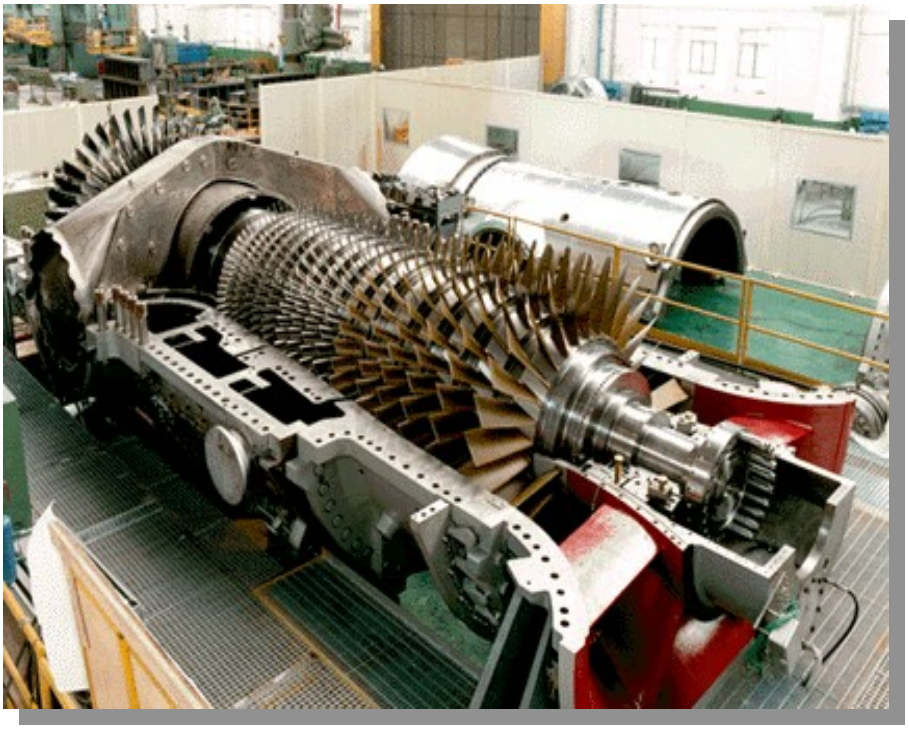
GT OPERATION PHILOSOPHY



CONTENTS

5.1 PREPARATION FOR GENERAL START UP

The preliminary checks and inspections listed in this chapter shall be performed when the gas turbine must be restarted after long shutdown period as after major inspection or after preservation.
When the plant is in standstill for a short period, for example at the weekend or extended turning gear operation, or for minor maintenance works, these start-up preparations are not necessary.

LUBE OIL SYSTEM MBV

- Inspection of the oil filter on the return line to the tank
- Check of the oil level and oil quality
- Visual inspection of the piping flanges, valves correct position and installation
- Test run of the oil pumps for abnormal vibrations, noise and correct consumption
- Test of the vapour extractor: the pressure in the tank shall be – 20 to 40 mm w.g. (this check can be performed with a U-tube manometer).

AIR FILTER AND INTAKE DUCT MBL

- Check the correct installation, sealing and securing.
- Check implosion flappers in the filter compartment to ensure freedom of movement and no leaks. Access doors must be without leaks and **locked**
- Check that the clean side of the filter is without damaged painting and without corrosion on the metal ducts.
- Check and clean carefully all the intake area.
- Perform a full filters cleaning cycle and check the correct operation
- Inspect the compressor shutoff damper and check the correct operation.

FUEL OIL SYSTEM FOR HSD AND NAPHTA, MBN

Warning: *After any GT shut down all the fuel oil system must be flushed with HSD.*
Before any maintenance work or minor repair, the system shall be inertised with nitrogen supplied to the proper N2 connection. Care shall be take that the fuel oil building is absolutely free of naphta.

- Perform visual inspection to all the system: flanges connections, drain closed, leak-tightness
- Check fuel oil intake system: tank, filters, pumps, measuring instruments, valves correct position, etc.
- Check the cleanness of the fuel oil filter
- Test run of the booster pumps upstream the suction of the injection pump
- Check the fuel oil injection pump according to the instruction of the supplier. It must be ensured that the isolating valves upstream and downstream of the selected running pump are **locked open** and that the same valves of the stand by pump are **locked closed**. Use only HSD for pump test and check the pump for abnormal noise, vibration and power consumption.
- Test run of the leakage recovery pump filling the leakage oil tank, if necessary
- Check the correct operation of the venting line through the sight glass.
- Check accumulators for correct pre-charge pressure
- Check the vapour trap and separator.

FUEL GAS SYSTEM MBP

- Since a pressure test of the entire gas system up to the burners should be carefully carried out, the manufacturer recommends a leak test using the gas turbine compressor
- The inspection for leaks should be done, according to the manufacturer procedure, not only on the fuel gas system, but also in the other internal piping systems and casing flanges e.g.:

1. Fuel oil lines up to fuel oil emergency stop valve
2. Ignition gas lines up to the check valves
3. NOx water lines up to the water stop valve
4. Pulse and instrumentation lines

The following steps shall be performed:

- Prepare the gas turbine for “compressor washing“ mode
- Remove the flange insulation caps which are to be checked for leakage integrity
- Select the washing operating mode and start-up GT
- Release the interlock of one fuel gas changeover valve using the hand held controller and open the valve

Note*: if the fuel oil system is to be checked at same time as the leak test of the fuel gas system, also one fuel oil ball valve assembly must be opened using the hand held controller.*

After the above mentioned shutoff elements have been opened, the compressor air enters into the systems in reverse direction with a slight overpressure.
Any leaks can then be located using leakage detection sprays or soapy water.

After the test has been performed, close the shutoff devices and actuate the interlocks using the hand held controller.
The washing program shall be shutoff.

- Check and clean the fuel gas filter upstream the second shutoff valve
- Check the open position of the instruments intercepting valves
- Check that the “fuel gas lock “ switch operates properly: when the second fuel gas shutoff element and fuel gas emergency stop valve are closed, the venting valve is open.
- Check the operational gas pressure upstream the emergency stop valve.

IGNITION GAS SYSTEM MBQ

- Perform a leakage test of the ignition gas cylinder compartment up to the connection of ignition gas solenoid valve N° 2

Attention: *the leakage test should be preferably done at an air pressure of about 5 bar.*

- Check the absence of leakage from flange connections, valves, measurement connections, etc. with a soap solution or a snuffer probe.
- Check to determine whether the ignition gas cylinders are available: two full and two empty.

Note: *The two empty cylinders serve as accumulator with the purpose to increase the gas volume availability.*

- Check the ignition gas pressure with all the valve of the cylinders open
- Leak test of the ignition gas pipelines, through fuel gas supply by manual shutoff valve up to 3-way spool valve, including the check valve on the gas cylinders outlet
- Check ignition gas pressure upstream the ignition gas valve N° 2
- Check the ignition current presence at all ignition burners

Procedure:

- Block the ignition gas system
- Simulate ignition speed in control system or bring the GT to washing speed
- Open ignition gas solenoid valve N° 2 (ignition is switched on simultaneously)
- Pull out the ignition caps one by one and hold directly at the spark plug
- Verify clearly audible and visible sparks present at the top of the device.

HYDRAULIC SYSTEM - MBX

Check the oil tank level

- If the hydraulic oil has been changed, check the oil quantity and quality
- Check the open position of the instruments isolating valves
- Check the oil temperature monitoring, start-stop of both pumps with low oil temperature and oil in circulation. Check the start-stop of the fans with high oil temperature
- Check that the return line filter is clean, control the operation of the change-over valve. Check the correct operation of the pollution device
- Check the control valve with electric position controller; check the control valve stroke according to the electric nominal value indication; compare the position with the analogue indicator of the main control area
- Check the emergency trip valve actuator, operation of activation-deactivation congruence with the end position alarm. Record the opening and closing times

BLOW-OFF SYSTEM - MBA

- Check the accumulation of condensed water in the pressure vessel
- Check the opening and closing function of the pneumatic servomotors of the blow-off valves and record the time response
- Check the limit position signal

Note: *for the shut-down test, the pressure vessel shall be charged with external air > 5 bar through the connection provided on the pressure vessel.*

SUPERVISORY AND PROTECTIVE EQUIPMENT

- Check the readings of thermocouples, resistance thermometer and temperature sensors. At standstill, the readings should be on the order of the ambient temperature.

- Control the display of the ATK turbine exhaust temperature: display = AT – (correction factor x compressor inlet temperature)
- Clean the lenses and silica glass on thermal radiation sensor of the combustion chambers flame monitor
- Check the vibration measuring equipment: correct mounting and electrical connections, correct functioning of the indicating and recording instruments
- Check visually all the measuring and indicating instruments: ready for operation

5.2 GENERAL OPERATING INSTRUCTIONS

INTRODUCTION

The following general operating instructions are provided as a tool for the control console operator to enable him to recognise any problems occurring and implement the correct measures at the right time . Furthermore, they facilitate enhancement of safety and a certain degree of problem consciousness.

TURBINE STANDSTIL AFTER LOSS OF POWER SUPPLY

In the event of loss of power supply during operation, the machine is disconnected from the grid and allowed to coast down to a stop with the emergency oil pump running. In such circumstances the console operator is not allowed to shut off the emergency oil pump, because it is imperative to cool down the turbine with the lube oil in circulation as long as possible.

If the emergency oil pump is temporarily shut-off after the shaft stop, the turbine bearing will overheat due to thermal adsorption from the casing.

Because the batteries have a limited capacity, will be very important a rapid reconnection to power supply to prevent shaft distortion.

SHAFT DISTORSION AFTER LOSS OF THE POWER SUPPLY DURING STANDSTILL

In the event that the hot turbine comes to standstill after loss of electric power supply, the shaft distortion must be anticipated.

In such case, is not permitted to restart the GT with the start-up converter under any circumstances because this operation could cause severe damage to the shaft glands and blading.

The console operator shall take the following actions:

- As soon as the power supply is restored, start up the main oil pump and the jacking oil pumps.
- Attempt to turn the shaft with the manual turning gear and, if this operation will be impossible, the GT must stay in stop position for at least 24 hours. After this time, as a rule, it will be possible to turn the shaft.
- If it is possible to turn the shaft manually, start the hydraulic turning gear immediately
- Continue the turning for at least one hour without interruption to eliminate the shaft distortion which has already occurred and to prevent excessive start-up vibrations
- After this, the GT can be restarted normally.

ATK (TET) MEASUREMENT DIFFERENCES

The ATK measurements displayed during the GT operation indicate certain differences caused by cooling air flow in the gas turbine and by clearance deviations within allowable tolerances

When temperature differences are evaluated, the critical factor is not the absolute difference, but rather the change in differences over a period of time.

The operator should therefore compare always the temperature readings with the reference initial measurements. In this case, if large differences appear, compared to previous equal load conditions, it means that a fault is present and corrective measures are required.

OPERATION OF THE GAS TURBINE IN THE RANGE NEAR THE DIFFUSION - PREMIX CHANGEOVER TEMPERATURES

The control console operator should ensure that the turbine is not operating in a load range too close to the “diffusion-premix” changeover temperatures for extended periods.

The atmospheric temperature changes, also changes the ATK and the consequences of an operation too close to the changeover can result in an undesired changeover from diffusion mode to premix mode and vice versa.

To avoid this problem, the operator should maintain a sufficient margin from this load.

OBSERVATION OF FLAME

The main flame and the upper rows of the refractory rows tiles can be observed through the sight glass installed in the manhole cover.

The operator shall become familiar and expert with the form, length and appearance of the flames, comparing day by day the situations in the various loads.

To facilitate this observation, he may hold a piece of white paper or cardboard, keeping a constant distance from the cone sight glass.

This technique is particularly useful to observe the contour of the fuel oil flames.

In same load conditions, the operator has to remember that the flame projection on the paper appears reversed.

In the event that some difference is detected, the burners must be inspected at the next possible opportunity.

If these changes are simultaneous with significant AT temperatures differences increasing, it is clear that the burner fault is the cause.

5.3 START-UP WITH FUEL GAS

INTRODUCTION

The following general operating instructions are provided as a tool for the control console operator to give him a guideline on the activities to be performed in FG start-up of the GT.

It is assumed that the GT is ready for operation.

The plant specific preparations and checks have been performed according to the instructions given in the specific sections:

- General preparation
- Function test before start-up
- General operating notes

NOTES ON THE START-UP OPERATING PROGRAM

Before start-up the operators should familiarise with the sequence of steps for the sub-groups controls in the operating program including the associated process sequences.
The indicated shutdown criteria in the event of a failed start must be also well-known in order to take the correct decision according to the failure cause.
The control commands of the SGC operating program of the subsequent steps are based on the standard version INFI 90. A detailed description with the applicable functional diagrams are given in the proper sections of the operating manual.

SEQUENCE FOR START-UP PROGRAM

Initial conditions:

The GT is in the step "**turning gear operation"** or "**shaft standstill**" of the automatic shutdown program (the appropriate step is indicated on the video).

- Tile "**ready for start-up**" is illuminated when the turbine is ready for operation
  The operator must choose manually the appropriate operating mode using the following selection criteria:

1. Selection of the start-up fuel: in our case fuel gas
2. Manual or automatic synchronisation
3. Selection of the loading gradients: normal or fast
4. Input of the target load to reach (e.g. base load or partial load)
5. Specification of burner mode: diffusion/premix operation

SEQUENCE OF STEPS OF THE MAIN GT SEQUENCER MBY01EC001

The program is initiated by pressing the start-up switch MYB01EC001.
By this command, automatically the step indication changes from the shutdown program e.g. step 61 to step 01of the start-up program.

After the input of the start command, the GT runs by the sequenced steps up to the selected point (e.g. base load) and the sequence of the steps is indicated on the console.

The following control commands are divided into individual steps:

Step 1:

- No command:
  Interrogation:
- Start mode selected (gas or oil, gas in this case described in the following):

Step 2

- SLC generator auxiliary equipment	ON
- SLC lube oil pumps	ON
- Emergency lube oil pump	ON
- SLC shaft turning gear	OFF
- Turning gear valve	Closed
- SLC compressor shutoff damper	Open
- Excitation equipment	OFF
- Synchronisation equipment	OFF
- Compressor heating/dryer	OFF
- SLC cooling water pumps	ON
- SLC lifting oil pumps	ON
- SLC hydraulic oil pumps	ON
- Fuel shutoff valves	Closed
- GT drain valves	Closed
- Purging solenoid on comb. chamber	Test Open
- IGV position	Minimum

Step 3:

- All blow off valves	Open
- SFC	Prepared
- Venting system	ON

Step 4-5-6-7

- Those steps are not used in simple cycle. In combined cycle step 4 and 5 are used to wait for the boiler purging procedure.

Step 8:

- According to the selected start-up fuel (gas in this case), the main GT sequencer calls in operation the fuel sequencer: NG SEQUENCER IN AUTO

Start of the fuel gas sequencer MBP01EC001

Step 1:

- No command for fuel gas start-up

Step 2:

- NG vent valve MBP13AA501 Closed
- NG vent valve MBP14AA501 Closed
- Pilot gas vent valve MBP15AA501 Closed

Step 3:

- Start up Converter ON
- Ignition gas valve 1 MBQ11AA001 Open

Step 4:

- NG diffusion ball valve MBP21AA001 Open
- NG diffusion ball valve MBP22AA001 Open

Step 5:

- No command, waiting for the ignition speed S.TURB.09 reached

Step 6:

- NG control valve MBP15AA151 In start-up position
- Ignition gas valve 2 MBQ11AA002 Open
  (when speed = S.TURB.09 ~ 480 rpm)

Note: *when ignition gas valve N°2 is open and the ignition spark plugs are energised, the ignition gas burners are in operation.*

Note:

Step 7:

- NG stop valve MBP13AA051 Open

Note: *The OPEN command is issued to the FG emergency stop valve 10 seconds after the opening of ignition gas valve N° 2.*
The signal "FLAME ON" must be indicated on the console at least 12 seconds after the OPEN command of the FG ESV. In the event that the flame is not detected, the ESV shall be closed 12 second after and the start-up is aborted.

Step 8-9:

- No command, the GT is accelerating to nominal speed

Step 10:

- Command given to main GT sequencer MBY01EC001:
- SUCCESSFUL NG START UP

Return to the main GT sequencer MBY01EC001

Step 8:

- No command, SUCCESSFUL NG START UP followed

Step 9:

- No command,
  Speed increases up to 70% of nominal speed and the SFC is automatically switched OFF

Step 10-11:

- No command

Step 12:

- Excitation ON

Step 13:

- Synchronization ON

The generator is connected to the grid and is loaded up to the pre-selected target power output.

5.4 START-UP WITH FUEL OIL

INTRODUCTION

The following general operating instructions are provided as a tool for the control console operator to give him a guideline on the activities to be performed in FO start-up of the GT. It is assumed that the GT is ready for operation.

The plant specific preparations and checks have been performed according to the instructions given in the specific sections:

- General preparation
- Function test before start-up
- General operating notes

NOTES ON THE START-UP OPERATING PROGRAM

Before start-up the operators should familiarise with the sequence of steps for the sub-groups controls in the operating program including the associated process sequences.

The indicated shutdown criteria in the event of a failed start must be also well-known in order to take the correct decision according to the failure cause.

The control commands of the SGC operating program of the subsequent steps are based on the standard version INFI 90. A detailed description with the applicable functional diagrams are given in the proper sections of the operating manual.

SEQUENCE FOR START-UP PROGRAM

Initial conditions:

The GT is in the step "**turning gear operation"** or "**shaft standstill**" of the automatic shutdown program (the appropriate step is indicated on the monitor).

- Tile "**ready for start-up**" is illuminated when the turbine is ready for operation
  The operator must choose manually the appropriate operating mode using the following selection criteria:

  1. Fuel selection: in our case, fuel oil
  2. Manual or automatic synchronisation
  3. Selection of the loading gradients: normal or fast
  4. Input of the target load to reach (e.g. base load or partial load)

SEQUENCE OF STEPS OF THE MAIN GT SEQUENCER MBY01EC001

The program is initiated by pressing the start-up switch MYB01EC001.

By this command, automatically the step indication changes from the shutdown program e.g. step 61 to step 01 of the start-up program.

After the input of the start command, the GT runs by the sequenced steps up to the selected point (e.g. base load) and the sequence of the steps is indicated on the console.

The following control commands are divided into individual steps:

Step 1:

No command

Interrogation:

- Start mode selected (gas or oil, oil in this case described in the following):

Step 2

- SLC generator auxiliary equipment	ON
- SLC lube oil pumps	ON
- Emergency lube oil pump	ON
- SLC shaft turning gear	OFF
- Turning gear valve	Closed
- SLC compressor shutoff damper	Open
- Excitation equipment	OFF
- Synchronisation equipment	OFF
- Compressor heating/dryer	OFF
- SLC cooling water pumps	ON
- SLC lifting oil pumps	ON
- SLC hydraulic oil pumps	ON
- Fuel shutoff valves	Closed
- GT drain valves	Closed
- Purging solenoid on comb. chamber	Test Open
- IGV position	Minimum

Step 3:

- All blow off valves	Open
- SFC	Prepared
- Venting system	ON

Step 4-5-6-7

- Those steps are not used in simple cycle. In combined cycle step 4 and 5 are used to wait for the boiler purging procedure.

Step 8:

- According to the selected start-up fuel (fuel in this case), the main GT sequencer calls in operation the fuel sequencer: FO SEQUENCER IN AUTO

Start of the fuel oil sequencer MBN01EC001

Step 1:

- No command for fuel oil start-up

Step 2:

- SLC HSD booster pumps ON
- FO control valve MBN54AA151 Start-up position
- HSD isolating valve MBN11AA001 Open

Step 3:

- Fuel injection pump MBN12AP001 ON
- FO recirculation valve MBN55AA001 Open
- SLC recirculation mode OFF

Step 4:

- SFC ON
- GT drain valve 1 MBA18AA001 Open
- GT drain valve 1 MBA18AA002 Open
- Ignition gas valve 1 MBQ11AA001 Open
- FO combined ball valve MBN21AA001 Open
- FO combined ball valve MBN22AA001 Open

Step 5:

- Ignition gas valve 2 MBQ11AA002 Open
- (when speed = S.TURB.09 ~ 480 rpm)

Note: *when ignition gas valve N°2 is open and the ignition spark plugs are energised, the ignition gas burners are in operation.*

Step 6:

- FO stop valve MBN13AA151 Open
  (at the same time the command open is effective also for the return stop valve MBN52AA051

Note: *The OPEN command is issued to the FO emergency stop valve 10 seconds after the opening of ignition gas valve N° 2.*
The signal "FLAME ON" must be indicated on the console at least 12 seconds after the OPEN command of the FG ESV. In the event that the flame is not detected, the ESV shall be closed 12 second after and the start-up is aborted.

Step 7:

- No command
  The GT is accelerating to nominal speed

Step 8:

- Command given to main GT sequencer MBY01EC001:
- SUCCESSFUL FO START UP

Note: ignition gas valves 1 and 2 receive the CLOSE command when the nominal speed is reached.

Return to the main GT sequencer MBY01EC001

Step 8:

- No command, SUCCESSFUL NG START UP followed

Step 9:

- No command,
  Speed increases up to 70% of nominal speed and the SFC is automatically switched OFF

Step 10-11:

- No command

Step 12:

- Excitation ON

Step 13:

- Synchronization ON

The generator is connected to the grid and is loaded up to the pre-selected target power output

5.5 GENERATOR SYNCHRONIZATION

AUTOMATIC SYNCHRONIZATION VIA SGC PROGRAM

After GT start-up, the gas turbine is maintained at rated speed S.TURB.00 (3000 rpm) by the speed control.

When start-up via the SGC operating program, the automatic synchronizing equipment is switched on in the appropriate step.

The synchronising equipment measures the turbine speed:

- Grid frequency
- Grid phase angle
- Grid voltage

and matches those parameters with the grid data.

With the synchronoscope in the 12 o'clock position, the circuit breaker is closed when grid and generator parameters are matched, thus connecting the generator to the grid.

On closing of the generator circuit breaker, the load controller automatically assumes control functions and loads the gas turbine depending on pre-selection of the loading gradient until the target output is achieved.

MANUAL SYNCHRONIZATION

In the normal course of events, the automatic synchronising equipment performs all of these processes. However, manual synchronisation is also possible.

The generator can be connected to the grid by manual switch MKA01DE011 on the control console once generator parameters have been matched to those of the grid.

Matching turbine speed to the grid frequency is performed via the control console key for speed set-point MBY101DU010.

5.6 GT OPERATION MODE

GT CONTROL SYSTEM CONFIGURATION

The GT is controlled by a proper electronic digital control system, integrated into the redundantly configured automation system (INFI 90).

The GT control system uses the following individual modes of operation:

- Start-up mode
- Speed controller
- Load controller
- TETC limit controller
- Turbine limit load controller
- Compressor pressure ratio limiter (β limiter).

The output signals from these controllers are passed through a MIN. gate, which determines any control action to be executed by the Master controller. The active controller is indicated on the control room console.

OPERATION WITH SPEED CONTROLLER

A run-up transmitter governs the turbine speed via a start-up control loop.

The speed controller cuts and overrides the start-up control loop above a specified speed range (i.e. 2850 rpm) and governs the turbine during the final run-up to rate or synchronisation speed.

This control function is performed automatically when the subgroup control-operating program is activated (automatic synchronisation), but if synchronisation is manually performed, for example, the operator must use the control console proper pushbutton to adjust the speed. The set point adjuster covers the speed range from 2850 to 3090 rpm. The speed controller is primarily used during no-load operation before synchronisation.

However, it is also possible to change the GT control from load-controller operation to speed-controlled load operation and vice-versa by a manual selection on the operator console. The control loop automatically matches the set points to prevent significant load changes during changeover.

This operation mode shall be activated only in exceptional circumstances and only during steady state operation.

Changeover from one controller to another is forbidden for process engineering reasons when the GT is running on fuel gas in premix mode.

OPERATION WITH LOAD CONTROLLER

The subgroup control-operating program automatically changes over from the speed control to the load control when the generator circuit breaker has been closed after synchronisation.

The load controller increases or reduces load in order to reach the selected target value. This is set by means of the load set point adjuster on the keyboard and is displayed on the load set point panel.

The operator shall specify the load target value before activating the subgroup control operating program.

The proper control switch on the console is activated to select various gradients for the operating modes “normal loading” and “rapid loading”. Both of these modes are

characterised initially (after synchro) by an automatic step of anti motorising load of 15 MW. The load is after increased by the “normal loading” selection with a rate of 11 MW/min, or by the “rapid loading” with a rate of 30 MW/min. The two ways are valid until the “base load”. From “base load” to “peak load” for both the modes, the rate is 4MW/min. During unloading operations with the load set-point adjuster, the same gradients are used as for the “normal loading” to decrease gas turbine load to the target. This is the recommended unloading operation for varying load.

If the operating program requires the GT out of the grid prior shutdown, the control switch MYB01EC001 activates the stop program via the proper subgroup and the machine is unloaded with the same gradients described above.

The load controller is switched off when the GT is isolated from the main grid and the GT coasts down.

The load controlled is tripped instantly if a malfunction (e.g. load rejection) isolates the plant from the main grid. The gas turbine control automatically assumes the function of an integral speed control system to return to nominal speed.

OPERATION WITH “TETC” LIMIT CONTROLLER

This limit controller limits the turbine’s TETC outlet temperature (as protection against thermal overloading). It initiates control actions to prevent any further load increasing if the fixed temperature limits for base or peak loads, required by the load controller demand, are exceeded. The operator can deactivate the temperature limit controller by reducing the load until the indication on the console (illuminated tile) indicates that the controller has assumed load control functions.

OPERATION WITH THE TURBINE LIMIT CONTROLLER

This controller limits the turbine’s maximum mechanical load. These conditions can occur at low intake temperature and a high atmospheric air pressure (large compressor mass flow) which would jeopardise the gas turbine without reaching the temperature limit.

The maximum permitted load is specified by the manufacturer and is permanently programmed as limit on the load controller.

Control action by this controller trips the load controller and interrupts loading, preventing any further load increases.

OPERATION WITH GENERATOR LIMIT CONTROLLER

This limit controller protects the generator from electrical over load. It also intervenes if the permanently programmed limit is exceeded, as indicated by an illuminated tile on the control console. The load controller remains in operation, however.
The output signal from the limit controller only limits load set point, control which subsequently reduces the active power to below the limit. The limit controller is then deactivated. The new set point serves as a target value for the load controller, which then determines the current effective power.
Information and settings are given in the documentation of the generator manufacturer.

SPECIAL CASES

Following partial or full load rejection and before further unloading (island operation) or shut-down, the turbine shall be maintained at the momentary load point for the same time as for a normal shut down. This reduces thermal stresses on blading.
Shutdown experiments to test dynamic behaviour shall be avoided to not subject the turbine to unnecessarily high thermal stresses. Load rejection to auxiliary power from ¼ of the base load is sufficient to verify correct functioning of the control equipment.
The momentary increase of speed, which takes place on the full load rejection, can be calculated as 1% less than the overspeed trip actuation value (3240 rpm).

5.7 FUEL GAS OPERATION

INTRODUCTION TO HYBRID BURNER

The hybrid burner is used to achieve low-NO_X gas emissions by burning fuel gas.
It comprises the following burner assemblies

- Diffusion burner used in diffusion mode
- Ignition gas burner used during start-up (ignition phase)
- Premix burner used in premix mode
- Pilot burner used in premix mode

All burners are connected to the respective supply systems required for the various operating modes.

DIFFUSION MODE

The GT can, as a matter of principle, only be started in diffusion mode and operated in this mode until the partial load range is reached.

With a partial load of 50% of the base load the gas turbine is switched over to the premix operating mode which is characterised by emissions with a low NOx level, and can be still loaded up to the base or peak load. If the operator intends to continue operating in diffusion mode up to base load or even peak load, the preset pushbutton must be pressed.

The sub-group control program is activated to start the GT in diffusion mode and load the machine up to pre-selected load.

Due to its environment impact, however, the diffusion mode is not recommended and should only be used in exceptional cases. At higher GT discharge gas temperature, the combustion should be changed to premix mode.

PREMIX MODE

Premix mode operation is only possible above a set corrected GT outlet temperature. The changeover to premix mode is not allowed below this temperature by a protective interlock.

To initiate the premix mode operation, the operator must press the push-button “premix burner” on the control console. This selection can be made prior to start the sub-group control program, but the option remains inactive until the changeover temperature is reached. If the GT is operating in diffusion mode above the limit temperature, it means that the interlock above mentioned is active.

This premix mode interlock is not reset until a manual intervention occurs, e.g. reducing the load set point and thus reducing the TATK.

The following conditions are a prerequisite to enable the premix changeover sequence:

- Premix mode selection at control console
- TATK = TT.ATK.01 + 5°C (490°C): change-over temperature from diffusion mode to premix mode (TATK permissive limit)
- Initial row of compressor stationary blades closed at minimum position: 37°degrees.
- Fuel oil emergency valve CLOSED
- Diffusion gas and premix gas shutoff ball valves, including the pilot gas shutoff valve in diffusion mode position
- Fuel gas pressure (MBP13 CP001) downstream of emergency valve > 16.3 bar
- Combustion air control in proper position.

If these criteria are fulfilled, the changeover from diffusion to premix mode takes place automatically via the following control actions when the changeover temperature TT.TATK. is reached (490 °C).

- Further loading prevented by interlock on the load set point adjuster.
- Opening of the pilot gas shutoff valve
- After the OPEN feedback signals of the shutoff valves have been received, the pilot gas control valve is switched from its initial position during diffusion mode (G.PILOT.01: 20% open) to the controlled position G. PILOT.02-03 between 2 to 3.5 mm as a function of the compressor inlet temperature.
- When the pilot gas control valve has reached its specific position, the control command to open the shutoff valves of the premix burners is issued.
- After the OPEN feedback signals of the shutoff valves for premix burners have been received, the CLOSE command is issued to the diffusion burners valves.
- On the receiving of the CLOSED feedback signals from the diffusion burners shutoff valves, the load increase interlock is released, and the load can restart increasing.

PROCEDURE FOR CHANGE OVER FROM PREMIX TO DFFUSION MODE

The GT must be changed over from premix to diffusion mode during shut down, as a matter of principle

There are two possibilities to initiate this procedure:

1. TATK dependent changeover

   In order to return to diffusion mode, the GT can be unloaded manually using the load set point adjuster until changeover temperature TT.TATK.04 (480°C) has been reached.

   An interlock inhibits the return to diffusion mode above this temperature.
2. Manual changeover from premix to diffusion mode.

   If the actual TATK lies within the range from the base load temperature of 540°C to 480°C, the changeover to diffusion mode can be made immediately by pressing the appropriate pushbutton on the control console.

The following apply to both the previous variants

- Load>base load
- Premix, diffusion and pilot gas shutoff valves in the premix mode position

The fulfilment of changeover criteria presupposes the following automatic sequence of operations:

- Load increase discontinued (interlocked)
- Compressor initial blades pitch and mixing air opening in fixed position
- Opening of diffusion burner shutoff valves
- With diffusion burner shutoff valves OPEN, the premix shutoff valves begin to close
- With the premix shutoff valves are CLOSED, the pilot gas control valve is open to the defined diffusion mode position: G.PILOT.01: 20% open.
- When this position is reached, the CLOSE command is issued to the pilot burner shutoff valves
- Receipt of CLOSED position signal of pilot burner shutoff valves concludes the changeover process and the turbine is now in diffusion mode.

Interlocks for load reduction and mixing air adjusting device and compressor blade pitch adjustment are now re-enabled.

Note: whenever the changeover command has been given, either from premix to diffusion mode or vice versa, the process must be completed regardless to the operating parameters (e.g. TATK).

PROTECTIVE DEVICES FOR PREMIX MODE

Additional protective devices are provided to ensure stable hybrid burner combustion at all times. When these devices respond, some changes in operating mode are initiated.

In the event of inadmissible fluctuations in fuel gas pressure upstream of the GT, the hybrid burner protection is activated and prevents unstable combustion conditions.

A pressure transducer installed downstream of the fuel gas emergency stop valve is used to generate various limits from control equipment output signals. The former are used to trigger the following automatic sequences:

- Limit of gas pressure P.GAS.06 (15.5 bar): increase the opening of the pilot gas flow and at the same time reduce the output from peak load to base load changing the related TATK limits.
- Limit of gas pressure P.GAS.03 (<15.1 bar): return from premix to diffusion mode
- Limit of gas pressure P.GAS.07 (< 14 bar): GT trip, provided because the limit response of the premix burner shutoff valves does not give yet the signal CLOSED

position. This protection is set in the event of a disturbance involving rapid fuel gas pressure reduction at a rate greater than required by the changeover from premix to diffusion mode previously triggered by the pressure signal of 15.1 bar.

Note: The changeover from premix to diffusion mode by the pressure signal of 15.1 bar occurs in the same sequence of the temperature dependant changeover.

The changeover back to premix mode cannot be initiated until the fuel gas pressure is > 16.3 bar and the operator presses the pushbutton “Premix mode”. For a stable premix mode, it must however be sure about the gas supply pressure to meet the requirements of this kind of operation.

RECOMMENDATIONS

As a rule, the operating modes described above are automatically implemented by the gas turbine control equipment, regardless of whether they are process sequences or safety-related.

The direct intervention by the operator is restricted to the selection of desired mode.

This allows the operator to concentrate on monitoring proper plant operations, along with the associated valves settings, switching sequences, operating limitations, etc.

Important indications as load, fuel pressure, turbine outlet temperature, combustion chambers differential pressure, stationary blades pitch, mixing air aperture position and the position of the pilot gas control valve must be monitored continuously during the changeover phases.

After completion of changeover to the other burner mode, it is recommended that a plant walk-down be performed, including the flames visual inspections.

Steady-state regime of operation near the changeover limits should be avoided to prevent continually repeated changeovers and unstable operating conditions.

5.8 SHUTDOWN AND SHAFT TURNING OPERATION

GENERAL

When the GT is running with load or no-load, the shutdown can be initiated by means of the following signals:

- The sub-group control (SGC) shutdown program

  Intentional shut down is actuated by pressing the STOP pushbutton on the control keyboard
- Forced shutdown by some protection as a result of a disturbance to the GT

  The shutdown is initiated as a protective measure, e.g. in the event of a drop in fuel pressure. The sub-group control, automatically start the shutdown program, which leads the GT to the out of service situation
- Emergency trip by safety and protective equipment.

  The trip occurs when certain protection signals are present from:
  - the turbine itself
  - the generator
  - the heat recovery boiler
  - other external sources

  Under emergency trip initiated by a protection intervention, the GT is immediately shutdown by the closure of the emergency stop valve.
- Manual trip by the emergency shutdown pushbutton

This operation must be used only in case of true emergency, not for normal shut down.

OPERATING SEQUENCE

When STOP pushbutton is pressed, the rundown to 2 MW is initiated in accordance with the selected gradients. At that point the generator circuit breaker opens and the Fuel oil or gas ESV closes completely.

Turbine speed decreases to the speed set point for the turning gear start-up (120 rpm).

The STOP program begins with:

Step 51:

- SGC auxiliary power changeover ON
- SGC lubricating oil pumps ON
- SGC turning gear ON
- Jacking oil pumps ON
- Fuel pre-selection for manual operation enable Reset

Step 52:

- Turbine controller Unload

Note: *unload to < 2MW (E.LEIST.03)*

Step 53:

- Auxiliary bearing oil pump OFF
- Synchroniser OFF
- Blow-off valve 2 Open

Note: *Generator circuit breaker Open*

Step 54:

- Turbine emergency stop valves Trip

Fuel gas operation:

- Fuel gas emergency stop valve Closed
- Diffusion burner shutoff valves Closed

Fuel oil operation:

- SGC fuel oil booster pumps OFF
- Fuel oil injection pump OFF
- Fuel oil booster pumps 1and 2 OFF
- Fuel oil ESV Closed

Step 55:

- No command

Inquiry on the following commands:

Fuel gas operation:

- Fuel gas vent valve Open
- Diffusion burner isolation valves Closed

Fuel oil operation:

- Fuel oil ball valve assemblies Closed
- Fuel oil return isolation valve Closed
- SGC fuel oil booster pumps OFF

Inquiry: Turbine speed >200rpm

Step 56:

- Fuel oil drain valve Open

Condition for opening: Speed < S.TURB.21 (900 rpm)

Step 57:

- SGC generator cooling air damper Closed

Note: ***initiation of 24 hours cooling down period on turning gear***

Step 58:

- SGC turning gear OFF
- Turning gear OFF
- SGC bearing oil cooler OFF

Step 59:

- No command

Inquiry: Turbine speed > 90 rpm

Waiting period 30 min.

Step 60:

- SGC lube oil pumps OFF
- SGC lube oil circulation ON
- SGC jacking oil pumps OFF
- Jacking oil pumps OFF
- SGC cooling supply system OFF

Step 61:

- No command

Waiting period: 6 hours, prior to the intermittent shaft turning operation).

Step 62:

- SGC generator auxiliary equipment ON

Step 63:

- No command

Note*: After the time has been elapsed (6 hours), the program returns to step 51 to initiate intermitted shaft turning. A timer is set to limit shaft turning operation to a period of 2 minutes, after that the program returns to step 61 and the 6 hours waiting period.*

When the Sub Group Control shutdown program is activated, these sequences are continually repeated.

AUTOMATIC SHAFT TURNING OPERATION

Following each turbine shutdown, the shaft turning gear is automatically controlled, activated and deactivated by the sub group control shutdown program.

The cool-down turning of 24 hours is started by the speed signal of 120 rpm. After 24 hours is deactivated and the shaft turning operation is continued by means of timers with 2 minutes of tuning and 6 hours of interval.

MANUAL ACTIVATION OF THE SHAFT TURNING GEAR

It is possible, out of the sub group control program, to start the turning gear manually by push-button on the console.

It is recommended to start-up the turning gear by activating the sub-loop control as follows:

- SGC lube oil pump ON

Activates: Main lube oil pump and vapour oil extractor.

Note: *If no lube oil pressure signal is received, the auxiliary lube oil pump and emergency oil pump are automatically started.*

The emergency oil pump can be put out of service only manually by operator.

- SGC jacking oil pump ON

Activates: Jacking oil pump

Note*: check the correct oil pressure*

- SGC turning gear ON

Opens the ball valve MBV41AA001 for lube oil supply to the Turning gear turbine.

Note: *When this ball valve is open, the GT shaft begins to turn, standing up to 75-90 rpm.*

SHAFT TURNING BY MANUAL TURNING GEAR

If for some reason the turning gear is not available for operation, the shaft can be turned by means of the manual turning gear installed at the coupling flange of the intermediate shaft, as in the GT description, with a hook spanner. Before to do this, the operator must activate the lube oil pump, the jacking pumps, the oil vapour extractor. If this procedure is executed when the turbine casing is hot (> 100°C), the shaft must be turned of 180 angular degrees every 15 minutes.

5.9 GT OUT OF SERVICE - MANDATORY MEASURES

GENERAL

When the GT is out of service for an extended period of time, some mandatory measures must be taken.

It is assumed that the GT is not in stand-by and without extensive maintenance.

SGC operating program

- Sub-group control	Deactivated
Press Stop button	STOP button illuminated

Intake and exhaust isolation

- Compressor isolation dampers	Closed
- Exhaust gas damper	Closed
- Access doors to air intake-exhaust-compressor	Locked

Fuel oil system

- SGC fuel oil booster pumps	Deactivated
- Power supply elect. Motors booster pumps	Deactivated
- Injection pumps	Deactivated
- Fuel oil emergency stop valve	Closed
- Ball valve assemblies	Closed
- Return flow shutoff valve	Closed
- Leakage oil pump	Stand-by
- Leakage oil tank level monitor	Stand-by
- Recirculation ball valve	Closed (to naphta)

Fuel gas system

- Fuel gas reducing station isolation	Closed
- Fuel gas secondary shutoff	Closed
- Fuel gas emergency stop valve	Closed
- Fuel gas venting valve	Open
- Fuel gas shutoff valve	Closed

Ignition gas system

- Manual shutoff	Closed
- Ignition gas valve 1 (3 ways)	A/C Open; B Closed
- Ignition gas valve 2	Closed
- Power supply for ignition transformer	Deactivated
- Ignition gas cylinders	Closed

Lube and jacking oil System

- Power supply for electric motors:	Deactivated
Main lube oil pump	
Auxiliary lube oil pump	
Emergency lube oil pumps	
Jacking oil pumps	
Oil vapour extractors	
- SGC lube oil pumps	Deactivated
- Oil tank level monitor	Stand-by
- Temperature monitor	Stand-by
- SGC oil circulation	Deactivated
- SGC jacking oil pumps	Deactivated
- Ball valve for turning gear	Closed

Hydraulic oil system

- Power supply for electric motors	Deactivated
Main hydraulic oil pumps	
- Oil tank level monitoring	Stand-by
- Temperature monitoring	Stand-by

Blow-off system

- Compressed air tank for blow-off valve	Empty

Drain system

- Drain header	Drained
- All drain valve upstream the header	Closed
- Water supply between duct and disposal tank	Drained

Cooling water system

- Cooling water supply	Closed
- SGC bearing oil cooler	Deactivated
- Water side of GT bearing oil cooler	Drained
- Water side of generator bearing oil cooler	Drained

Note: *The operator should take appropriate measures to avoid accelerated corrosion on components exposed to cooling water.*

Start-up converter

- Prevent plant start-up	Locked

Generator

- Internal Heating	ON

Standstill heating

-Turbine dehumidifier	ON

Note*: the dehumidifier must be operated during the entire shutdown period.*
Open connections between the turbine and piping or tanks containing water must be avoided to prevent the inlet of moisture.
The humidity level inside turbine should be checked at regular intervals. It should be ensured that the mean relative humidity never exceeds 50%.

Electrical A.C. distribution system

Bus bars supplied at nominal voltage by external grid

Batteries

Rectifier supplied

D.C. normal and emergency bus bars supplied at nominal voltage

UPS system

In operation: supplied by batteries and emergency supply ready

Related bus bars supplied at nominal voltage: 220 V A.C.

DCS supervision system

Supplied. All the components in service

Fire fighting system

In service and ready for operation

Emergency diesel

Ready for operation