PLANT START-UP AND SHUT-DOWN
SEQUENCE DESCRIPTION

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1.0 GENERAL

This document is to describe the overall start-up and shut-down sequence of a Combined Cycle Power Plant. The detailed start-up and shut-down sequence of equipment and unit systems shall be described in the relevant documents of the equipment and the unit systems.

Only details described herein are the automatic start-up and shut-down sequences of power block which are not described elsewhere.

The power block consists of GTG’s, HRSG’s and STG.

Except the power block, all auxiliary systems including system filling, electrical and I&C system are started up or shut down step by step manually by the operators in control room and local as required. The operation of each auxiliary system is automated as described in relevant system description.

This sequence assumes that the plant fire fighting system is always in operation.
2.0  **Plant Start-up SEQUENCE**

2.1  **Plant Start-up Preparation Sequence**

2.1.1  **Energizing of Electrical and I&C System**

Energizing of plant electrical, instrumentation and control system shall be performed by receiving start-up electricity from the grid. Electricity export system to the grid shall be made as ready, too.

Details of energizing sequence and making electricity export system ready shall be described in separate documents.

2.1.2  **Check of Plant Battery Limit(BL) Conditions**

The following conditions should be satisfied for start-up.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>At BL of fuel gas system</td>
<td>Main shut-off valve open</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At BL of raw. water system</td>
<td>Pressure &gt; Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.1.3  **Start-up of Cycle Make-up System**

Permissive : Demi. water storage tank level > Low - Low

If filling is required, cycle make-up system shall be started first.

If filling is not required, the start-up of cycle make-up system shall be performed after the operation of compressed air system.

Operation of cycle make-up system shall be confirmed by the following conditions.
2.1.4 Filling

Permissive: Cycle make-up system in Operation

If the liquid level of tanks, vessels and basins is lower than those required, filling shall be performed to the levels for start-up.

Details of filling sequence shall be described in the operation manual of equipment and the system description of auxiliary systems.

The filling shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas Supply Line</td>
<td>Gas pressure in normal pressure</td>
<td></td>
<td>Substitute nitrogen filled fuel gas line with natural gas</td>
</tr>
<tr>
<td>HRSG HP drums</td>
<td>Level ≥ Start-up level</td>
<td></td>
<td>Start-up level shall be defined by HRSG supplier.</td>
</tr>
<tr>
<td>HRSG IP drums</td>
<td>Level ≥ Start-up level</td>
<td></td>
<td>Start-up level shall be defined by HRSG supplier.</td>
</tr>
<tr>
<td>HRSG LP drums</td>
<td>Level ≥ Start-up level</td>
<td></td>
<td>Start-up level shall be defined by HRSG supplier.</td>
</tr>
<tr>
<td>Condenser hotwell</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulating water pump pit</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed cooling water head tank</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw water storage tank</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demi. water storage</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment/System</td>
<td>Condition</td>
<td>Tag No.</td>
<td>Remarks</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>tank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel oil day tank of diesel engine fire water pump</td>
<td>Level &gt; Low</td>
<td></td>
<td>Local panel</td>
</tr>
<tr>
<td>Diesel oil day tank of emergency diesel engine generator</td>
<td>Level &gt; Low</td>
<td></td>
<td>Local panel</td>
</tr>
<tr>
<td>Main cycle chemical solution tanks</td>
<td>Level &gt; Low</td>
<td></td>
<td>Local panel</td>
</tr>
<tr>
<td>Sodium hypochlorite tank</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condenser vacuum pump separators</td>
<td>Level &gt; Low</td>
<td></td>
<td>Local panel</td>
</tr>
<tr>
<td>GTG lube oil tanks</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STG lube oil tank</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aux boiler drum</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂, CO₂, N₂ Gas Storage System</td>
<td>Gas pressure in normal pressure</td>
<td></td>
<td>Local Gauge</td>
</tr>
</tbody>
</table>

Before filling, it is required to assure whether all manual drain valves for emptying of system lines are closed and all instrumentation root valves are manipulated for filling. Vent valves are closed manually after confirmation of filling by local operators.

### 2.1.5 Waste Water Transfer System

All sump pumps shall be READY and set to AUTO mode at local control panel.

It should be also confirmed that the waste water treatment plant is ready to operate and receive the waste water from the power plant.

### 2.2 Plant Base Utility Start-up Sequence

#### 2.2.1 Start-up of Aux. Circulating Water System

An aux. circulating water system shall be started in order to supply cooling water to closed cooling water system, especially for supplying cooling water to air compressors and seal water coolers of vacuum pumps. In order to prevent the aux. circulating water pump from operation under its minimum flow, the water flow circuit to closed cooling water heat exchangers shall be secured.
Operation of aux. circulating water system shall be confirmed by the following conditions. Prior to aux CWP running, pump chamber traveling screen system shall be ready to operate in order to screen seawater.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aux circulating water pump chamber water level</td>
<td>Level &gt; Low Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One aux. circulating water pump</td>
<td>Running</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Discharge pressure &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulating water chemical feed system</td>
<td>Operating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2.2 Start-up of Closed Cooling Water System

After start-up and operation of aux. circulating water system, the closed cooling water system shall be started to supply cooling water to equipment coolers including air compressors.

Operation of closed cooling water system shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>One closed cooling water pump</td>
<td>Running</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Discharge pressure &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One closed cooling water heat exchanger</td>
<td>- Discharge temperature &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Discharge temperature &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed cooling water head tank</td>
<td>Level control valve in AUTO mode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2.3 Start-up of Compressed Air System

Permissive: Closed cooling water system in Operation

After start-up and operation of closed cooling water system, the compressed air system shall be started to supply compressed air to the plant, especially instrument air to control valves.
Operation of compressed air system shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>One air compressor</td>
<td>AUTO mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed air system</td>
<td>- Common header pressure &gt; Low</td>
<td></td>
<td>- No system common alarm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2.4 Start-up of Fuel Gas System

Permissive: Natural gas pressure at BL > Low

Compressed air system in Operation

Natural gas system shall be started to supply fuel to GTG’s.

Operation of natural gas system shall be confirmed by the following conditions.

1) Fuel Gas Side Lined-Up

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shut-off valve for main supply header</td>
<td>Valve Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent valve for main supply header</td>
<td>Valve Close</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shut-off valve for unit supply</td>
<td>Valve Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent valve for unit supply</td>
<td>Valve Close</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel gas particulate filter</td>
<td>Upper Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel gas heater</td>
<td>Upper HTR Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower HTR Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel gas scrubber</td>
<td>Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel gas drain tank</td>
<td>Drain pot level &lt; High</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Heating Water (IP Feedwater) Side Lined-Up
Step 1
Prior to the initiation of a GT/HRSG startup, the feedwater supply isolation valve, heater inlet isolation valve, heater outlet isolation valve and feedwater return isolation valve are closed. The temperature control valve is held closed by an interlock. The feedwater supply line vent valve and feedwater return line vent valve are open to allow any gas leak to feedwater system to vent out. The temperature set point is 48 deg.C and ramp rate is 1.1.deg.C/sec of set point after IP economizer is in service.

Note
Before GT/HRSG startup, heater inlet isolation valve and heater outlet isolation valve shall be closed until the feedwater temperature is cooled down. If these valves are open without enough cooled down, hot feedwater will be flashed and gas detection bridle pipe located at heater top needs to be vented before plant start-up.

Step 2
Once the feedwater system (boiler feedwater pump) is in operation, heater inlet isolation valve is closed. Feedwater supply isolation valve is opened initiating feedwater flow through the vent line to purge the vent line through feedwater supply line vent valve. After a short second delay, the feedwater supply line vent valve is closed and then the heater inlet isolation valve and Heater outlet isolation valve are open to initiate water to the heater. Purging will occur via flow through the Heater outlet isolation valve and the feedwater return line vent valve. After short second delay after the heater inlet isolation valve and the heater outlet isolation valve are open, the feedwater return line vent valve will be closed and the feedwater return isolation valve is opened aligning the vent and isolation valves for normal operation.

Step 3
Flow is established by automatic opening of the fuel gas temperature control valve to a pre-set minimum flow control position once the following conditions are satisfied AND maintained.
- Feedwater is operation AND
- Condensate System is operating AND
- The valves are lined up

Note
In no case the fuel gas temperature exceeds the preset 48 °C other than Fuel
Gas Performance Heater Permissive Signal pick up. Start up with feedwater higher than 48 °C [120 °F], the fuel gas temperature control valve shall be closed before gas turbine startup.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedwater supply isolation valve</td>
<td>Valve open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedwater supply line vent valve</td>
<td>Valve closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heater inlet isolation valve</td>
<td>Valve open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heater outlet isolation valve</td>
<td>Valve open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedwater return line vent valve</td>
<td>Valve closed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedwater return isolation valve</td>
<td>Valve open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel gas temperature control valve</td>
<td>Minimum Open Position when feedwater temp &lt; 48 °C</td>
<td></td>
<td>Activation of Temperature control deferred till Feedwater system, Condensate system in operation.</td>
</tr>
<tr>
<td>Fuel gas heater</td>
<td>HTR upper channel bridle level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HTR lower channel bridle level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedwater bridle pipe</td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2.5 Operation of Auxiliary Steam System

The operation of the auxiliary steam system is required to supply steam to the plant steam users, such as condenser/HRSG sparging system, STG warming system, STG gland seal steam system, etc.

Normal steam source of auxiliary steam system is the cold reheat steam system of the Unit and an auxiliary boiler has been provided for cold start-up of entire power plant.

The auxiliary steam system is common for both Units. Therefore, if one Unit operating, the auxiliary steam for the start-up of the other Unit can be supplied from the Unit operating.

If the first Unit was being started up, start-up of auxiliary boiler is required for supplying
steam to the auxiliary steam system.

Operation of the auxiliary steam system shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxiliary steam header</td>
<td>Pressure &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature &gt; Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The start-up sequences and start-up ready list of auxiliary boiler shall be described in a separate document to be prepared by auxiliary boiler supplier.

Before the start-up of the auxiliary boiler, the following permissives should be satisfied.

Permissive:  
- Closed cooling water system in Operation
- Fuel gas supply system in operation
- Cycle make-up system in Operation
- Compressed Air system in Operation

**2.3 Plant Auxiliary System Start-up Sequence**

After closed cooling water system and compressed air system are in operation, the following systems shall be started regardless of the order of description below, as long as the permissives are satisfied.

**2.3.1 Start-up of Circulating Water System**

Circulating water system shall be started in order to supply cooling water to condenser.

Operation of circulating water system shall be confirmed by the following conditions.

Prior to CWP running, pump chamber traveling screen system shall be ready to operate in order to screen seawater.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulating water pump chamber water level</td>
<td>Level &gt; Low Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One circulating water</td>
<td>Running</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Plant Start-up and Shut-Down Sequence

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pump</strong></td>
<td>- Discharge press. not Low(&gt; Low)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Discharge MOV “Open”</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condenser</strong></td>
<td>- Inlet valve Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Outlet valve “Open”</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Circulating water chemical feed system</strong></td>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Condenser tube cleaning system</strong></td>
<td>Intermittently operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Debris Filter</strong></td>
<td>Intermittently operating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 2.3.2 Start-up of Condensate System

**Permissive**: Compressed air system in Operation

Demin. water system in Operation

Condensate system shall be started for:
- providing gland steam condenser with cooling water,
- providing seal water to water seal valves and
- supplying the condenser condensate to HRSG.

Operation of condensate system shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condenser</strong></td>
<td>Level &gt; Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>One condensate pump</strong></td>
<td>Running</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Min. flow control valve in AUTO mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Condenser level control valve in AUTO mode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PLANT START-UP AND SHUT-DOWN SEQUENCE

Equipment/System | Condition | Tag No. | Remarks
--- | --- | --- | ---
- | Condensate dump control valve in AUTO mode | | |
- | Discharge pressure > Low | | |

Operation of condensate system does not mean the condenser is in operation. Condenser in operation shall be confirmed during the automatic start-up sequence of power block.

### 2.3.3 Start-up of Feed Water System

Permissive: Compressed air system in Operation

Condensate system in Operation

Closed cooling water system in Operation

HRSG LP drum level NOT Low

FW Pumps lube oil system in service

Feed water system shall be started to supply feed water for HRSG’s.

Operation of feed water system shall be confirmed by the following conditions.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed water pumps</td>
<td>Running</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP feed water presssure</td>
<td>Disch. Press. &gt; Low</td>
<td></td>
<td>HP Eco. Inlet Pressure (HP steam system by HRSG Vendor)</td>
</tr>
<tr>
<td>IP feed water presssure</td>
<td>Disch. Press. &gt; Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.3.4 Bypass System(HP and HRH) Ready for Operation

The bypass system shall be ready for operation according to the procedure prepared by the bypass valve supplier.

The bypass system shall not be activated at this stage and activated when the condenser pressure is low enough to accept bypass steam during the automatic start-up sequence.
of power block.

2.4 Power Block Start-up Sequence

The power block equipment consisting of GTG’s, HRSG’s and STG, shall be placed on readiness for automatic start-up.

2.4.1 GTG on Barring Gear Operation

Permissive: Compressed air system in Operation
Closed cooling water system in Operation

GTG auxiliary systems, such as lubricating oil system, hydraulic oil system, gas fuel system, inlet air system, etc., shall be started and/or put into ready-to-start status, and then finally GTG shall be placed on barring gear operation for start-up.

The start-up sequences of GTG auxiliary systems and the start-up ready list of GTG’s shall be described in a separate document to be prepared by GTG supplier.

2.4.2 HRSG on Ready to Start

Permissive: Compressed air system in Operation
Closed cooling water system in Operation
Condensate system in operation
Feed water system in operation

HRSG’s shall be placed on ready to start according to the procedure prepared by HRSG supplier.

Readiness of HRSG’s for start-up shall be confirmed by the following conditions, which shall be finally confirmed by HRSG supplier.

<table>
<thead>
<tr>
<th>Equipment/System</th>
<th>Condition</th>
<th>Tag No.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP drum</td>
<td>- Level ≥ Start-up level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Drum level control valve in AUTO mode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For the cold start-up of HRSG’s (when HP drum water temperature is less than 100 °C), perform the following actions:

- Ensure that all condensed steam has been evacuated from the superheaters and reheaters before starting up the HRSG’s by opening the superheater and reheater drains.

- If HRSG’s have been standing full of water for some time, it is recommended to open the drains on the economizers and evaporators for a short period (until flow is verified) to drain any accumulated solids.
HRSG valves shall be lined up in accordance with HRSG manufacturer’s list.

2.4.3 STG on Turning Gear Operation

Permissive: Compressed air system in Operation
Circulating Water system in Operation
Closed cooling water system in Operation

STG auxiliary systems, such as lubricating oil system, control oil system, gland steam system, drainage system, exhaust spray water system, etc., shall be started and/or put into ready-to-start status, and then finally STG shall be placed on turning gear operation for start-up.

The start-up sequences of STG auxiliary systems and the start-up ready list of STG shall be described in a separate document to be prepared by STG supplier.

(After long term shut down, minimum 3 hrs operation of turning shall be required before STG running)

2.4.4 Condenser Vacuum-up

Permissive: STG on turning gear Operation
Condensate system in Operation
Circulating water system in Operation
Closed cooling water system in Operation
Auxiliary steam system in Operation
Compressed air system in Operation

Condenser vacuum-up shall be performed, when the warming-up of STG or the start-up of power block is required. For condenser vacuum-up, the sealing of STG gland should be performed in advance.

The gland steam temperature requirements of STG are as below.

- STG Very Hot or Hot Start: 350 °C to 540 °C
- STG Warm Start: 210 °C to 390 °C
- STG Cold Start: 150 °C to 260 °C
Whereas, the auxiliary steam temperature varies as below depending on the steam source.

- Supply from cold reheat steam system : 320 °C through 370 °C
- Supply from auxiliary boiler : 260 °C constant

Condenser vacuum-up procedure shall be performed in the following sequence. Each step shall be initiated by the operator at DCS.

**Step A.**

Depending on STG Start-up mode, the electric heater shall be activated or deactivated as below, in order to comply with STG steam temperature requirements.

- STG Very Hot or Hot Start : Activated
- STG Warm or Cold Start : Deactivated

**Step B.**

The operator initiates at DCS the opening of the steam seal auxiliary feed isolation drain valve in order to drain condensate and make steam superheated before being supplied to STG gland steam system.

If the auxiliary steam temperature is lower than 400 °C for STG Very Hot or Hot Start, the electric superheater shall increase the steam temperature to 400 °C.

If STG is in Cold Start mode and the auxiliary steam system is being supplied from the cold reheat steam system of the other Unit, the auxiliary steam temperature is not proper for STG gland sealing and the start-up of auxiliary boiler is required for supply of colder steam. In this case, the auxiliary boiler shall be started and then the auxiliary steam supply isolation valve of the cold reheat system of the other Unit shall be close. The auxiliary steam supply isolation valve of the cold reheat system of the other Unit shall be open when the auxiliary boiler is shut down.

**Step C.**

When the auxiliary steam temperature to STG gland steam system satisfies the STG temperature requirement after the opening of the steam seal auxiliary feed isolation drain valve, DCS shall take 5 minute time delay and flag to the operator “ST GLAND SEAL STEAM READY”.
After the flagging of “ST GLAND SEAL STEAM READY” by DCS, the operator initiates the sending of “ST GLAND SEAL START” signal to STG TCS after confirming the steam temperature for himself.

Step D.

After receiving the “ST GLAND SEAL START” signal from DCS, STG TCS shall open the steam seal auxiliary feed valve isolation valve and then send a signal of “ST STEAM SEAL AUX FEED VALVE OPEN” to DCS.

After receiving the signal of “ST STEAM SEAL AUX FEED VALVE OPEN” from STG TCS, DCS shall close the steam seal auxiliary feed isolation drain valve.

Step E.

After receiving the “ST GLAND SEAL START” signal from DCS, STG TCS shall perform the gland sealing of ST.

When STG gland steam system is operating, STG TCS shall send a signal of “SEAL STEAM COMPLETE” to DCS and then DCS shall flag “SEAL STEAM COMPLETE” to the operator.

Step F.

After flagging “SEAL STEAM COMPLETE” on DCS, the operator initiates the start-up of Condenser Air Removal System.

2.4.5 ST Pre-Warming

Permissive : STG on turning gear Operation
Condensate system in Operation
Closed cooling water system in Operation
Auxiliary steam system in Operation
Condenser vacuum < 7.5 inch Hg abs.(0.25 kg/cm² abs.)
HRSG cold reheat isolation valves(MOV-1329A/B & MOV-2329A/B) Close

If STG HP shell metal temperature is less than 150 °C(Ambient Cold Start), STG TCS shall send a digital signal of “ST PRE-WARMING REQUIRED CONDITION” to DCS. (Hold) for the operator’s acknowledgement of STG Pre-warming Start
If the digital signal of “ST PRE-WARMING REQUIRED CONDITION” was received, DCS shall send a digital signal of “ST PRE-WARMING START” to STG TCS, and then STG TCS shall start STG HP turbine pre-warming sequence including holding time after confirming condenser vacuum and auxiliary steam conditions. After completion of STG pre-warming, STG TCS will send a digital signal of “ST PRE-WARMING COMPLETED” to DCS.

As long as STG is in “ST PRE-WARMING REQUIRED CONDITION”, the start-up of STG will not be permitted by STG TCS.

2.4.6 Automatic Start-up of Power Block

When the plant is ready for start-up of power block by completing the start-up sequences above, the automatic start-up of the power block shall be initiated by operator, and the plant shall be started and loaded to the target load automatically.

Since the start-up of power block to target load is performed automatically, it is recommended for operators to check with time the readiness of plant for start-up before the automatic start-up of power block is initiated.

The automatic start-up sequence of power block has been attached as Attachment A.

Start-up sequencing of power block can be performed in either of full-automatic and semi-automatic.

In the sequence description following, the step with “(Go/Hold)” mark stands for the selection point for “Go” or “Hold” by operator. The “Go” or “Hold” selection may be performed at any time before the step is passed. If all “Go/Hold” are selected as “Go” before APS starts, the power block starts in full-automatic mode.
3.0 Plant Shut-down SEQUENCE

The plant shut-down sequence is reverse order of start-up sequence.

After shut-down of power block, the shut-down of auxiliary systems depends on. When next start-up is expected soon, the auxiliary systems shall remain in operation, whereas the auxiliary systems shall be shut down and placed on preservation status when long time shut-down is expected.

Therefore, the plant shut-down sequence has not been described here except the power block automatic shut-down sequence.

3.1 Automatic Shut-down of Power Block

The shut-down of power block shall be performed automatically by initiation of operators.

There are three kinds of automatic power block shut-down as below.

- One GT/HRSG shut-down with STG continued operation
- Last GT/HRSG and STG shut-down.
- Both GT/HRSG’S and STG Shut-down

The automatic shut-down sequence of power block has been attached as Attachment B.

3.2 Emergency Shut-down

The emergency shut-down sequence on trip of GTG, HRSG and STG, has been attached as Attachment C.
4.0 **ABBREVIATION**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APS</td>
<td>Automatic Plant Start-up System</td>
</tr>
<tr>
<td>APC</td>
<td>Automatic Plant Control System</td>
</tr>
<tr>
<td>STG TCS</td>
<td>STG Turbine Control System</td>
</tr>
<tr>
<td>GTG TCP</td>
<td>GTG Turbine Control Panel</td>
</tr>
</tbody>
</table>

(End)
Attachment A  POWER BLOCK AUTOMATIC START-UP SEQUENCE

Step 10  OPERATOR INITIATION

Step 10-1  Selection of LEAD/LAG/IDLE Mode of Each GTG/HRSG Train

Operator selects on DCS manually LEAD/LAG/IDLE mode of each GTG/HRSG Train. LEAD GTG/HRSG starts first and LAG GTG/HRSG starts later. IDLE GTG/HRSG train shall not start.

In this description, it is assumed that GTG1/HRSG1 is selected as LEAD GTG/HRSG and GTG2/HRSG2 is selected as LAG GTG/HRSG.

In case that one GTG/HRSG train is started by APS while the other GTG/HRSG train is operating with STG, the GTG/HRSG train to start is selected as LAG and the GTG/HRSG train operating is selected as IDLE. If the case, APS begins at Step 100.

APS IN and APS OUT buttons in addition to APS START button are provided. To start APS, Operator should select APS IN button and then APS START button. To stop APS, Operator should select APS OUT button.

APS stops in the following three cases.
- Operator pushes APS OUT button.
- Trip occurs.
- APS is finished.

If Operator pushes APS OUT button or trip occurs, plant shall maintain the operating conditions at the time of APS stops. When APS is finished, APC takes over plant control.

Step 10-2 Target Load Input

Target load (CCPP MW output) to be achieved when APS is finished is input by Operator. When Operator inputs APS target load, the target load of Automatic Generation Control(AGC) is also changed to the APS target load automatically, so that CCPP output is synchronized to AGC target load automatically when APS is finished.
Step 10-3 Valve Line-up

APS checks valve line-up and puts automatic valves in AUTO or CAS(cascade) modes according to their own start-up control logic. The valves in steam/water cycle and fuel gas system are included in the line-up check.
Step 20 GTG1 (LEAD) START-UP TO TEMPERATURE MATCHING LOAD

Step 20-1 Start-up Mode Selection of STG1 and HRSG1

20-1-A) Start-up mode of STG shall be decided by STG TCS and send to DCS as one of digital signals. STG TCS selects its start-up mode based on steam turbine metal temperature ($ST_{Tm}$) as below.
(Refer to STG Supplier’s Document)

- **ST Cold Start**: $150 < ST_{Tm} < 220 \, ^\circ C$
- **ST Warm Start**: $220 < ST_{Tm} < 370 \, ^\circ C$
- **ST Hot Start**: $370 < ST_{Tm} < 520 \, ^\circ C$
- **ST Very Hot Start**: $520 < ST_{Tm}$

20-1-B) Start-up mode of HRSG1 shall be decided by DCS for each HRSG1 pressure level (HP, IP and LP) based on the pressure of respective drum as below. The logic diagrams to be prepared by HRSG supplier shall describe the selection sequence of HRSG Start-up Mode.

<table>
<thead>
<tr>
<th>(unit : kg/cm$^2$g)</th>
<th>Hot Start</th>
<th>Warm Start</th>
<th>Cold Start</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HP</strong></td>
<td>$&gt; 63.8$</td>
<td>$&gt; 3.51$</td>
<td>$&lt; 3.51$</td>
</tr>
<tr>
<td><strong>IP</strong></td>
<td>$&gt; 7.67$</td>
<td>$&gt; 0.707$</td>
<td>$&lt; 0.707$</td>
</tr>
<tr>
<td><strong>LP</strong></td>
<td>$&gt; 3.51$</td>
<td>$&gt; 0.707$</td>
<td>$&lt; 0.707$</td>
</tr>
</tbody>
</table>

Step 20-2 GTG1 Ready to Start

DCS sends “RESET” and “CUSTOMER PERMISSIVE TO START” digital signal to GTG1 TCP, when HRSG1, STG1 and all BOP equipment are ready to start and all GTG1 trip/runback conditions are checked as clear.

GTG1 TCP uses this signal as one of its own start-up permissives. When all permissives of GTG1 are met and auxiliary checks are satisfied, GTG1 TCP sends to DCS a digital signal of “READY TO START”.
(Go/Hold) for the operator’s acknowledgement of GTG1 firing.

Step 20-3 GTG1 FSNL

After receiving the signal of “READY TO START” from GTG1 TCP, DCS deactivates the plant load control signal to GTG1 so that GTG1 load control by APS is not affected by APC.
Then DCS sends “START” signal to GTG1 TCP so that GTG1 starts.

When GTG1 reaches Full Speed No Load (FSNL), GTG1 TCP shall send an signal of “FULL SPEED NO LOAD”, which shall be used as the indication of “GTG1 on FSNL” in DCS.

**Step 20-4  GTG1 Minimum Load**

Upon GTG1 on FSNL, GTG1 is synchronized manually by the operator or automatically by GTG1 TCP depending on the operator’s selection of synchronization type. After synchronization, GTG1 is automatically loaded to its minimum load by GTG1 TCP.

When GTG1 reaches the minimum load, GTG1 TCP shall send an signal of “MINIMUM LOAD”, which shall be used as the indication of “GTG1 on Minimum Load” in DCS.

**Step 20-5  GTG1 Temperature Matching**

Once GTG1 has been reached at Minimum Load, GTG1 shall be put into temperature matching.

Temperature matching can be initiated between the Minimum Load and 50 % of GTG base load. Temperature matching of GTG is performed as below.

If the target temperature for temperature matching is lower than the GTG exhaust gas temperature at the load before temperature matching initiation, GTG load is decreased to the Minimum Load if GTG load is higher than the Minimum Load, and then GTG IGV is opened to the angle having the target temperature.

If the target temperature for temperature matching is higher than the GTG exhaust gas temperature at the load before temperature matching initiation, GTG load is increased to a load having the target temperature with its IGV at the minimum angle.

GTG exhaust gas temperature profile for cold start-up is as below.
PLANT START-UP AND SHUT-DOWN SEQUENCE

ENGSOFT Lab

- From FSNL to the Minimum Load (the minimum IGV)
- Temperature matching for Cold Start (IGV open to an angle higher than the minimum IGV)
- Temperature matching OFF (IGV close to the minimum angle)
- Normal operation with the minimum IGV
- Normal operation with the IGV angle higher than the minimum IGV

GTG Exhaust Gas Temperature Profile for Cold Start-up

1: From FSNL to the Minimum Load (the minimum IGV)
2: Temperature matching for Cold Start (IGV open to an angle higher than the minimum IGV)
3: Temperature matching OFF (IGV close to the minimum angle)
4: Normal operation with the minimum IGV
5: Normal operation with the IGV angle higher than the minimum IGV
The temperature matching shall be performed two times as below.

1) First temperature match for HRSG at 400 °C(752 °F) until reheat flow establishment
2) Second temperature match for STG as defined by STG TCS until STG is on IPC(Inlet Pressure Control) Mode

**First Temperature Matching for HRSG**

Once GTG1 has been reached the Minimum Load, DCS shall set the “EXHAUST TEMP MATCH TEMPERATURE” analog signal of GTG1 TCP at 400 °C regardless of HRSG1 Start-up Mode.

Then, DCS sets the “EXHAUST TEMP MATCH RAMP RATE” analog signal of GTG1 TCP at the maximum value (1.1 °C per second).

Then, DCS sets the “EXHAUST TEMPERATURE MATCH CONTROL ON” signal of GTG1 TCP, which enforces GTG1 to perform temperature matching by modulating IGV’s or modifying GTG load.

IGV modulating for temperature matching is performed at the minimum load of the GTG and GTG load modification for temperature matching is performed between the minimum load and 50% load.

The First Temperature Matching shall continue until HRSG1 reheat flow establishment. HRSG1 reheat flow establishment shall be acknowledged by the following.

- HRSG1 HP start-up vent valve Close
- HRSG1 HP steam flow > 54 ton/hr
- HRSG1 HP and HRH bypass spray valves in AUTO(CAS) mode

When HRSG1 HP steam flow is higher than 46.36 ton/hr, HRSG1 HP and HRH attemperator shall be set at the rated steam temperature and put into AUTO(CAS) mode.

**Second Temperature Matching for STG**

GTG exhaust gas matching temperature of STG is selected by STG TCS and send to DCS as one of analog signals. The name of analog signal is “GT TEMP MATCHING CONTROL SET POINT”. STG TCS selects the matching temperature as below. The matching temperature is both the HP and HRH steam temperature(HP_Ts and HRH_Ts), not GTG exhaust gas temperature.

- **ST COLD START** : HP_Ts < 250 °C
PLANT START-UP AND SHUT-DOWN SEQUENCE

- ST WARM START: $250 \, ^\circ\text{C} \leq \text{HP}_{\text{Ts}} \leq 370 \, ^\circ\text{C}$
- ST HOT START: $370 \, ^\circ\text{C} < \text{HP}_{\text{Ts}} < 520 \, ^\circ\text{C}$
- ST VERY HOT START: $\text{HP}_{\text{Ts}} > 520 \, ^\circ\text{C}$

When HRSG1 reheat flow has been established and HRSG1 HP bypass spray valve is in CAS mode, DCS selects the lowest temperature among the followings and sets the “EXHAUST TEMP MATCH TEMPERATURE” analog signal of GTG1 TCP at the temperature selected. The condition of HP bypass spray valve in CAS mode is required in order to prevent HP steam higher than 400 oC temperature from being bypassed to cold reheat piping without desuperheating.

- “GT TEMP MATCHING CONTROL SET POINT” value from ST TCS plus an offset. The offset is considered for the temperature difference between GTG exhaust gas and HRSG HP steam, and set at 3 °C.

- The rated steam temperature plus the offset defined above. HP and RH desuperheaters of HRSG1 are not in operation until HRSG1 steam flow is greater than 25% MCR flow.

Since GTG1 is still in “EXHAUST TEMPERATURE MATCH CONTROL ON” mode, merely change of “EXHAUST TEMP MATCH TEMPERATURE” enforces GTG1 to perform temperature matching by modulating IGV’s or modifying GTG load.
Step 30 HRSG1 (LEAD) START-UP TO STG PIPING DRAIN

Step 30-1 HRSG1 Air Vent

The logic diagrams to be prepared by HRSG supplier shall describe the HRSG1 Air Vent sequence.

Step 30-2 HRSG1 Pressurization Vent

The logic diagrams to be prepared by HRSG supplier shall describe the HRSG1 Pressurization Vent sequence.

Step 30-3 HRSG1 Superheater Drain

The logic diagrams to be prepared by HRSG supplier shall describe the HRSG1 Superheater Drain sequence.

Step 30-4 HRSG1 Piping Drain

30-4-A) HRSG1 HP piping drain valves

Upon GTG1 reaches the Minimum Load and HRSG1 HP drum pressure is higher than 0.707 kg/cm²g, HRSG1 HP piping drain valves are fully open, and stay at the fully open position for 2 minutes. Then, HRSG1 HP piping upstream drain valves shall be fully close, except the drain valve just upstream of HRSG1 HP isolation valve that shall be fully close when HRSG1 HP isolation valve is fully open.

30-4-B) HRSG1 IP piping drain valve

There is no HRSG1 IP piping drain valve upstream of IP isolation valve

30-4-C) HRSG1 HRH piping drain valves

Upon GTG1 reaches the Minimum Load and HRSG1 HRH pressure is higher than 0.707 kg/cm²g, the HRSG1 HRH piping drain valves are fully open, and then stay at the fully open position for 5 minutes. Then, HRSG1 HRH piping upstream drain valves shall be fully close, except the drain valve just upstream of HRSG1 HRH isolation valves that shall be fully close when HRSG1 HRH isolation valves are fully open.
30-4-D) HRSG1 LP piping drain valves

Upon GTG1 reaches the Minimum Load and HRSG1 LP drum pressure is higher than 0.707 kg/cm²g, HRSG1 LP piping drain valves are fully open, and then stay at the fully open position for 5 minutes. Then, HRSG1 LP piping upstream drain valves shall be fully close, except the drain valve just upstream of HRSG1 LP isolation valve that shall be fully close when HRSG1 LP isolation valve is fully open.

The opening and closing set pressure of drain valves as well as their delay timer setting shall be adjusted at field.
(Hold) for the operator’s acknowledgement of HRSG1 isolation valve open.

Step 30-5 HRSG1 Isolation Valve Open

HRSG1 isolation valves are in close position because the isolation valves are closed in shut-down sequence.

During start-up, warming-up of piping and valves are very important. Especially warming-up of HP stop/check valves is important. If HP stop/check valves are insufficiently warmed up, pressure imbalance between two HRSG’s occurs during second train addition because HP stop/check valves are not fully lifted up due to cold jamming. The pressure imbalance is suddenly collapsed and pressure between two HRSG’s is balanced when pressure is built up and HP stop/check valves are suddenly open, and then the HRSG’s can be tripped by HP drum level fluctuation.

The sooner the isolation valves or isolation bypass valves are open, the better for warming up of piping and valves. For warming of common piping and valves, opening of isolation valves is better in case of HRSG1(LEAD HRSG). However, in order to apply same logic for both LEAD and LAG HRSG’s, isolation bypass valves are open first before isolation valves are open.

HP and CRH isolation valves are located at each HRSG area, whereas HRH isolation valves are located in same area near condenser to make short HRH bypass discharge pipe length of large diameter. Therefore, the HP and CRH lead piping of HRSG2 is short, while the HRH lead piping of HRSG2 is long. In this consideration, HRH isolation valves are not equipped with isolation bypass valves, whereas HP and CRH isolation valves are equipped with isolation bypass valves.
30-5-A) HRSG1 HRH and CRH isolation valves

After GTG1 is reset for start, the HRSG1 CRH isolation bypass valve shall be fully open.

After GTG1 reaches the Minimum Load and HRSG1 HRH pressure is higher than 0.707 kg/cm² g, HRSG1 HRH isolation valve is open first and then HRSG1 CRH isolation valve is open. The HRSG1 CRH isolation bypass valve shall be fully close when HRSG1 CRH isolation valve is fully open.

30-5-B) HRSG1 HP isolation valve

After GTG1 is reset for start, the HRSG1 HP isolation bypass valve shall be fully open.

Upon HRSG1 HRH and CRH isolation valves are fully open, HRSG1 HP isolation valve shall be fully open.

When HRSG1 HP isolation valve is fully open, HRSG1 HP isolation bypass valve shall be fully close.

30-5-C) HRSG1 IP isolation valve

The logic diagrams to be prepared by HRSG supplier shall describe the HRSG1 IP isolation valve opening sequence.

30-5-D) HRSG1 LP isolation valve

After GTG1 is reset for start, the HRSG1 LP isolation bypass valve shall be fully open.

After GTG1 reaches the Minimum Load and HRSG1 LP drum pressure is higher than 0.707 kg/cm² g, HRSG1 LP isolation valve shall be fully open.

When HRSG1 LP isolation valve is fully open, HRSG1 LP isolation bypass valve shall be fully close.

**Step 30-6  STG Piping Drain**

Upon Step 30-5 HRSG1 Isolation Valve Open has been completed, STG piping drain starts.
30-6-A) STG HP piping drain valves

Once GTG1 reaches the Minimum Load; HRSG1 HP drum pressure is higher than 0.707 kg/cm²g; and HRSG1 HP isolation valve is fully open, STG HP piping drain valves are fully open, and stay at the fully open position for 5 minutes. Then, when DCS receives the digital signal of “IPC CONTROL ON” from STG TCS, the drain valves are fully close.

Once GTG1 reaches the Minimum Load; HRSG1 HP drum pressure is higher than 0.707 kg/cm²g; and HRSG1 HP isolation valve is fully open, the upper seat drain valves of STG HP CMV(Combined Main Valve) and HRH CRV(Combined Reheat Valve) shall be open. The STG seat drain valves shall be closed by STG TCS at around 10% STG load.

30-6-B) STG HRH and CRH piping drain valves

Once GTG1 reaches the Minimum Load and HRSG1 CRH/HRH isolation valves are fully open, the STG HRH and CRH piping drain valves, except the drain valve located between STG HP turbine exhaust and CRH Non-return Valve, are fully open, and then stay at the fully open position for 5 minutes. Then, if HRSG1 cold reheat pressure is higher than 3.5 kg/cm²g, the drain valves, except those located just upstream of STG IP turbine inlet, are fully close.

The drain valves just upstream of STG IP turbine inlet are fully close when DCS receives the digital signal of “IPC CONTROL ON” from STG TCS.

30-6-C) STG LP piping drain valve

Once GTG1 reaches the Minimum Load and HRSG1 LP isolation valve are fully open, STG LP piping drain valve shall be fully open, and then stay at the fully open position for 5 minutes. The drain valve will be fully close when DCS receives the digital signal of “LP-CV PRESS. CONTROL ON STATUS” from STG TCS.

The opening and closing set pressure of drain valves as well as their delay timer setting shall be adjusted at field.
Step 40. BYPASS VALVE OPERATION

Step 40-1 HP and HRH Bypass Valves

Steam pressure of HRSG HP and reheat steam system is controlled by HP and HRH bypass valves by dumping the steam into condenser, from the time that the bypass valves are put in AUTO mode through the time that STG is in IPC mode and thereby STG takes over the steam pressure control from the bypass valves.

When the following conditions are satisfied after GTG1 is at the Minimum Load and HRSG1 HP drum pressure is higher than 0.707 kg/cm\(^2\)g, the HP and HRH bypass valves shall be put in AUTO(CAS) mode. Once the bypass valves are put into AUTO(CAS) mode, their minimum opening shall be 10%.

1) Condenser pressure < 10 inch Hg abs. (0.34 kg/cm\(^2\) abs.)
2) GTG1 in First Temperature Matching for HRSG1 at 400 °C
3) HRH bypass valve body preheating O.K. (HRH bypass body preheating valve should be put into AUTO as soon as APS starts. The body preheating valve opens at saturation temperature plus 30 °C and closes at saturation temperature plus 90 °C automatically.)

The design temperatures of cold reheat piping and HRH bypass outlet piping are 400 °C and 360 °C respectively. 400 °C HP steam bypassed becomes approximately 368 °C in cold reheat piping at 6 kg/cm2g and approximately 362 °C in HRH bypass outlet piping at 0.1 kg/cm2a. Therefore, bypassing of 400 °C HP steam without desuperheating at the First Temperature Matching mode is acceptable for the piping all the way through condenser.

Since GTG1 Second Temperature Matching for STG is performed only after HRSG1 HP bypass spray valve in CAS mode, bypassing of HP steam higher than 400 °C temperature without HP bypass spray valve activation is prevented.

HP bypass spray valve shall be put in AUTO(CAS) mode when the following conditions are satisfied.

1) HRSG1 HP steam pressure > 30 kg/cm2g
2) HP bypass valve opening > 13%

HRH bypass spray valve shall be put in AUTO(CAS) mode when the following conditions are satisfied.

1) HRSH1 hot reheat steam pressure > 6 kg/cm2g
2) HRH bypass valve opening > 13%

The bypass valve manufacturer informed that the minimum steam volume flow for effective water spray of HP bypass valve is 0.72 m\(^3\)/sec while that of HRH bypass valve is 2.8 m\(^3\)/sec. The conditions above have been calculated from bypass valve manufacturer’s data to have the minimum volume flows.

Before the bypass valves are put in AUTO mode, the set pressure of the bypass valves shall be set at the following pressure.

1) HRSG1 HP bypass valve: The minimum HP floor pressure (50 kg/cm\(^2\)g)

2) HRSG1 HRH bypass valve: The minimum hot reheat floor pressure (6.5 kg/cm\(^2\)g)

Before HRSG1 HP bypass spray valve is put into AUTO mode, the set temperature of HRSG1 HP bypass spray valve shall be set at 360 °C regardless of STG start-up modes.

HRH bypass spray valve is controlled by enthalpy control at 675 kcal/kg target enthalpy. Therefore, there is no need to set the target temperature of HRSG1 HRH bypass spray valve.

HRSG HP and HRH bypass valve shall have **Set Point Ramp Function**. If the current line pressure is lower than or higher than the set point pressure, the set point pressure shall ramp from the current line pressure to the set point pressure with the allowable ramp rate allowed by the system, i.e. within allowable drum temperature ramp rate (HP drum: 3.9 °C/min., IP drum: 10 °C/min.) and within allowable drum level (between -50 mm and -350 mm for both HP and IP drums).

Once HRSG1 HP and HRH bypass spray valves are placed in AUTO; GTG1 is in the Second Temperature Matching mode for STG; and HRSG1 HP/CRH/HRH steam isolating valves are open, the DCS will send a signal to the STG TCS the “ST PERMISSIVE TO START”.

**Step 40-2 HRSG1 LP Economizer Bypass Valve**

There is no bypass valve for HRSG LP steam system. Therefore, during start-up the LP economizer bypass valve, ST LPCV drain valves and LP start-up vent valve are used to control HRSG LP steam generation and thereby to control HRSG LP steam pressure and superheat degree.
Upon APS On, HRSG1 LP start-up vent valve is open to 10% in case of cold start-up mode and 0% in case of warm or hot start-up mode of HRSG1.

Upon GTG1 is at the Minimum Load and HRSG1 LP drum pressure is higher than 0.707 kg/cm², HRSG1 LP economizer bypass valve shall be put in AUTO mode.

Before the LP economizer bypass valve is put in AUTO mode, the set pressure of the LP economizer bypass valve shall be set at 4.0 kg/cm². The bypass valve shall control HRSG LP drum pressure.

If HRSG1 LP steam pressure rises over the set pressure of LP economizer bypass valve even with LP economizer bypass valve higher than 85% opening, then HRSG1 LP start-up vent valve shall control LP steam pressure at 4.0 kg/cm² (split-range control).

The maximum opening of LP economizer bypass valve shall be limited to 85% for maintaining minimum flow through LP economizer in any case.

Upon HRSG1 LP economizer bypass valve is in AUTO mode and “LP-CV PRESS. CONTROL ON STATUS” signal comes from STG TCS, LP start-up vent valve shall be closed if it was open, monitoring HRSG1 LP drum level maintained within -50 mm and -350 mm. When LP start-up vent valve is closed, LP start-up vent set pressure is increased to 8 kg/cm².

Then, when LP start-up vent valve is closed, HRSG1 LP economizer bypass valve shall be closed by increasing its set pressure to 7.6 kg/cm².

The HRSG LP Economizer Bypass Valve shall have Set Point Ramp Function. If the current HRSG LP drum pressure is lower than or higher than the set point pressure, the set point pressure shall ramp from the current HRSG LP drum pressure to the set point pressure with the allowable ramp rate allowed by the system, i.e. the allowable LP drum temperature ramp rate (27.8 °C/min.).
Step 50 STG START-UP TO STG IPC ON

Step 50-1 STG Start Permissives

(Go/Hold) for the operator’s acknowledgement of STG start-up including administrative check of steam quality and STG trip conditions in advance, and RESET for STG. When the following conditions are satisfied, DCS shall send a digital signal of “ST START” to STG TCS and then STG TCS shall start STG.

1) DCS has received a digital signal of “ST READY FOR START” from STG TCS.
2) HRSG1 HRH, CRH, HP isolation valves are fully open
3) GTG1 load is higher than its Minimum Load
4) HRSG1 HP and HRH bypass valves are in AUTO or CAS mode.
5) HP steam pressure at STG inlet is higher than 49 kg/cm² ± 5%.
6) HRSG1 HP and HRH steam temperatures are within the range allowed by STG.
7) Condenser pressure is lower than the set value for STG rolling, i.e. 4 inch Hg abs.(0.13 kg/cm² abs.)

Step 50-2 STG Heat Soak Operation and Synchronization

When STG TCS receives the signal of “ST START” from DCS, STG TCS shall start STG from 1400 rpm heat soak operation through 3600 rpm heat soak operation.

When STG has finished 3600 rpm heat soak operation, STG is synchronized manually by the operator or automatically by STG TCS depending on the operator’s selection of synchronization mode.

Step 50-3 STG Transfer from ICV to CV and IPC On

After synchronization, STG TCS shall load STG at its initial load (= the minimum load), hold STG at its initial load for stress relieving and then transfer from ICV to CV control.

Once STG ICV to CV transfer is complete, STG TCS shall put STG in IPC (Inlet Pressure Control) mode and then send a signal of “ST IPC ON” to DCS.

STG TCS puts STG in IPC On mode only when HP steam pressure is higher than a low limit value. The low limit value is 42 kg/cm². In STG cold start-up mode, GTG1 load for Second Temperature matching for STG is low and HP steam flow from HRSG1 is sometimes insufficient for STG Transfer from ICV to CV, resulting in HP bypass valve close and HP steam pressure drop at
the end of STG Tranfer from ICV to CV. If the case, the low limit value, after discussion with STG manufacturer, may be lowered to make STG IPC On for all possible cases.

STG IPC Controller has Proportional(P) function only. Therefore HP steam pressure on STG IPC On mode does not keep a constant set pressure, but increase as STG load increases.

**Step 50-4  HRSG1 HP and HRH Bypass Valve Close**

Upon DCS receives the digital signal of “ST IPC ON” from STG TCS, DCS shall force HRSG1 HP bypass valve to be fully close. The HP bypass valve closing shall be performed by floating the HP bypass valve set pressure by 3 kg/cm²g above the current HRSG1 HP line pressure, only after HRSG1 HRH bypass valve is close. If required, HP bypass valve closing rate shall be adjusted.

If STG loading rate exceeds allowable limit during HP bypass valve close, STG TCS itself prevent excess loading by throttling its control valves.

During HP bypass valve closing period, HP steam pressure is maintained by STG IPC controller at its minimum floor pressure and it needs not to monitor HP drum temperature ramp rate.

Upon HRSG1 HP bypass valve is fully close, DCS shall send a signal of “HP TURBINE BYPASS VALVE FULL CLOSE” to STG TCS.

It may occur that HRSG1 HP steam generation is not enough for STG ICV to CV Transfer. If the case, STG TCS shall force to finish STG ICV to CV Transfer and activate STG IPC, upon receipt of the signal of “HP TURBINE BYPASS VALVE FULL CLOSE” from DCS, but only when HP steam pressure is higher than a low limit value(42 kg/cm²g).

Independent from HRSG1 HP bypass valve close, HRSG1 HRH bypass valve shall be close or remain open depending on STG start-up mode and consequent GTG1 load. If STG start-up mode is cold and consequent GTG1 load is low, HRSG1 HRH bypass valve shall be close on STG ICV to CV Transfer because reheat pressure on STG ICV full open is lower than the minimum hot reheat floor pressure (6.5 kg/cm²g). If STG start-up mode is hot, HRSG1 HRH bypasss valve shall be open on “ST IPC ON” because GTG1 load is high. Upon DCS receives the digital signal of “ST IPC ON” from STG TCS, HRSG1 HRH bypass valve is forced to be fully close by floating HRH bypass valve set pressure by 2 kg/cm² above the current HRSG1 HRH line pressure.

**Step 50-5  GTG1 Load Up by Temperature Matching**

Until HP steam temperature reaches its rated temperature, STG requires that HP steam temperature increasing rate does not exceed a limit given by STG TCS. This temperature
limiting requirement can not be satisfied by load control of GTG1, especially due to HRSG HP steam temperature control difficulty at high GTG exhaust gas temperature region. Therefore, until HP steam temperature reaches its rated temperature, GTG load increase shall be achieved by Temperature Matching function of GTG.

Upon “ST IPC ON” or “ST LOAD-UP ON” is arrived from STG TCS, DCS sets the “the “EXHAUST TEMP MATCH RAMP RATE” analog signal of GTG1 TCP at the limit value being received from STG TCS (2.5 °C/min.), and then sets the “EXHAUST TEMP MATCH TEMPERATURE” analog signal of GTG1 TCP at a temperature higher than the rated HP steam temperature, 567 °C. Herein 600 °C has been selected. Since GTG1 is still in “EXHAUST TEMPERATURE MATCH CONTROL ON” mode, merely change of “EXHAUST TEMP MATCH TEMPERATURE” enforces GTG1 to perform temperature matching for the high temperature by increasing GTG load.

Between approximately 25% and 60% GTG load, GTG exhaust gas temperature reaches its maximum temperature, i.e. combined cycle isotherm temperature.
Step 60  GTG1 LOADING TO 100 MW

When HRSG1 HP steam temperature becomes higher than the rated temperature minus 5 °C, GTG1 loading shall be performed by GTG1 load control after terminating GTG1 temperature matching control.

There are three ways for GTG load control as below.
- Lower or Raise load control
- Target load control

Lower or Raise load control is used in Automatic Generation Control (AGC) of APC, where incremental change of GTG load is required for both increase and decrease depending on grid requirements. Herein APS, Target load control is used because only increase to a certain load is required.

GTG TCP does not provide GTG load control function for target load based on percent(%) base load. Therefore, herein GTG1 loading shall be performed to a target MW output by Target load control.

When HRSG1 HP steam temperature becomes higher than the rated temperature minus 5 °C, DCS sets GTG1 Target load control at 100 MW, and sets its ramping rate at the allowable load ramp rate of STG1 multiplied by 2.67. Then, DCS shall set the “EXHAUST TEMP MATCH CONTROL_OFF” and “TARGET LOAD CONTROL ON” analog signals of GTG1 TCP, which enforces GTG1 to end Temperature Matching control and start External load control.

During GTG1 load ramp-up to 100 MW by Target load control, the following conditions shall be monitored and the ramping rate of Target load control shall be set at 0 MW/min. if the conditions exceed the limits. Upon the conditions comes within the limit, the ramping rate of Target load control shall be set again at the allowable load ramp rate of STG1 multiplied by 2.67.

1) HRSG1 HP steam temperature limit : the rated temperature plus 5 °C
2) HRSG1 HP drum temperature change rate limit : 3.9 °C /min.

STG TCP will send an analog signal of “LOAD UP RATE LIMIT SET VALUE” to DCS as the allowable load ramp rate of STG.

When the load on one GTG is being held constant or one GTG is not operating, then a raise of 2%
on the other GTG will result in an increase of 0.75% on the STG. When the load on both GTG’s is increased 1%, the output of the STG will increase 0.75%.

Therefore, DCS will set the ramp rate of GTG1 at the ramp rate of the “LOAD UP RATE LIMIT SET VALUE” multiplied by 2.67 (= 2 / 0.75).

If GTG2 has been selected as LAG unit for next start-up, and then keep GTG1 at 100 MW until the GTG2/HRSG2 steam addition to STG is completed.

If GTG2/HRSG2 train has not been selected as LAG unit for next start-up, the plant load control signal to GTG1 shall be activated at 100 MW, and GTG1/HRSG1 train with STG shall be loaded up to target load by Automatic Generation Control of APC.
Step 70        STG LOW PRESSURE CONTROL VALVE (LPCV) ON

When the following conditions are satisfied, STG LPCV will be put into AUTO (CAS) mode by STG TCS.

1) STG is in IPC mode.
2) STG load is more than 35% load.
3) LP steam pressure is higher than 1.1 kg/cm\(^2\)g
4) LP steam temperature has more than 28 °C superheat degree

The STG load at one GTG 50% base load is approx. 35%. Therefore, STG LPCV may be put into AUTO mode during GTG2 ramp-up period to 50% base load.

STG LP admission steam system is operated in sliding pressure mode with 1.2 kg/cm\(^2\)g floor pressure. STG LPCV controls its upstream pressure at 1.2 kg/cm\(^2\)g and forms the floor pressure. At STG 35% load, the STG LPCV stage pressure is approx. 2.0 kg/cm\(^2\)g and the HRSG1 LP drum pressure is controlled at 4.0 kg/cm\(^2\)g by HRSG1 LP Economizer Bypass Valve before STG LPCV is put into AUTO mode.
Step 100  GTG2 (LAG) START-UP TO TEMPERATURE MATCHING LOAD

The start-up timing of GTG2 shall be selected by the operator based on start-up conditions and his own experience. The best timing of GTG2 start-up is that, when GTG1 reaches 100 MW, GTG2 reaches 100 MW at the same time in order to have the shortest start-up time.

Step 100-1  Start-up Mode Selection of HRSG2

Same with Step 20-1-B except HRSG2 instead of HRSG1

Step 100-2  GTG2 Ready to Start

Same with Step 20-2 except GTG2 instead of GTG1

Step 100-3  GTG2 FSNL

GTG2 start-up is allowed only when GTG1 has been synchronized in order to assure that LEAD GTG starts first. Others are same with Step 20-3 except GTG2 instead of GTG1.

Step 100-4  GTG2 Minimum Load

Same with Step 20-4 except GTG2 instead of GTG1.

Step 100-5  GTG2 Temperature Matching

Once GTG2 has been reached the Minimum Load, GTG2 shall be put into temperature matching. For GTG2, the temperature matching for HRSG at 400 °C is only required.

Once GTG2 has been reached at Spinning Reserve Load, DCS shall set the “EXHAUST TEMP MATCH TEMPERATURE” analog signal of GTG2 TCP at 400 °C regardless of HRSG2 Start-up Mode.

Then, DCS sets the “EXHAUST TEMP MATCH RAMP RATE” analog signal of GTG2 TCP at the maximum value (1.1 °C per second).
Then, DCS sets the “EXHAUST TEMPERATURE MATCH CONTROL ON” signal of GTG2 TCP, which enforces GTG2 to perform temperature matching by modulating IGV’s or modifying GTG load.

IGV modulating for temperature matching is performed at the minimum load of the GTG and GTG load modification for temperature matching is performed between the minimum load and 50% load.

The HRSG2 Temperature Matching shall continue until HRSG2 reheat flow establishment. HRSG2 reheat flow establishment shall be acknowledged by the following:

- HRSG2 HP start-up vent valve Close
- HRSG2 HP steam flow > 54 ton/hr
- HRSG2 HP and HRH bypass spray valves in AUTO(CAS) mode

When HRSG2 HP steam flow is higher than 46.36 ton/hr, HRSG2 HP and HRH attemperator shall be set at the rated steam temperature and put into AUTO(CAS) mode.
Step 110 HRSG2 (LAG) START-UP TO HRSG2 PIPING DRAIN

Step 110-1 HRSG2 Air Vent

Same with Step 30-1 except HRSG2 instead of HRSG1.

Step 110-2 HRSG2 Pressurization Vent

Same with Step 30-2 except HRSG2 instead of HRSG1.

Step 110-3 HRSG2 Superheater Drain

Same with Step 30-3 except HRSG2 instead of HRSG1.

Step 110-4 HRSG2 Piping Drain

Same with Step 30-4 except GTG2 and HRSG2 instead of GTG1 and HRSG1.

Step 110-5 STG Branch Pipe Warming-up

When LAG HRSG is being warmed up, the branch pipe from each steam level isolation valve of LAG HRSG to the branch point of the common steam pipe is not warmed up due to no steam flow until each steam level isolation valve is open and main steam flow exists. For this purpose, isolation bypass valves are open first.

110-5-A) HRSG2 HP isolation bypass valve

After GTG2 is reset for start, the HRSG2 HP isolation bypass valve shall be fully open so that steam from HRSG1(LEAD) flows reversely through HRSG2 HP piping drain valve and warms up the branch pipe.

The HRSG2 HP isolation bypass valve shall be fully close when HRSG2 HP isolation valve is fully open.

110-5-B) HRSG2 CRH isolation bypass valve

After GTG2 is reset for start, the HRSG2 CRH isolation bypass valve shall be fully open so that steam from HRSG1(LEAD) flows reversely through HRSG2 reheater drain valve and warms up the
branch pipe.

The HRSG2 CRH isolation bypass valve shall be fully close when HRSG2 CRH isolation valve is fully open.

110-5-C) HRSG2 LP isolation bypass valve

After GTG2 is reset for start, the HRSG2 LP isolation bypass valve shall be fully open so that steam from HRSG1(LEAD) flows reversely through HRSG2 LP piping drain valve and warms up the branch pipe.

The HRSG2 LP isolation bypass valve shall be fully close when HRSG2 LP isolation valve is fully open.

No bypass valves for HRSG HRH isolation valves have been provided because the location of HRSG HRH isolation valve is located close to the branch point of the common HRH pipe.
Step 120  BYPASS VALVE OPERATION

Step 120-1  HRSG2 HP and HRH Bypass Valves

When the following conditions are satisfied after GTG2 is at the Minimum Load and HRSG2 HP drum pressure is higher than 0.707 kg/cm²g, the HP and HRH bypass valves shall be put in AUTO(CAS) mode. Once the bypass valves are put into AUTO(CAS) mode, their minimum opening shall be 10%.

1) Condenser pressure < 10 inch Hg abs. (0.34 kg/cm² abs.)
2) GTG2 in Temperature Matching for HRSG1 at 400 °C
3) HRH bypass valve body preheating O.K. (HRH bypass body preheating valve should be put into AUTO as soon as APS starts. The body preheating valve opens at saturation temperature plus 30 °C and closes at saturation temperature plus 90 °C automatically.)

HP bypass spray valve shall be put in AUTO(CAS) mode when the following conditions are satisfied.

3) HRSG1 HP steam pressure > 30 kg/cm²g
4) HP bypass valve opening > 13%

HRH bypass spray valve shall be put in AUTO(CAS) mode when the following conditions are satisfied.

3) HRSH1 hot reheat steam pressure > 6 kg/cm²g
4) HRH bypass valve opening > 13%

Before the bypass valves are put in AUTO mode, the set pressure of the bypass valves shall be set at the following pressure.

1) HRSG2 HP bypass valve: The minimum HP floor pressure(50 kg/cm²g)

2) HRSG2 HRH bypass valve: The minimum hot reheat floor pressure(6.5 kg/cm²g)

Before HRSG2 HP bypass spray valve is put into AUTO mode, the discharge temperature of HRSG2 HP bypass valve shall be set at 360 °C regardless of STG start-up mode.

HRH bypass spray valve is controlled by enthalpy control at 675 kcal/kg target enthalpy. Therefore, there is no need to set the target temperature of HRSG2 HRH bypass spray valve.
HRSG HP and HRH bypass valve shall have **Set Point Ramp Function**. If the current line pressure is less than or higher than the set point pressure, the set point pressure shall ramp from the current line pressure to the set point pressure with the allowable ramp rate allowed by the system, i.e. within allowable drum temperature ramp rate (HP drum: 3.9 °C/min., IP drum: 10 °C /min.) and within allowable drum level (between -50 mm and -350 mm for both HP and IP drums).

**Step 120-2 HRSG2 LP Economizer Bypass Valve**

Same with Step 40-2 except GTG2 and HRSG2 instead of GTG1 and HRSG1.
Step 130  GTG2 LOADING TO 100 MW

Since GTG2/HRSG2 as LAG train is not connected with STG yet, HP steam temperature increasing rate of STG is not applied to GTG2/HRSG2 train. Therefore, GTG2 loading to 100 MW shall be performed solely by GTG2 Target load control.

When HRSG2 reheat flow has been established, DCS sets GTG1 Target load control at 100 MW, and sets its ramping rate at its maximum value or higher. GTG’s maximum ramping rate is 8.8% base load per minute and the maximum ramping rate in the unit of MW/min varies depending on ambient air temperature. GTG1 ramping rate shall be set at 8 MW/min, a half of the maximum ramping rate of 17 MW/min, for stable HRSG operation. For HRSG only, there is no limit in gas or steam temperature change rate.

Then, DCS shall set the digital signal of “EXHAUST TEMPERATURE MATCH CONTROL_OFF” and “TARGET LOAD CONTROL ON” analog signals of GTG2 TCP, which enforces to end Temperature Matching control and start Target load control.

During GTG2 load ramp-up to 100 MW by External load control, the following conditions shall be monitored and the ramping rate of External load control shall be set at 0 MW/min. if the conditions exceed the limits. Upon the conditions comes within the limit, the ramping rate of External load control shall be set again at the allowable load ramp rate of STG1 multiplied by 2.67.

1) HRSG1 HP steam temperature limit : the rated temperature plus 5 °C
2) HRSG1 HP drum temperature change rate limit : 3.9 °C /min.
Step 140  HRSG2 STEAM ADDITION TO STG

Step 140-1 HRSG2 HP and HRH Bypass Valve Set Value Adjustment

HRSG2 HP and HRH bypass valve set pressures (50 kg/cm²g and 6.5 kg/cm²g respectively) are nearly same with STG inlet HP and hot reheat pressure at GTG1 100 MW output having HRSG1 HP and HRH bypass valves closed. Therefore, if HP and HRH bypass valve capacities are sufficient, HRSG2 HP and hot reheat steam pressures before addition are nearly same with HRSG1 HP and hot reheat steam pressures, or can be made same by adjusting HRH set pressure.

Step 140-2 HRSG2 HRH, CRH and HP Isolation Valve Open

HRSG2 HRH isolation valve shall be open when the following conditions are satisfied.
- GTG1 output > 97 MW
- Output difference between GTG1 and GTG2 < 3 MW
- Pressure difference over HRSG2 HRH isolation valve < 3.5 kg/cm²
- Temperature difference over HRSG2 HRH isolation valve < 17 °C
- HRSG2 HRH bypass valve in AUTO(CAS) and its opening > 13%
- HRSG2 hot reheat start-up vent valve close
- HRSG2 steam quality OK

HRSG2 CRH isolation valve shall be open when HRSG2 HRH isolation valve is fully open. When HRSG2 CRH isolation valve is fully open, fully close is HRSG2 CRH isolation bypass valve that was open in Step 110-5.

When HRH isolation valve is fully open, hot reheat steam of HRSG2 flows into STG and hot reheat steam pressure of HRSG1 and HRSG2 is equalized at the middle of original two pressures, still having HRSG2 HRH bypass valve fully open. This does not make any disturbance in STG control.

HRSG2 HP isolation valve shall be open when the following conditions are satisfied.
- GTG1 output > 97 MW
- Output difference between GTG1 and GTG2 < 3 MW
- Pressure difference over HRSG2 HP isolation valve < 5 kg/cm²
- Temperature difference over HRSG2 HP isolation valve < 17 °C
- HRSG2 HP bypass valve in AUTO(CAS) and its opening > 13%
- HRSG2 HP start-up vent valve close
- HRSG2 HRH and CRH isolation valves fully open

When HRSG2 HP isolation valve is fully open, fully close is HRSG2 HP isolation bypass valve that was open in Step 110-5.

Before HRSG2 isolation valves are open, the HRSG2 HP and HRH bypass valves shall be forced to stay at the current opening.

**Step 140-3  HRSG2 HP and HRH Bypass Valve Close**

When HRH and CRH isolation valves are fully open, the set pressure of HRSG2 HRH bypass valve shall set at the analog signal of "HRH BYPASS PRESS CONTROL SET POINT" being received from STG TCS that represents hot reheat steam pressure of STG load at the moment. Then HRSG2 HRH bypass valve is put into AUTO(CAS) mode.

At 30 seconds after HRSG2 HRH bypass valve has been put into AUTO(CAS) mode and HRSG2 HP isolation valve is fully open, the HRSG2 HP bypass valve shall be forced to be close to its minimum opening while monitoring the following.

1) HRSG2 HP drum water temperature ramp rate shall not exceed the allowable HP drum temperature ramp rate (3.9 °C/min.)

2) HRSG1 and HRSG2 HP and hot reheat steam temperatures shall not exceed the rated temperature plus 5 °C.

When HRSG2 HP bypass valve reaches its minimum opening (initially 12.5%), HRSG2 HP bypass valve is forced to be fully close and then the set pressure of HRSG2 HP bypass valve is released to float 3 kg/cm² above the current HRSG2 HP line pressure.

As HRSG2 HP bypass valve is close, HRSG2 HRH bypass valve shall be automatically close because the set pressure of HRSG2 HRH bypass valve shall follow the HRH system natural pressure being received from STG TCS as the analog signal of “HRH BYPASS PRESS CONTROL SET POINT”.

When HRSG2 HRH bypass valve reaches its minimum opening, HRSG2 HRH bypass valve is forced to be fully close and then the set pressure of HRSG2 HRH bypass valve is released to float 2 kg/cm² above the current HRSG2 HRH line pressure.

If HRSG2 HRH bypass valve does not reach its minimum opening even though the HRSG2 HP
bypass valve is fully close by any reason, HRSG2 HRH bypass valve is forced to be fully close, and then the set pressure of HRSG2 HRH bypass valve is released to float 2 kg/cm² above the current HRSG2 HRH line pressure.

**Step 140-4 HRSG2 LP Economizer Bypass Valve Set Pressure Adjustment**

When the following conditions are satisfied, the set pressure of HRSG2 LP Economizer Bypass Valve shall be adjusted to the current HRSG1 LP drum pressure, so that sudden pressure spike does not occur upon the HRSG2 LP isolation valve is open

- GTG1 output > 10 MW
- Temperature difference over HRSG2 LP isolation valve < 50 °C

**Step 140-5 HRSG2 LP Isolation Valve Open**

When the following conditions are satisfied, HRSG2 LP isolaton valve shall be fully open.

- GTG1 output > 10 MW
- Pressure difference over HRSG2 LP isolation valve < 1 kg/cm²
- Temperature difference over HRSG2 LP isolation valve < 50 °C

When HRSG2 LP isolation valve is fully open, fully close is HRSG2 LP isolation bypass valve that was open in Step 110-5.

**Step 140-6 HRSG2 LP Economizer Bypass Valve**

Upon GTG2 starts by APS, HRSG2 LP start-up vent valve is open to 10% in case of cold start-up mode and 0% in case of warm or hot start-up mode of HRSG2.

Upon GTG2 is at the Minimum Load and HRSG2 LP drum pressure is higher than 0.707 kg/cm²g, HRSG2 LP economizer bypass valve shall be put in AUTO mode.

Before the bypass valve is put in AUTO mode, the set pressure of the bypass valve shall be set at 4.0 kg/cm²g. The bypass valve shall control HRSG LP drum pressure.

Upon HRSG2 LP economizer bypass valve is in AUTO mode; “LP-CV PRESS. CONTROL ON
STATUS" signal comes from STG TCS; and HRSG2 LP isolation valve is fully open, HRSG2 LP start-up vent valve shall be closed if it was open, monitoring HRSG2 LP drum level maintained within -50 mm and -350 mm. When HRSG2 LP start-up vent valve is closed, the LP start-up vent set pressure is increased to 8 kg/cm²g.

Then, when HRSG2 LP start-up vent valve is closed, HRSG2 LP economizer bypass valve shall be closed by increasing its set pressure to 7.6 kg/cm²g.
Step 200  APC CONTROL

When HRSG2 HP bypass valve starts to close in Step 140-3, the plant load control signal to GTG1 and GTG2 shall be activated, and the Power Block Unit shall be loaded up to target load by Automatic Generation Control (AGC) of APC.

APS sequence logic shall be finished only when Step 140 “HRSG2 STEAM ADDITION TO STG” is finished, even though target load has already been achieved before Step 140 is finished.

Normally target load is achieved before Step 140 is finished because it takes less than 10 minutes for both GTG’s to reach base load from 100 MW, while Step 140 takes more than 15 minutes. Time for Step 140 depends on HRSG steam temperature control characteristics, and the saturation and ramping rate of STG.

AGC of APC shall take care of target load by adjusting GTG’s output, even though STG output varies as Step 140 proceeds.

(End)
Step 500 OPERATOR INITIATION

Step 500-1 Selection of GTG/HRSG Train to be Shut-down

Operator selects on DCS manually a GTG/HRSG Train to be shut down.

The GTG/HRSG to be shut down first shall be titled as LEAD train for shut-down.

It is assumed that GTG1/HRSG1 is selected as the train to be shut down.

Operator initiates Shut-down on DCS.
Step 510  GTG1/HRSG1 ISOLATION

Since operation with load imbalance between two GTG/HRSG trains over 5% may causes problems in the operability of STG and HRSG's, APC controls each train in approximately same load during normal operation.

Therefore, before GTG1/HRSG1 isolation, the loads of two trains are approximately same, and during GTG1/HRSG1 isolation, imbalance of HP and reheat steam flow between two HRSG's should be controlled within 5%.

Step 510-1  GTG1 and GTG2 Load Down to 100 MW

DCS shall deactivate the plant load control signal to GTG1 and GTG2.

After deactivation of the plant load control, GTG1 and GTG2 load shall be down to 100 MW, while monitoring the following.

- HRSG1 and HRSG2 HP steam temperature < the rated temperature plus 5 oC
- Output difference between GTG1 and GTG2 < 5%

Load-down of GTG1 and GTG2 shall be performed using the Target Load Control of GTG TCP and the ramping-rate shall be set at the allowable load ramp rate of STG multiplied by 1.33.

Step 510-2  HRSG1 LP Steam Isolation

After Step 510-5, HRSG1 HP and Reheat System Isolation, HRSG1 LP isolation valve shall be close. When the isolation valve starts to close, the LP Startup Vent Valve opens to 10% and LP Economizer Bypass Valve controls the LP drum pressure at 4.0 kg/cm²g.

If LP Economizer Bypass Valve opening reaches 85%, the Valve maintains 85% and LP Startup Vent Valve controls LP steam header pressure at 4.0 kg/cm²g. The reason why LP Economizer Bypass Valve opening is limited at 85%, is to keep the minimum flow through LP Economizer.

When DCS receives a signal of "SHUTDOWN" from GTG1 TCP, LP Startup Vent is closed.

Step 510-3  HRSG1 HRH Bypass Valve Set Value Setting

When GTG1 and GTG2 outputs becomes less than 100 MW by Step 510-1, the set pressure of HRSG1 HRH bypass valves shall be set as below so that the HP steam bypassed by
HRSG1 HP bypass valve can flows through HRSG1 HRH bypass valve. Since HRSG1 HRH set pressure follows the natural pressure of HRH system, HRSG1 HP steam bypassed to HRSG1 CRH system shall flow through HRSG1 HRH bypass valve naturally.

1) HRSG1 HRH bypass valve : “HRH BYPASS PRESS CONTROL SET POINT” value from ST TCS

The set pressure offset value is not required because such pressure difference does not make severe disturbance in STG and reheat steam system.

The discharge set temperature of HRSG1 HP bypass valve shall be adjusted to 345 °C. HRSG1 HP bypass discharge temperature actually has no limit because cold reheat piping has been designed for cold condition of one HRSG while the other HRSG is operating.

HRSG1 HRH bypass spray control need not to be set temperature adjustment because HRH bypass spray is controlled by constant enthalpy control (675 kcal/kg).

**Step 510-4  HRSG1 HP Bypass Valve Open**

Once HRSG1 HRH bypass valve set value setting is completed, the HRSG1 HP bypass valve shall be forced to be open to its final opening while monitoring the following.

1) HRSG1 HP bypass discharge temperature < 365 °C

2) HRSG1 HRH bypass discharge temperature < 260 °C

In HP and HRH bypass valve opening, bypass discharge temperature control is not stable, so that monitoring of the discharge temperature is required. On the other hand, HRSG HP drum temperature change rate is not a concern because HRSG is in hot condition.

The final opening of HRSG1 HP bypass valve shall be selected so that HRSG1 HP bypass flow can be same with HRSG1 HP steam flow generated within +/- 5% range. HRSG1 HP steam flow generated shall be the flow measured by HRSG1 HP steam flow meter, and HRSG1 HP bypass flow shall be calculated based on valve opening, inlet pressure, inlet temperature, outlet pressure, valve constant to be provided by the bypass valve manufacturer.

As HRSG1 HP bypass valve is open, HRSG1 HRH bypass valve shall be automatically open because the set pressure of HRSG1 HRH bypass valve shall follow the HRH system natural
pressure being received from STG TCS as the analog signal of “HRH BYPASS PRESS CONTROL SET POINT”.

**Step 510-5  HRSG1 HP and Reheat System Isolation**

At one minute time delay after HRSG1 HP bypass valve reaches its final opening, the HRSG1 isolation valves shall be fully close in the order of HP, CRH and HRH. The time delay is to wait until HRSG1 HRH bypass valve is stabilized for new STG load.

Upon HRSG1 HRH isolation valve is fully close, the set pressure of HRSG1 HP and HRH bypass valve shall be held at the current line pressure so that HRSG1 HP and reheat system pressure can be controlled constant at the current line pressure after isolation valve close.

**Step 510-6  GTG1 Shut-down**

When HRSG1 HRH and LP isolation valves are fully close, GTG1 shall be shut down by sending the digital signal of “STOP” to GTG1 TCP from DCS.

When GTG1 has been shut down, DCS shall receive a signal of "SHUTDOWN" from GTG1 TCP.

**Step 510-7  HRSG1 Bypass Valve Close**

During GTG1 shut-down period, HRSG1 HP and HRH bypass valves shall be close automatically as the steam generation from HRSG1 HP and IP steam drums decreases.

When HRSG1 HP and HRH bypass valves reach their minimum opening, HRSG1 HP and HRH bypass valves are forced to be fully close and then the set pressure of HRSG1 HP and HRH bypass valves are released to float 3 kg/cm² and 2 kg/cm² above the current HRSG1 HP and HRH line pressure respectively.

During GTG1 shut-down period, HRSG1 IP Back Pressure Control Valve shall be close automatically as the steam generation from HRSG1 IP steam drums decreases. When HRSG1 IP Back Pressure Control Valve is fully close, HRSG1 IP isolation valve(MOV 1328) may be fully close if required.

During GTG1 shut-down period, HRSG1 LP Economizer Bypass Valve is also close automatically
as the heat absorption in HRSG1 LP evaporator decrease. When HRSG1 LP Economizer Bypass Valve is fully close, the set pressure of HRSG1 LP Economizer Bypass Valve is released to float 2 kg/cm² above the current HRSG1 LP drum pressure.
(End)
Attachment B.2 LAST GTG/HRSG AND STG SHUT-DOWN SEQUENCE

Step 600 OPERATOR INITIATION

Step 600-1 Selection of Last GTG/HRSG Train to be Shut-down

Operator selects on DCS manually a GTG/HRSG Train to be shut down as the last train.

It is assumed that GTG2/HRSG2 is selected as the last train to be shut down.

The GTG/HRSG to be shut down last shall be titled as LAG train for shut-down.

Operator initiates Shut-down on DCS.
Step 610    GTG2/HRSG2 AND STG SHUT-DOWN

Step 610-1    GTG2 Load Down to 100 MW

DCS shall deactivate the plant load control signal to GTG2 so that GTG2 load control by APS is not affected by APC.

After deactivation of the plant load control, GTG2 load shall be down to 100 MW, while monitoring the following.

- HRSG2 HP steam temperature < the rated temperature plus 5 oC

Load-down of GTG2 shall be performed using the Target Load Control of GTG TCP and the ramping-rate shall be set at the allowable load ramp rate of STG multiplied by 2.67.

Step 610-2    HRSG2 HP and HRH Bypass Valve Set

When GTG2 load reaches 100 MW, HRSG2 HRH bypass spray valve shall be put into CAS mode, and then the set pressure of HRSG2 HRH bypass valves shall be set at 6.5 kg/cm²g and put into CAS mode. By this action, there is steam flow through HRSG2 HRH bypass valve because hot reheat steam pressure at 100 MW GTG2 load is higher than 6.5 kg/cm²g.

As HRSG2 HRH bypass valve opens, the HRH bypass spray control is not stable and the bypass discharge steam temperature rises over the set temperature of HRH bypass spray contol valve. If HRH discharge steam temperature is higher than 260 oC, HRH bypass valve opening shall be stopped and wait till the discharge steam temperature drops below 260 oC.

When HRSG2 HRH steam pressure drops below 7 kg/cm²g, HRSG2 HP bypass spray valve shall be put into CAS mode, and then the set pressure of HRSG2 HP bypass valves shall be set at 48 kg/cm²g and put into CAS mode. By this action, there is steam flow through HRSG2 HP bypass valve because HP pressure at 100 MW GTG2 load is higher than 48 kg/cm²g.

As HRSG2 HP bypass valve opens, the HP bypass spray control is not stable and the bypass discharge steam temperature rises over the set temperature(345 oC) of HP bypass spray control valve. If HP discharge steam temperature is higher than 350 oC, HP bypass valve opening shall be stopped and wait till the discharge steam temperature drops below 350 oC.

Step 610-3    HRSG2 LP Economizer Bypass Valve Set

This Step is not required.
Step 610-4  STG Stop Signal

When HRSG2 HP bypass and bypass spray control valves has been put into CAS mode and HRSG2 HP steam pressure is less than 50 kg/cm², DCS shall send to STG TCS digital signals of “STOP”.

Step 610-5  HRSG2 LP Steam Isolation

Upon receipt of “STOP” signal from DCS, STG TCS puts IPC off and enters load control.

First, STG TCS shall close the STG Low Pressure Control Valve according to its control logic and then send a digital signal of “LP-CV PRESS. CONTROL STATUS OFF COMMAND” to DCS, when the STG Low Pressure Control Valve starts to close.

When receiving the digital signal of “LP-CV PRESS. CONTROL STATUS OFF COMMAND” from STG TCS, the set pressure of HRSG2 LP Economizer Bypass Valve shall be set at 4.0 kg/cm² and HRSG2 LP steam generation is suppressed. Upon 1 minute elapsed after HRSG2 HP Economizer Bypass Valve set at 4.0 kg/cm², HRSG2 LP isolation valve is fully closed.

Step 610-6  STG Shut-down

Once STG Low Pressure Control Valve is fully close, STG TCS starts load down as below.

1) Decrease STG load to 25% load.
2) Transfer from CV to ICV at 25% STG load.
3) Decrease STG load to 5% load rapidly.
4) Shut-down STG

When STG is shut down, STG TCS shall send a digital signal of “SHUTDOWN” to DCS.

During STG shut-down period, the steam generated from HRSG2 HP and IP drum flows through HRSG2 HP and HRH bypass valves. No steam is generated from HRSG2 LP drum.

Upon STG shut-down, the upper seat drain valves of STG Combined Main Valves(CMV) and Combined Reheat Valves(CRV) are open automatically by STG TCS. If the operator wants to keep HRSG2 in pressurized condition, the operator may be send, the signals of “ST CMV UPPER SEAT DRAIN VALVE CLOSE” and/or “ST CRV UPPER SEAT DRAIN VALVE CLOSE” to STG TCS.
Step 610-7  HRSG2 HP, CRH and HRH Isolation Valve Close

If required, HRSG2 HP, CRH and HRH isolation valves shall be closed manually by Operation, only when DCS receives the digital signal of “SHUTDOWN” from STG TCS.

If hot restart with condenser operated is expected, HRSG2 HP isolation valve may be open to supply the gland seal steam to STG from the hot water stored in HRSG2 HP drum.

Step 610-8  GTG2 Shut-down

When HRSG2 HRH isolation valve is fully close, GTG2 shall be shut down by sending the digital signal of “STOP” to GTG2 TCP from DCS.

When GTG2 has been shut down, DCS shall receive a signal of “SHUTDOWN” from GTG1 TCP.

Step 610-9  HRSG2 Bypass Valve Close

During GTG2 shut-down period, HRSG2 HP and HRH bypass valves shall be close automatically as the steam generation from HRSG2 HP and IP steam drums decreases.

When HRSG2 HP and HRH bypass valves reach their minimum opening (initially 12.5%), HRSG2 HP and HRH bypass valves are forced to be fully close and then the set pressure of HRSG2 HP and HRH bypass valves are released to float 3 kg/cm² and 2 kg/cm² above the current HRSG2 HP and HRH line pressure respectively.

During GTG2 shut-down period, HRSG2 IP Back Pressure Control Valve shall be close automatically as the steam generation from HRSG2 IP steam drums decreases. When HRSG2 IP Back Pressure Control Valve is fully close, HRSG2 IP isolation valve may be fully close as required.

During GTG2 shut-down period, HRSG2 LP Economizer Bypass Valve is also close automatically as the heat absorption in HRSG2 LP evaporator decrease. When HRSG2 LP Economizer Bypass Valve is fully close, the set pressure of HRSG2 LP Economizer Bypass Valve is released to float 2 kg/cm² above the current HRSG2 LP drum pressure.

(End)
Attachment B.3  BOTH GT/HRSG’S AND STG SHUT-DOWN SEQUENCE

Step 700  OPERATOR INITIATION

Step 700-1  Selection of Both GTG/HRSG’s with STG Shut-down

Operator selects on DCS manually Both GTG/HRSG’s with STG Shut-down.

It is assumed that GTG1/HRSG1 is selected as LEAD GTG/HRSG and GTG2/HRSG2 is selected as LAG GTG/HRSG.

Operator initiates Both GTG/HRSG’s with STG Shut-down on DCS.
Step 710  GTG1 and GTG2 Load Down TO 100 MW

Same with Step 510-1

Step 730  GTG1/HRSG1 ISOLATION

When both GTG’s load is held at 100 MW, DCS shall initiate Step 510-2 HRSG1 LP Steam Isolation through Step 510-7 HRSG1 Bypass Valve Close.

Step 740  GTG2/HRSG2 AND STG SHUT-DOWN

When HRSG #1 HRH isolation valve is fully close, DCS shall initiate Step 610-2 HRSG2 HP and HRH Bypass Valve Set through Step 610-9 HRSG2 Bypass Valve Close.

(End)
Attachment C  EMERGENCY SHUT-DOWN SEQUENCE

C.1  GTG Trip

GTG trip simultaneously initiates the following.

1) Upon GTG trip, the set pressures of the associated HRSG HP, HRH and LP Economizer bypass valves are kept constant at the floating pressures just before GTG trip, while simultaneously the associated HRSG HP, CRH, HRH, and LP steam isolation valves are fully closed.

2) If the last GTG is tripped, STG is also tripped.

C.2  HRSG Trip

HRSG trip simultaneously initiates the following.

1) Trip of the associated GTG. Upon GTG trip, the set pressures of the associated HRSG HP, HRH and LP Economizer bypass valves are kept constant at the floating pressures just before GTG trip, while simultaneously the associated HRSG HP, CRH, HRH, and LP steam isolation valves are fully closed.

2) Shut-down of the associated HRSG according to normal shut-down procedure.

C.3  STG Trip

Upon STG trip, the bypass valves of both HRSG’s shall be open and direct the steam from HRSG’s to the condenser according to the emergency control logic of the bypass valves.

(End)