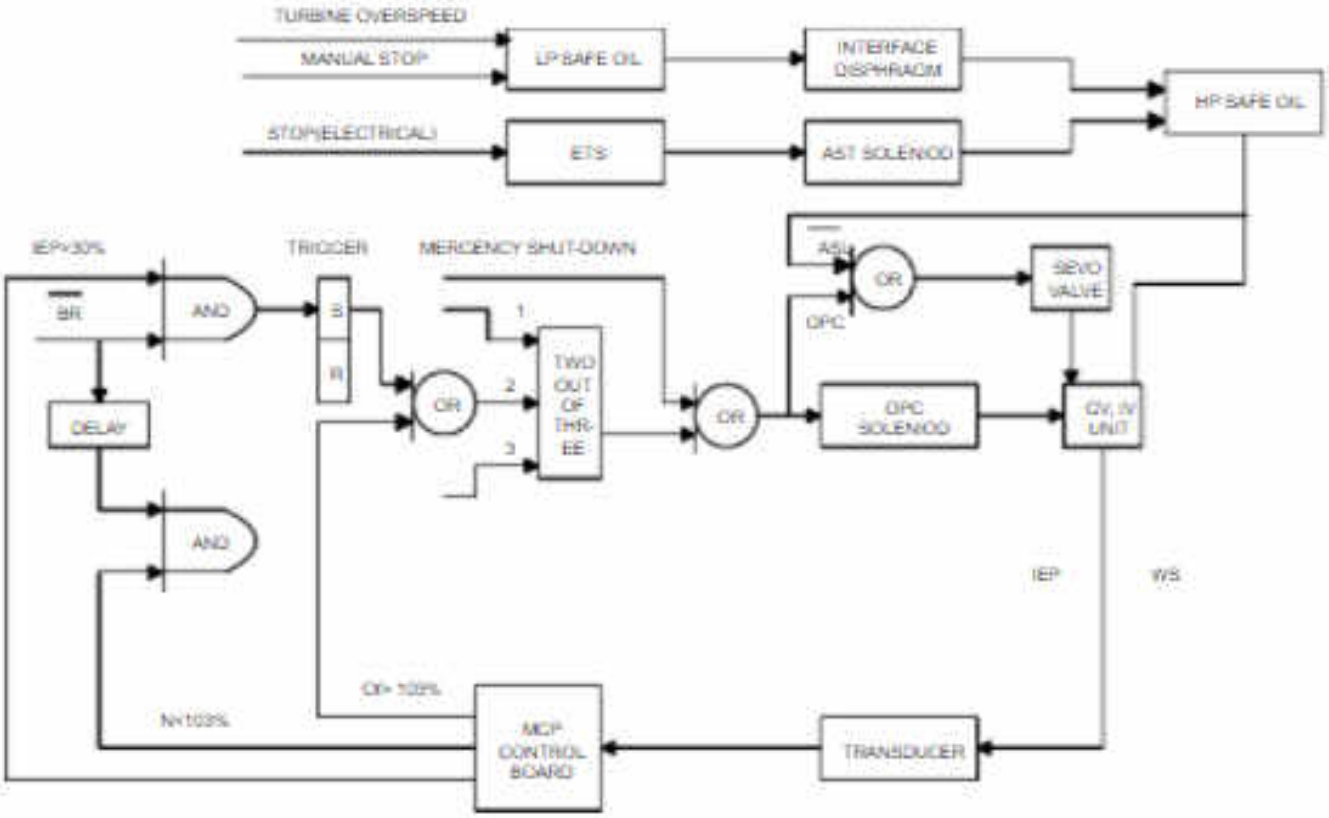
4) Communication Drive Software

There are four types of stations (drops) in DEH-V system, i. e. engineer station, operator station, basic control station and ATC station. The interchange of data among the stations is realized via redundant data highway (network). Each station has its own data communication drive software by which real time signals and configuring data can be transmitted and received.

Communication drive software performs signal packing, transmitting, receiving, unpacking functions. It also runs on Windows platform and use the same protocol with other software blocks.

4. Over-speed Protection System (OPC)

In order to guarantee the reliability of the turbine over-speed protection function, Following conditions will trigger OPC system:

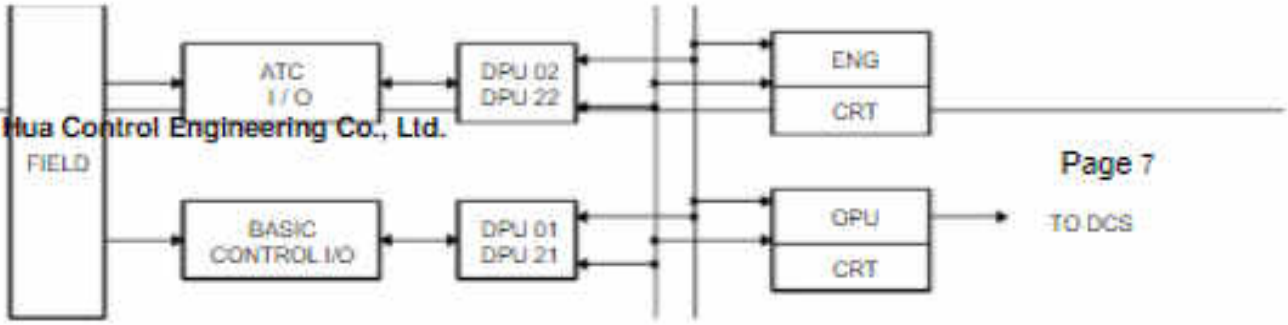


1)In any case that the turbine speed exceeds 103% of rated speed, the GV and IV will be closed till the speed is less 103% (n<103%).

2)When the intermediate discharge pressure (IEP) is greater than 30% of rated pressure, that means the turbine is running at the load exceeding 30% of rated load, and at same time the main breaker reject the unit from grids, the OPC system will send a command to close the GV and IV. After a delay of 5~10 seconds the speed runs down to a level less than 103% of rated speed, the trigger reset.

The OPC system adopts two-out-of-three design to secure the system reliability.

In addition to the above, OPC signals or the ETS triggering signals can be sent to the servo control loops directly, and then DEH servo control system will shut down the valves to prevent turbine over-speed. The shutdown signal from ETS will trigger AST solenoid valve control block to shut all valves immediately. The valve shutdown time though the OPC or AST loop is 0.15 second, which prevents turbine's over-speed effectively.



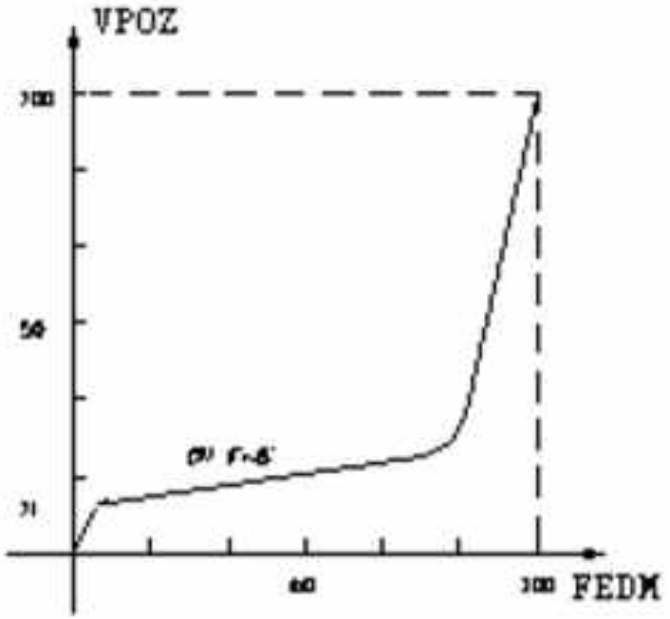
There are two control modes corresponding to the operation requirements of turbine.

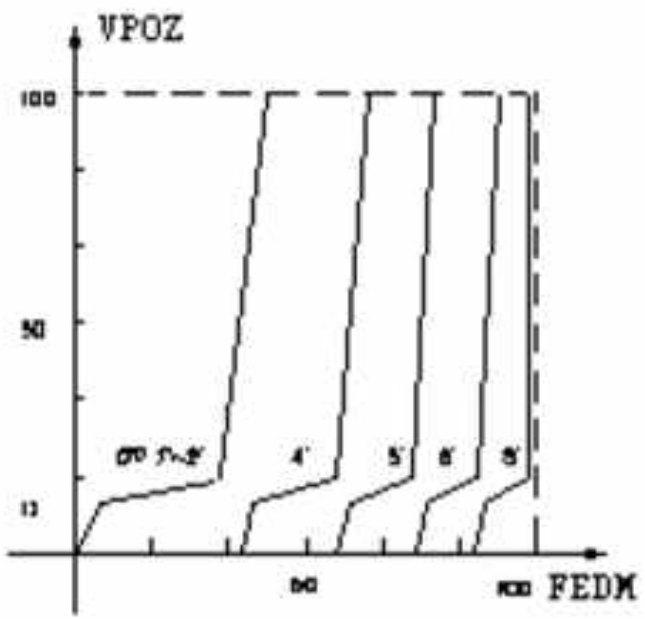
---Single valve operation

In this control mode, all governor valves are opened with same stroke, like a single valve. We call it single valve control mode or throttle control, which allows full arc steam admission.

---Multi-valve Control

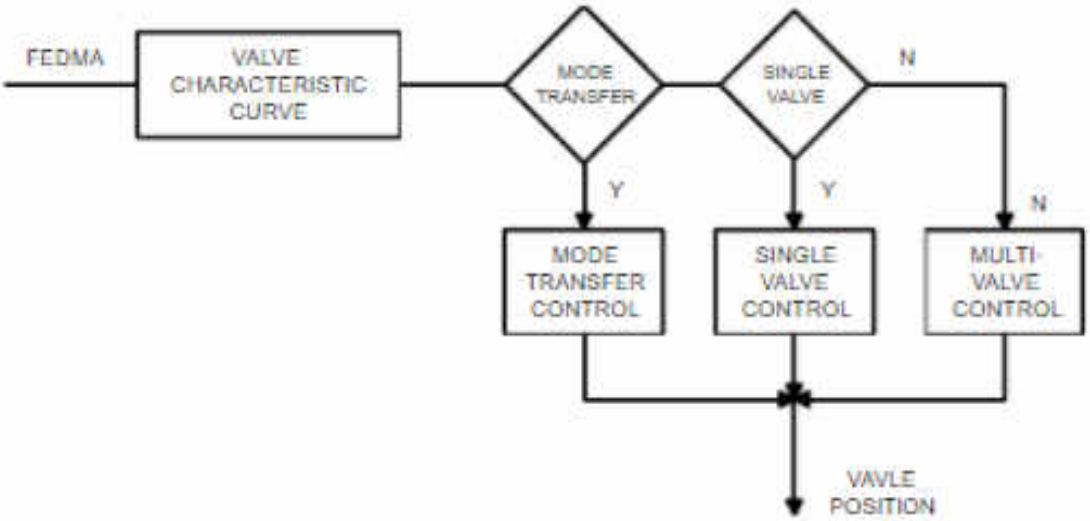
In this control mode the governor valves are opened in a predefined sequence. The total steam flow rate increases linearly. We call it multi-valve control mode or nozzle control, which allows partial-arc admission.





Generally, turbine cold startup and/or base load operation requires single valve control mode, i.e. full arc steam admission. While the unit runs with partial load, it is desirable to use multi-valve control mode, i.e. partial-arc admission, to improve unit efficiency. The two control modes can be transferred bumplessly.

The valve administration is realized through a specific software program.



There are pushbuttons on DEH-V control panel respectively for single valve control, multi-valve control. When operator presses the button, it takes 2~3 minutes to complete a bumpless transfer from single valve control mode to multi-valve control mode, or vise versa.

9. Automatic Turbine Control (ATC)

DEH-V provides ATC function. ATC is an abbreviation for Automatic Turbine Control.

When turbine starts up or experiences a load change, there exist in the turbine a steam temperature change and great internal temperature difference. The rotor may be subjected to significant heat stress in these cases. After many time circles of load increase and decrease, the turbine will be damaged because of heat fatigue. ATC function can control and ensure the turbine's lifetime. Xin Hua has developed a special ATC calculation program lifetime control curves.

Through ATC I/O channel in DEH cabinet the control program detects temperatures of different places in turbine and calculates HP and IP rotor's actual stress and compare with the permitted stress, then gets the difference. The difference can be transferred to speed or load demand and their changing rate to control turbine speed acceleration and load change through DEH. In the whole changing process, the closed-loop auto-control is performed and the rotor stress can be controlled in a permit range.

ATC settles the stress in closed-loop auto-control, besides, it has a perfect logic control and interlock loops to perform turning gear, warming up, valves transfer and synchronizing, etc. ATC can also monitors various safety parameters such as turbine's eccentricity, differential expansion, vibration, bearing metal temperature, axial displacement and generator's cooling system, etc.
ATC control task consists of a dispatching program and 16 periodic subroutines. Each fulfills different function.

10. Redundancy

DEH-V is designed to accommodate multiple levels of redundancy.

- Functional processor, redundant DPU;
- Redundant power supply;
- Redundant data highway;
- Redundant I/O module communication card;
- Redundant OPC solenoid valves;
- Redundant AST solenoid valves;
- Redundant drive fluid supply loops;
- Two-out-of-three signals
  - Transducers for speed sensing, megawatt sensing, main steam pressure sensing and regulation stage pressure sensing are triply configured. Three signals enter the DPU simultaneously and two-out-of the three will be used in the control loops.
  - Important contact signals, such as reset and synchronizing signals, come through three independent I/O cards and the two-out-of-three logic inside DPU before they are used in control loops.
  - OPC control loop is a two-out-of-three system.

11. Electro-hydraulic (EH) System

The Electro-Hydraulic (EH) system consists of fluid supply device, actuators and emergency trip facility (see attached drawing - EH system). The fluid supply device provides high-pressure fire resistance fluid to drive the servo actuators. The actuators respond to the commands from DEH-V processors and regulate the strokes of steam inlet valves. The emergency trip facility shuts down all valves in emergency conditions according to the trip parameters. When one of these parameters exceeds the operating limit value, the facility will shut all the steam inlet valves, or only shut the regulation valve, as the case may be.

11.1 Fluid Supply Device

The fluid supply device consists of fluid supply apparatus, fire resistant fluid polishing assembly and other EH components on the fluid piping. The fluid supply apparatus provides pressurized fluid required to drive actuators. It consists of fluid reservoir, fluid pumps, control block, fluid filters, magnetic plugs, relief valves, accumulators, heat exchangers, EH terminal box, some standard instruments for the alarm, indication and control of fluid pressure, fluid temperature, fluid level, one set of self-circulation fluid filter system and one set of self-circulation cooling system.

The requirement for power supply of fluid supply apparatus:
–Two sets of main fluid pumps: 30KW, 380VAC, 50HZ, three-phase
–One set of fluid filter pump: 1KW, 380VAC, 50HZ, three-phase
–One set of cooling fluid pump: 2KW, 380VAC, 50HZ, three-phase
–One group of electric heater: 5KW, 220VAC, 50HZ, single-phase

11.1.1 Working Process

The EH fluid is sucked by HP plunger oil pump from fluid reservoir via pump suction strainer. The pressurized fluid discharged from the pump through HP filter and check valve flows into the HP accumulators. The HP piping connecting with the accumulators sends the HP fluid to each actuator and emergency trip system.

The output pressure of fluid pump can be freely set in the range of 0~21Mpa. The normal working pressure is set from 11.0~15.0Mpa.

The relief valve will be activated when the fluid pressure in the HP header piping reaches 17 ±0.2 Mpa, and fulfill the over pressure protection function.

The drain from each actuator through pressurized drain piping, 3 mm filter and heat exchanger flows into reservoir.

The pressure switch on the HP header 63/MP, 63/HP, and 63/LP can startup the stand-by pump automatically and make alarm when the fluid pressure is off normal value. A reservoir temperature controller is equipped at the discharge piping end of heat exchanger. In the reservoir the measuring point for fluid temperature too high alarm and apparatus for fluid level alarm and trip are also equipped. The fluid level indicator is assembled on the side plate of reservoir.

11.1.2 EH fluid tank

The design capacity of the reservoir is 900 liter. Considering some water in the fire resistance fluid is corrosive to carbon steel, the reservoir is made of stainless steel.

There are fluid level switches (fluid level alarm and trip), magnetic plug, air purifier (also as fill assembly), control block and other EH components on reservoir cover. Besides, there is one group of heaters equipped under the reservoir bottom. It is necessary to electrify the heaters and heat the EH fluid when the fluid temperature is below 20 C^{O}.

11.1.3 Fluid Pumps

To maintain stable operation and decrease noise, the HP plunger pumps are used. In order to raise the reliability of fluid supply system, a redundant configuration is adopted, that is, one pump is in operation and the other is in standby condition. The two pumps are mounted beneath the EH fluid reservoir to ensure position suction.

11.1.4 Accumulator

A HP accumulator is mounted aside reservoir to maintain the pressure of relief valve and prevent it from vibration. The accumulator is connected with fluid system via an accumulator block with two shutoff valves mounted. These two shutoff valves are used in combination. They can isolate the accumulator from the system and release the HP fluid in the accumulator.

11.1.5 Heat Exchanger

Two heat exchangers are mounted on the side of the reservoir. The cooling water flows through in its tubes while the system fluid flows around the bundle in the shell. The cooling water flow quantity is controlled by temperature control valve at the exit of circulation cooling water in the heat exchange. Users shall provide cooling water with temperature lower than 35 $C^{\circ}$to the DEH-V.

11.1.6 Temperature control Circuit

The signal from the thermal switch (20/CW) controls the thermal relay to operate solenoid water valves. When the fluid temperature in the reservoir exceeds upper limit 55 °C, the temperature control valves will open and the cooling water flows through the heat exchanger to cool the fluid. When the fluid temperature falls to lower limit 38 °C, the control valves will close.

11.1.7 Fire Resistance Fluid

The drive fluid is fire resistance fluid. The normal working temperature of the fluid is from 20 °C to 60 °C.

In view of the special physical features of fire resistance fluid of organic phosphate type, all the sealing materials of the system are fluorine rubbers. The metal materials adopt stainless steel 1Cr18Ni9Ti as much as possible.

The physical and chemical properties of original EH fluid:

Viscosity (ASTMD 445-72)	98.9 °C (Saybolt) 43 s. (5mm^2/s)	
	37.8 °C (Saybolt) 220 s.(47mm^2/s)	
Acid Number (mg KOH/g)		0.03
Max. Foaming (Foam ASTMD)	892-72ml	10
Viscosity Index		0
Max. Colourity (ASTM)		1.5
The Specific Gravity 60 °F (16 °C)		1.142
Max. Water Content Wt %	0.03	
Max. Chlorine Content (X-ray Fluorescence Analysis)	20	
Particle Distribution NAS 5 grades or (SAEA-6D) Tentative	2	
Hydrolytic Stability (48 hrs.)		pass

Min. Resistivity OHM/cm		$12 * 10^9$
Min. Flashing Point		455°F (235°C)
Fire Point		665°F (352°C)
Auto-Ignition Temperature		1100°F (594°C)
Air Entrainment	(ASTMD 3427)	minutes
Expansion coefficient	at 100 F°(38 C°)	0.00038 1.0

11.1.8 Polishing filter assembly

The polishing filter assembly is used to store absorbent and condition the EH fluid (maintaining the fluid neutralization number and removing water particles etc). The assembly mainly consists of Fullers Earth filter and fine filter (cellulose filter).

A cellulose filter is connected in series with a diatom earth filter. They are located downstream independent circulation filter piping line.

A pressure gauge is assembled on each filter. When the gauge indicates abnormally high pressure, servicing of the filter is required. The filter cartridge of both filters can be replaced. When the shutoff valve in the line closed, the filter cover can be dismounted to replace the filter cartridge. If the pressure in either filter rises to 0.21Mpa with EH fluid temperature between 43°C ~54°C, the filter cartridge should be replaced.

11.2Self-Circulation Fluid Filter System

When the unit is in normal operation, the efficiency of fluid filtering is low. So the EH fluid quality will drop after a period of unit operating time. To maintain the fluid quality the turbine must be shutdown so to re-circulate the fluid. So as not to influence the normal operation of unit and ensure the cleanness of the EH fluid supply system as to improve and lengthen the reliability of system operation as well, an independent self-circulation fluid filter system is provided to EH supply system. The circulating pump sucks EH fluid from reservoir, through two filters with filtering precision 1 m m then returns to reservoir. The pump can be started up or shut off directly by the control button on ER terminal box. The flow rate of the pump is 20 l / m.

11.3Self-Circulation Cooling System

Except the normal returning fluid cooling system in EH fluid supply device, an independent self-circulation cooling system is also provided. In the case of abnormal operating state the temperature of reservoir can be controlled in the range of normal working temperature.

The cooling pump can be controlled by the temperature switch 23/CW, and also can be controlled by operator to manually start up or shut off it. The flow rate of the pump is 50 l/m.

11.4 Actuators

The EH servo actuator is one important component in DEH-V control system. For exemlpe, there are 10 actuators in a typical 300MW/600MW turbine control system. They respectively control the stroke of two HP throttle valves, four HP governing valves, two reheat main steam stop valves and two interceptor valves in a typical 300MW/600MW turbine control system.

11.4.1 HP Governor Valve Actuator and IP Governor Valve Actuator

These two type of actuators are control type. The steam valves can be controlled on any mid position to regulate steam entrance flow proportionally to meet the operation requirements.

11.4.2 Reheat Main Steam Stop Valve Actuator

This actuator is open-close type and the valve is working at either full open or full closed position.

11.4.3 HP Main Steam Stop Actuator

This actuator is servo control type actuator and controls the steam valve at any mid position while governing the steam entrance rate proportionally to meet the operation requirements

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11.5 Emergency Trip System

In order to prevent the turbine in operation from major damage due to the malfunction of some equipment, an emergency trip device is provided. In abnormal conditions, it trips the turbine so that the turbine is protected in safety. The emergency trip device monitors certain turbine parameters and closes all turbine steam inlet valves when the operating limits of these parameters are exceeded.

12. Specifications

- Speed Control: 20 ~ 3500 RPM Accuracy: ± 1 RPM
- Load Control: 0 ~ 115% of rated load Accuracy: ± 0.5 %
- Speed Droop: 3 ~ 6 %
- Dead Band: < 0.06 %
- Over-speed: < 107 % of rated speed
  (When turbine rejects load from rated condition)

13. Codes and Standards

DEH-V complies with the following codes and standards:

ANSI/IEEE 472	Guide for Surge Withstand Capability (SWC) Tests
ANSI/IEEE 488	Digital interface for Programmable Instrumentation
EIA RS-232-C	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
ISA IPTS 68	Conversion Tables for Thermocouples
ISA RP 55.1	Hardware Testing of Digital Process Computers
SAMA PMS 22.1	Functional Diagramming of Instrument and Control Systems
ANSI / NEMA ICS4	Terminal Blocks for Industrial Control Equipment and Systems
ANSI / NEMA ICS6	Enclosures for Industrial Control and Systems
UL 1418	Implosion protected Cathode Ray Tube for Television Type Applications
UL 44	Safety Standards for Rubber Installed Wires and Cables

Attachments:

1 DEH-V Control System Diagram

2 A Sketch of DEH-V Hydraulic Device