SYSTEM DESCRIPTION CJP10 TURBINE GOVERNOR	Respons. dept GPEL	Date 040220	Reg. E DB 101
	Prepared A. Pettersson		YAMAMA CEMENT

Approved 2004-03-01 Tomas Strömberg	Latest revision -	Archive	HG 6353
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PURPOSE OF THE SYSTEM

The purpose of the turbine governor is

- to control the amount of fuel fed to the gas turbine in order to
  - keep the machine at desired speed or load
  - avoid running in forbidden operating areas
  - avoid flame-out
- to control the machine during a fuel-change
- to control the position of the inlet guide vanes as a function of gas generator speed
- to control the bleed valve 2 as a function of gas generator speed

GENERAL DESCRIPTION OF THE SYSTEM

The turbine governor is digital and realised with ADVANT Control system components, AC servo driver boards and variable frequency drives.
Positioning is electrical, i.e. electrical signals from the turbine governor control AC servomotors, these motors actuate the fuel control valves, the inlet guide vanes and the combustion chambers bypass valves. A variable frequency drive controls the speed of the liquid fuel pump.
The controlled bleed valve 2 is provided with a pneumatic actuator.

Principles of the Function

The principal components (see figure below) are:
Transducer (1) for sensing governed variables (actual values such as speed, temperature, position. In the figure the rotor speed is shown).
Set values (2) of the controlled parameters.
Control channels (3): All incoming sensed quantities are compared with their setpoint and the deviation is adapted to derive the signals that control the servo motor drivers and /or the variable frequency drives.
Valve position loop controllers (4): Controls the position of the valves and vanes by the use of a position feedback signal.
AC Servo motors and drivers (5): The drivers transform the output signals from the governor into servo motor phase currents giving torque that move the valves and vanes.
Static Frequency Converter (6) controls the speed of the liquid fuel pump and thus the amount of fuel fed to the combustion chambers.
Pneumatic actuator (7) positions the controlled bleed valve 2.

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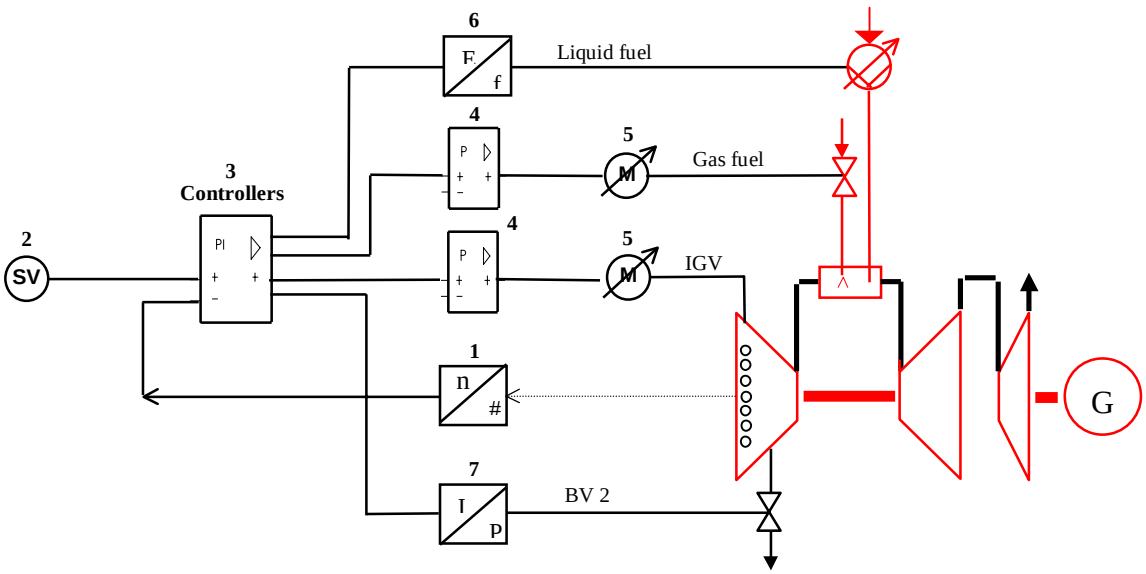

The actual values of the speeds are brought to the governor as a pulse train. Other feedback is transmitted in the form of standard current signals. In the various control channels the actual values are compared with their respective set values. The difference between actual and set value gives an error signal that then, properly manipulated, form the governor output signal. The output signal is proportional to a valve position or a liquid fuel pump speed respectively.
The control signals from the various control channels are connected to the servo motor drivers and / or the variable frequency drive via minimum selectors, thus the fuel flow is controlled by the channel requiring the smallest valve opening. An exception to this is the gas generator deceleration control that is connected through a maximum selector in order to prevent flameout of the burners. The channel in control is indicated on the operator station.

MAIN COMPONENTS

Survey

The governing of the gas turbine consists of the following digital equipment:
1) AC100, that handles the control of the turbine.
2) MOOG AC-drives and motors for the control of the gas valves and the compressor vanes.
3) ABB Static frequency converter for the control of the liquid fuel pumps.
4) Bently Nevada for speed measurements and over speed detection.

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Hardware

I/O boards

Please see system description protection system CAA.

AC-drives and motors

The drivers transform the output signal from the governor into servo motor phase currents giving torque that move the valves and vanes.

Static Frequency Converters

The Static Frequency Converters (SFC) controls the speed of the liquid fuel pump and thus the amount of fuel fed to the combustion chambers.

Speed Measurement

The Bently Nevada over speed protection system trips the turbine on over speed. The pulses from the speed pick-ups are transferred to the turbine governor (AC100) by means of buffers/amplifiers.

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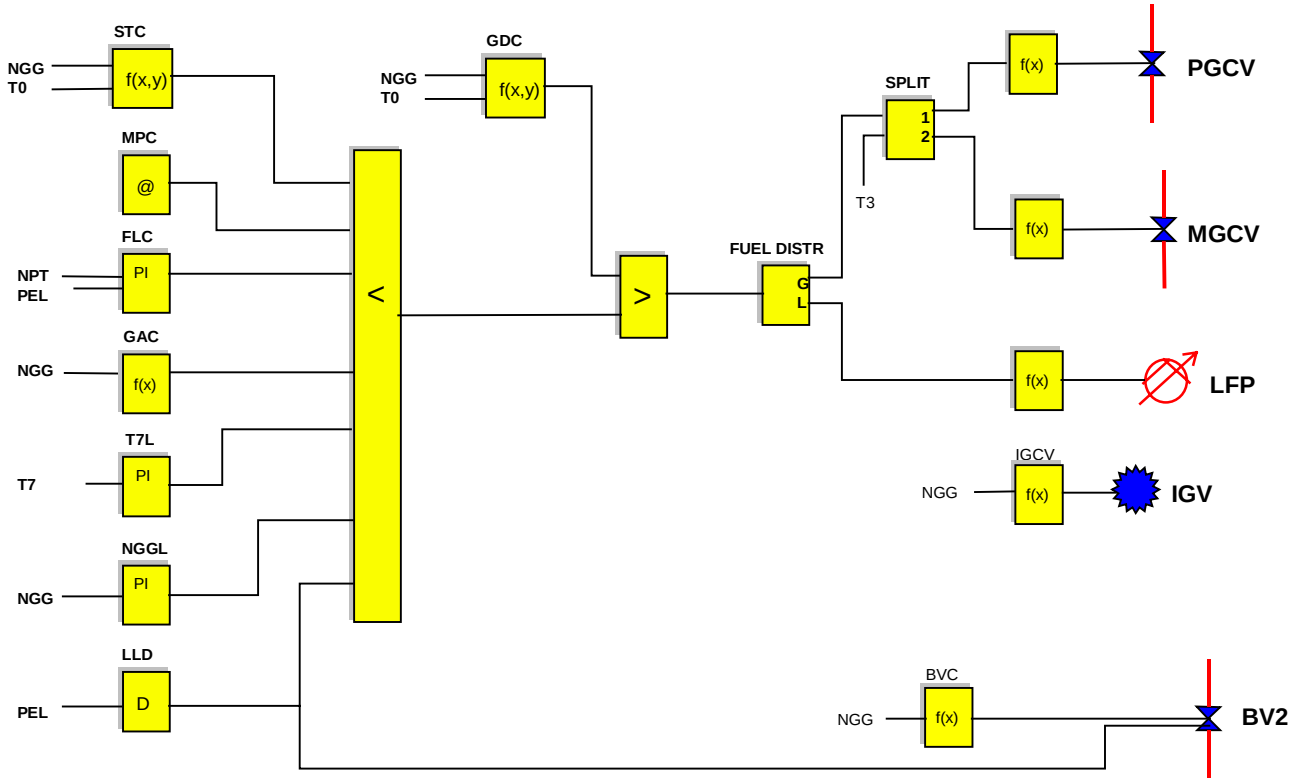
FUNCTION Block Diagram (Dual fuel)



- *BVC* — *Bleed valve 2 control*
- *BV2* — *Bleed valve 2*
- *FLC* — *Frequency load controller*
- *GAC* — *Gas generator acceleration control*
- *GDC* — *Gas generator deceleration control*
- *IGV* — *Inlet guide vanes*
- *IGVC* — *Inlet guide vanes control*
- *LFP* — *Liquid fuel pump*
- *LLD* — *Loss of load detection control*
- *MAX(>)* — *Selector for passing of max desired fuel flow*
- *MIN(<)* — *Selector for passing of min desired fuel flow*

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- *MGCV* *Main gas control valve*
- *MPC* *Maximum fuel servo position control*
- *NGG* *Gas generator speed*
- *NGGL* *Gas generator speed limiter*
- *NPT* *Power turbine speed*
- *PEL* *Electrical output*
- *PGCV* *Primary gas control valve*
- *STC* *Starting control*
- *TFLAME* *Calculated flame temperature*
- *T0* *Ambient temperature*
- *T3* *Compressor outlet temperature*
- *T7* *Power turbine exhaust temperature*
- *T7L* *Power turbine exhaust temperature limiter*

Description

Speed measurement

The turbine is equipped with four speed pickups. Two for gas generator speed measurement and two for power turbine speed control. The speed pickups are working according to eddy-current principals measuring the presence of cogs on a cogwheel on the turbine rotor.
Each speed pickup signal goes directly to its own individual pulse counting input in the 2-ch redundant *Bently Nevada* system. The speed signals are supervised to be a part of the turbine protection system. Over speed is sensed and the turbine is tripped if voted for in the 1-out-of-2 selector.
The digital turbine governor measures the frequency proportional to rotor speed from the pickups. The measured values from the two speed pickups are used to create a voted maximum value that then is used in the governor.

General

There are 7 control functions in total. Two are used at start (STC and NGGL), one at normal operation (FLC) and 5 as limit functions (MPC, GDC, T7L, NGGL and GAC).
All control functions is setting, as its output, a desired heat flow to be fed to the combustion chambers. Three of the controllers have PI-control characteristic.
A selector system chooses one of the control signals, at the time, to be in control.

Unless stated otherwise, all controllers have the following functions:

1) Only one controller could be in operation of the fuel servo (liquid fuel pump) through the selector system. Changing the appropriate set point makes changing of controller in operation, and the transition is always bumpless.

2) A lost controller feedback forces the corresponding controller to a non active status that leaves room for a backup controller to take over (only valid for NGGL, FLC and T7L). Thereby the unit continues to run at actual load level, until the error is fixed or the unit stopped by the operator. When the feedback error disappear the control changeless goes back to the previous situation, unless the operator meanwhile has given the faulty control function a new set point. In this case a change in working point could occur as the ordinary controller is switched back into operation with a new set point.
The MPC is used as backup control upon feedback error. The error freezes the actual desired heat flow signal and it becomes the set point for the MPC controller.

3) In the operator station the controller in operation is marked by having an active "in operation" indication.

STC, Starting control

TASK
In order to accelerate the gas generator at a limited rate, the starting control produces a set point for the desired heat flow as a function of time. It thereby prevents too rapid acceleration and thermal stress of the turbine.

SET POINT
The set point is ramped from ignition level with a certain ramp speed. The start position is affected by the ambient air temperature (T0). An increasing temp reduces the amount of starting fuel.
A kick function adds some more gas fuel during ignition.

OPERATION
The STC function will control the servo until NGGL takes over.

FEEDBACK
No feedback.

NGGL, Gas generator speed limiter

TASK
The NGGL controls the gas generator speed from 6000 rpm and up until FLC takes over at nominal speed. It also controls that the gas generator speed will not exceed maximum allowed speed.

SET POINT
When the gas generator speed is more than 6000 rpm the set point is ramped with to max setting. The set point has no manual mode and the operator is not able to change it.

OPERATION
NGGL takes over from STC when the gas generator speed is 6000 rpm and controls the servo until FLC takes over.

FEEDBACK
The feedback for NGGL is the gas generator speed.

FLC, Frequency and load controller

TASK
FLC takes over from NGGL and controls the turbine speed before synchronisation. At synchronisation an offset is added to the set point. After synchronisation the active power is controlled depending on the load set point and the droop set point.

SET POINT
The set point to the controller is a combination of the frequency set point, load set point and the droop set point. The operator can change all these set points.

OPERATION
FLC takes over from NGGL shortly before the turbine reaches nominal speed. It is normally in operation until full load is reached when T7L (or NGGL) takes over.

FEEDBACK
The feedback for FLC is the active load and the generator frequency. The generator frequency is calculated from the turbine speed.

MPC, Maximum servo position control

TASK
The MPC limits the maximum fuel input.

SET POINT
The operator sets the set point in MJ/s. Normally the set point corresponds to more than 100% load.

OPERATION
MPC is not used during normal operation but the operator can manually limit the maximum amount of fuel fed to the combustion chambers. It is also used as backup control upon feedback error. The error freezes the actual desired heat flow signal and it becomes the set point for the MPC controller.

FEEDBACK

No feedback.

GDC, Gas generator deceleration control

TASK
GDC shall keep up the amount of fuel, exactly at minimum demand to sustain flame. This task is very important if load rejections should occur and call for fuel below admissible value to sustain flame.

SET POINT
The GDC set point is a function of gas generator speed. The operator is not able to change the set point.

OPERATION
GDC is normally used only at load rejections.

FEEDBACK
No feedback.

T7L, Exhaust temperature limiter

TASK
T7L limits the exhaust temperature. This is the normal maximum load limiter.

SET POINT
The set point is a function of ambient temperature, ambient humidity, compressor delivery pressure, exhaust gas pressure and compressor inlet pressure. If the operator selects peak-load the set point is automatically adjusted to a higher value.

FEEDBACK
The feedback for T7L is the turbine exhaust temperature.

GAC, Gas generator acceleration control

TASK
GAC shall prevent the turbine from surging and from transient over temperatures in the gas generator during loading.

SET POINT
The set point is a function of normalised gas generator speed. The operator is not able to change the set point.

FEEDBACK
No feedback.

Fuel distribution (fuel change)

To accomplish a smooth transition when changing fuel the *fuel distribution circuit* puts a decrease ramp upon the valve of the fuel to be exchanged. This starts simultaneously with the opening of the new fuel valve. The controller in operation then controls the new fuel to keep the total heat flow fed to the machine at the desired level.

Load rejection

FUNCTION
The load rejection detection function senses the active power value, and calculates the rate of change over one sample. If it exceeds a certain level, nominally 12 MW, the main fuel is with maximum speed put to zero and the primary fuel to GDC level. When operating on liquid fuel the fuel pump speed goes to GDC level.

Start up

When starting up, the fuel control valve is opened (or the fuel pump is started) by the sequencer at the same time as the ignition is switched on.
The *starting control (STC)* controls the fuel flow to a scheduled value for ignition.
At approximately idle speed the *gas generator speed control* takes over and ramps the gas generator speed up to the point where synchronous speed of the power turbine is reached. Now the *frequency load control (FLC)* takes over.

Synchronising

When the AC generator has reached nominal voltage, the grid frequency discriminator is connected to bias the *frequency/load control*. In this way the correct synchronising speed is achieved.

Continuous operation

Normal operation

The *frequency/load control* governs the output according to the load set point and the droop setting. For operation on small networks and 0% droop, the frequency is controlled independently of the load. For operation on larger grid networks the droop setting must be greater than 0%. The output is controlled by means of the load control error signal. By the droop setting, a frequency increase provides a load reduction, and a frequency reduction provides load increase.

Low NO_x combustion chambers

When provided with dry low NO_x combustion chambers for gas fuel firing the unit is equipped with dual gas fuel control valves. One primary valve for start and low load operation and a main valve for high load operation. The governor controls these two valves in a way that the desired sequence is obtained.

Bleed valve 2 and Inlet guide vane control

Both parameters are controlled as a function of the gas generator speed. The bleed valve has a feed forward to open it quickly at load rejections.

Load limitation

The gas turbine output is limited by the *gas generator exhaust temperature control* (limiter).
The gas turbine output can also be restricted by the *gas generator speed control*.

Loss of load

To prevent the combustion chamber flame from extinguishing during a rapid reduction of the turbine load, the turbine governor has a flame sustain control. *The gas generator deceleration control (GDC)* ensures that the lowest possible fuel quantity, sufficient for keeping a stable flame, is supplied to the combustion chamber when the load is decreased.
A *loss of load detector (LLD)* senses a high negative derivative of the measured electrical output signal during or upon switching to isochronous operation. The *loss of load detector* then gives a full closing signal to the fuel controls that will engage the *gas generator deceleration control* to prevent flame out.

Turbine stop

Normal Stop

At a normal stop the governor first ramps down the output load to zero. Then the gas fuel control valves are brought to minimum position and the liquid fuel pump is brought to minimum speed.

Emergency stop

At a trip order the governor quickly closes the gas fuel control valves and / or stops the liquid fuel pump.

Stand still

After shut down the system is not in operation. It gives closing/stop orders to the fuel equipment.

DISTURBANCES

Gas turbine trip

Upon a GT-trip the governor immediately closes the fuel valves and stops the fuel pump.

Generator breaker trip

See description for **Loss of load.**

Loss of power supply

Loss of power supply to the digital turbine controller will give system fault and trip the turbine.

Other faults

- If measurement of the gas generator speed malfunctions, NGGL deactivates.
- If measurement of gas generator speed, power turbine speed or active load malfunctions, FLC deactivates.
- If measurement of gas generator speed malfunctions, GDC deactivates.

TECHNICAL SPECIFICATION

Design criteria and standards

The turbine governor meets requirements according to
- NEMA SM24 NEMA "D"
- IEC 45

Dimensioning data

Engineering data

Fuel servo response	0.35 sec/full stroke
Fuel pump response	0.35 sec/full speed
Bleed valve response	1.2 sec/full stroke
Inlet guide vane response	1.5 sec/full stroke
Frequency dead band	0% - adjustable is option
Frequency adjustment	10%
Droop setting	0 - 10%

Emergency power supply

N/A

Installation

N/A

Materials

N/A

Component data

N/A

TESTING AND SERVICE

Testing during normal operation

- At standstill there is a possibility to test the operation of the servos by a test function.

Accessibility during normal operation

N/A

INDEX OF COMPONENTS

N/A