



ديبلوم تطبيقات التحكم الأوتوماتيكي في نظم القوى الميكانيكية

MEP 599 Diploma Design Project-Spring Term 2016/2017

Investigation of Control and Protection Systems of a Practical 307MW Heavy Duty Gas Turbine

by Eng. Ahmed Shawkey Ghazala

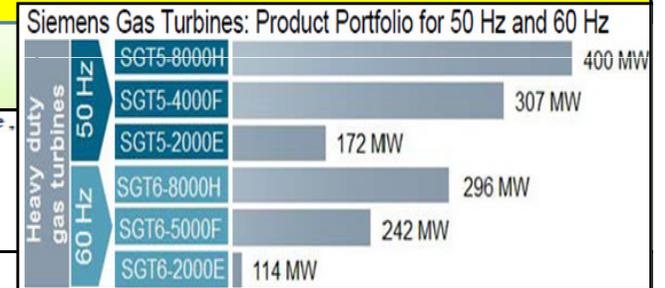
Supervised by

Associate Prof. Mohsen Sayed Soliman, ACC Manager & Dr. Amro Abdel Raouf, ACC Vice Manager

Mechanical Power Engineering Department

Abstract: The project includes investigation of various Control & Protection Systems of Siemens SGT54000F Gas Turbine which is a Practical 307MW Heavy Duty 50/60 Hz Gas Turbine used in Combined Cycle Power Plants.

Siemens proven SGT5-4000F gas turbine is characterized by high performance, low power generating costs, long intervals between inspections and service-friendly design. Optimized flow and cooling add up to the highest gas turbine efficiency levels and the most economical power generation in combined-cycle applications. Its state-of-the-art technology is based on proven design features.



SGT5-4000F gas turbine package

The gas turbine package for the SGT5-4000F consisting of turbine and generator, with the designation SGT5-PAC 4000F, enables economical power generation in a bandwidth up to 307 MW. Siemens gas turbine packages combine a standardized basic design with options for location- and customer-specific requirements, in order to provide an ideal solution for successful projects in each case. This approach allows low costs while at the same time providing flexibility for individual requirements.

- Accessible annular combustion chamber with 24 hybrid burners
- Ceramic heat shield in the combustion chamber
- 15-stage axial compressor with optimized flow distribution (CDA blades)
- Single crystal turbine blades with heat protection coating and film cooling
- Modern cooling technology
- Multiple fuel option
- Low-NOx combustion system

SGT5-4000F technical data

Siemens Gas turbine

ISO base power output (MW)	307
Heat rate (kJ/kWh)	9,001
Heat rate (Btu/kWh)	8,532
Efficiency (%)	40
Pressure ratio	18.8
Exhaust mass flow (kg/s)	723
Exhaust mass flow (lb/s)	1,595
Turbine speed (rpm)	3,000
Exhaust temperature (°C / °F)	579 / 1,074

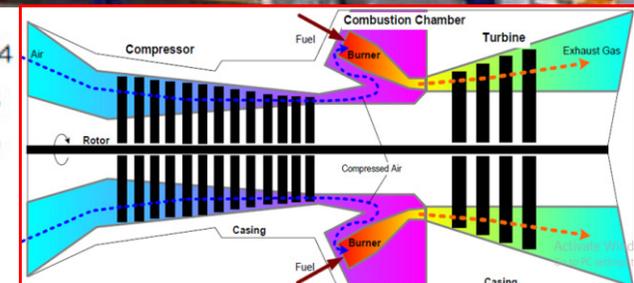
Gas turbine physical dimensions

Weight (t / lb)	312 / 688,000
Length (m / ft)	10.8 / 35
Width (m / ft)	5.2 / 17
Height (m / ft)	4.8 / 16



Technical data SGT5-4000F in combined cycle operation

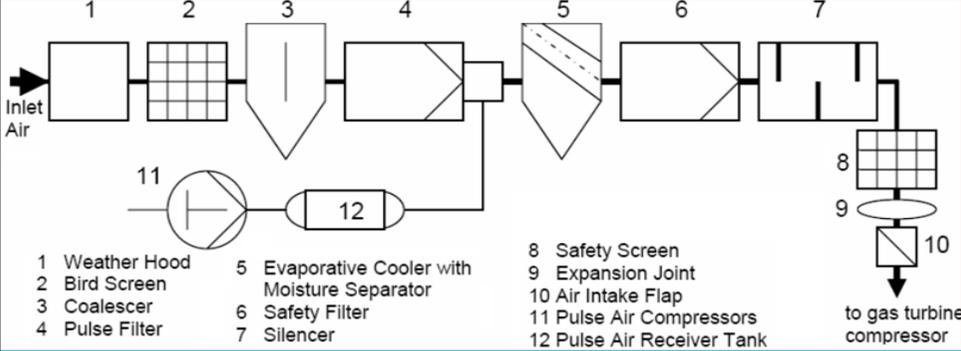
Siemens combined cycle power plant	1S	2x1
Net power output (MW)	445	890
Net efficiency (%)	58,7	58,7
Net heat rate (kJ/kWh)	6,133	6,133
Net heat rate (Btu/kWh)	5,812	5,812
Gas turbine gross power (kW)	-	601,000
Steam turbine gross power (kW)	-	304,000
Number of gas turbine/s	1	2
Pressure/Reheat	Triple / Yes	Triple / Yes



Air Intake System Task:

- 1- to supply gas turbine with required combustion air
- 2- to protect balding of GT compressor against premature wear.

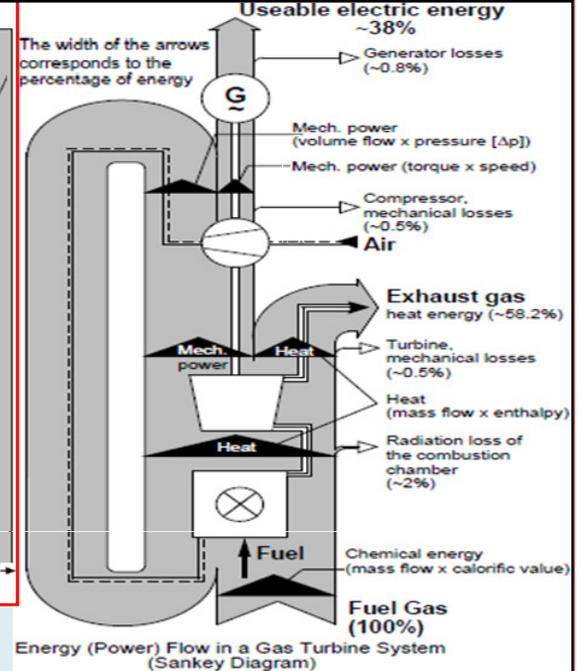
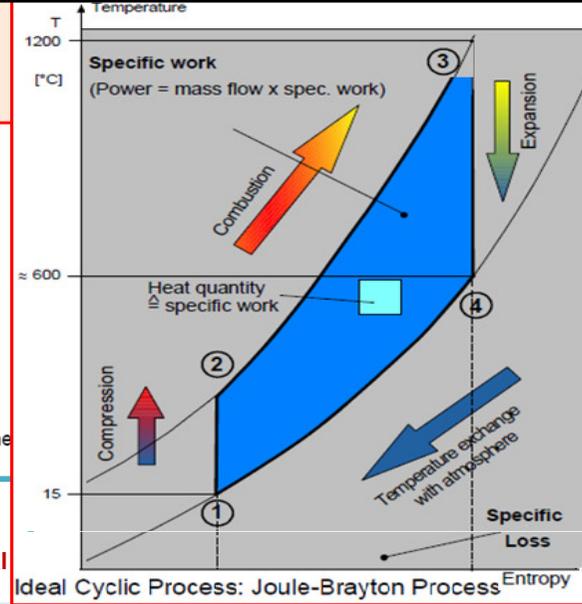
Combustion air to compressor is cleaned in a combination of filters.



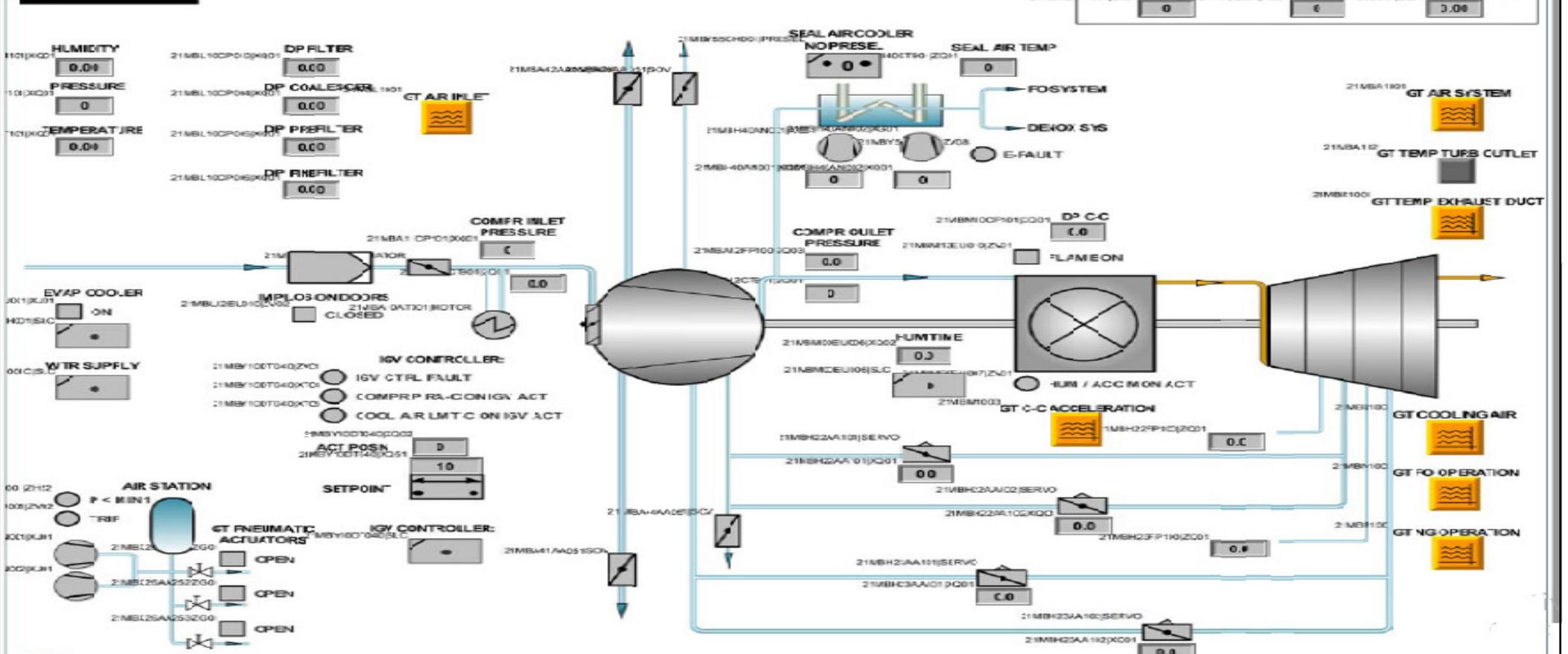
- 1 Weather Hood
- 2 Bird Screen
- 3 Coalescer
- 4 Pulse Filter
- 5 Evaporative Cooler with Moisture Separator
- 6 Safety Filter
- 7 Silencer
- 8 Safety Screen
- 9 Expansion Joint
- 10 Air Intake Flap
- 11 Pulse Air Compressor
- 12 Pulse Air Receiver Tank

To protect the air intake system against abnormal vacuum :
 -The system is monitored by differential pressure switches.
 -An alarm is given in control room as well as on local control panel when differential pressure over the filter system reaches 13 mbar.

Operation of the system at abnormal vacuum conditions is not allowed. The gas turbine will be tripped :
 If the differential pressure increase higher than >16 mbar, with a 2 of 3 logic within the GT I&C equipment.



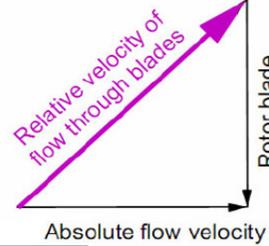
GT AIR SYSTEM



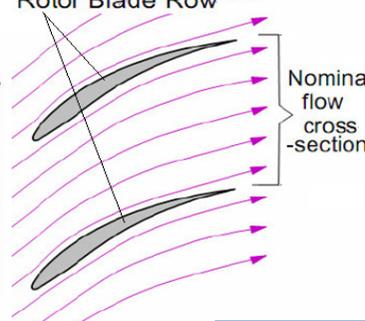
Compressor Surge Control / Blow Off System:

Axial compressor of GT is designed to run at rated speed of generator. In a certain speed range below the rated speed, the front stages of the compressor are so highly loaded aerodynamically that some flow separation occurs at the compressor airfoil surfaces due to excessive air deceleration. As a result, the overloaded compressor stages are now no longer capable of generating the necessary increase in air pressure, the phenomenon known as compressor surging occurs and the compressor throughput flow becomes unstable.

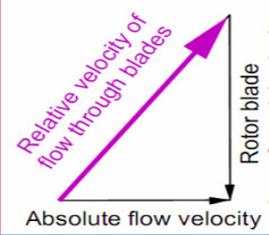
At normal operation (rated speed & discharge pressure)



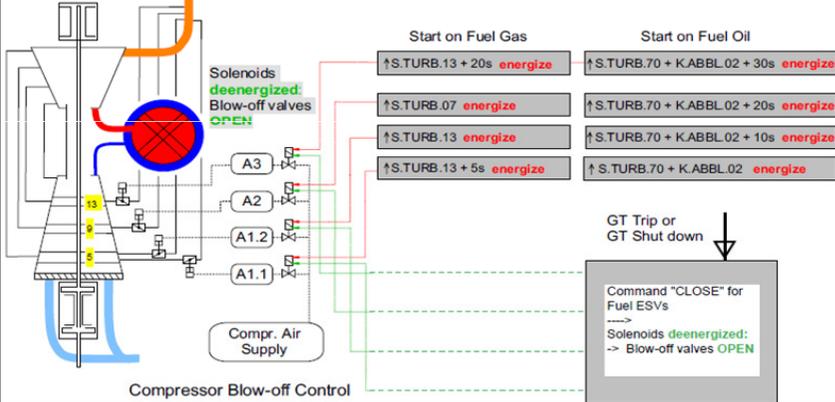
Rotor Blade Row



At deviating conditions (e. g. increased discharge pressure hence: reduced abs. flow velocity)

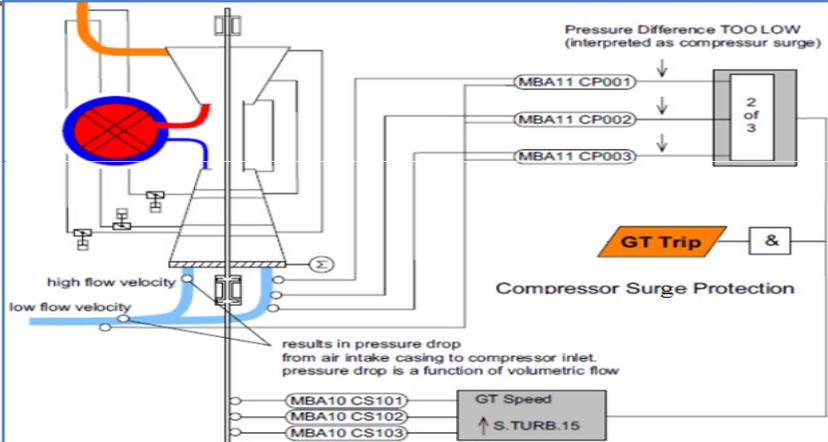


1-Speed Decline 2-Shutdown 3-GT Trip



Protection Functions of Blow-off Valves:

Startup is aborted if blow-off valves are not open. Gas turbine **trip** is triggered after a brief delay if the OPEN position of any blow-off valve is not detected in the speed range critical to compressor surging. The gas turbine is shut down if any of blow-off valves are still open and cannot be closed within a short time after reaching rated speed.

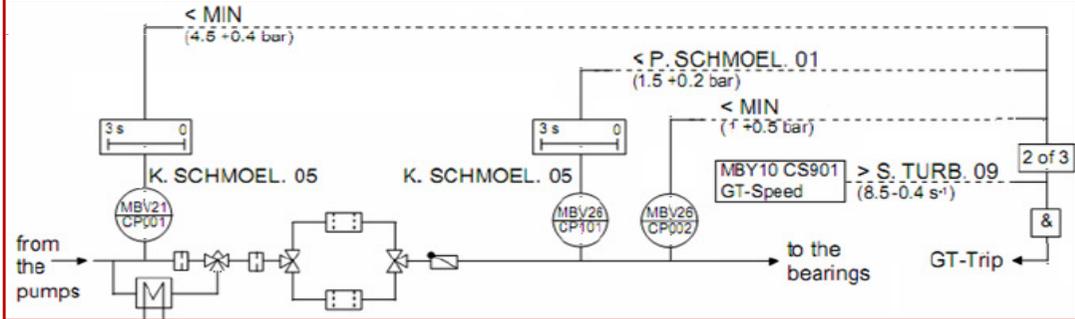
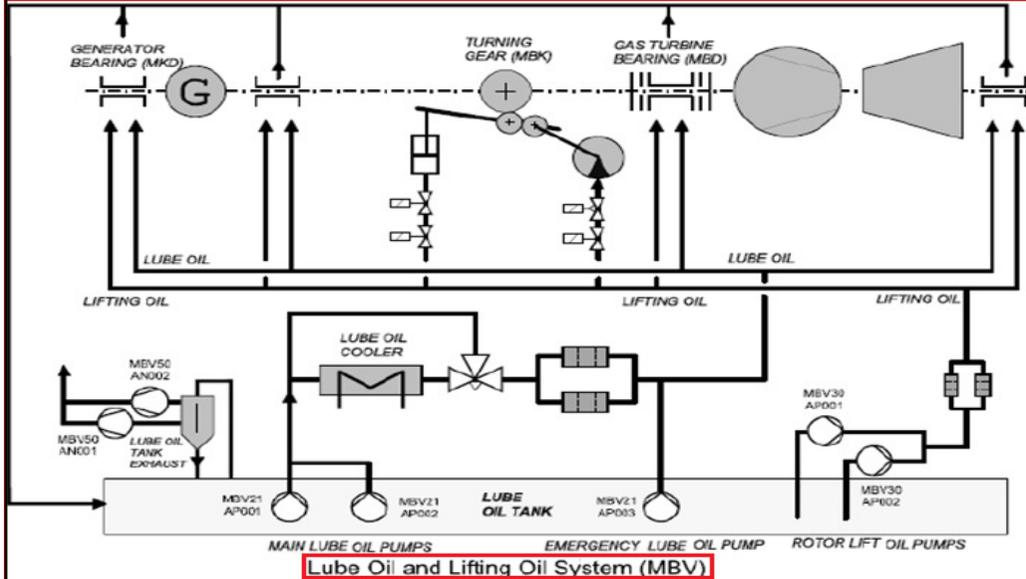


Lube & Lifting Oil System Task

The lube oil system :
1- Supplies oil to the compressor bearing and the turbine bearing of the gas turbine, as well as to the generator bearings. 2-Forms an oil film in the bearings that separates the rotating shafts from the bearing shells and thus minimizes friction. 3-the flow of lube oil removes heat from the bearings. 4- Oil flushes wear debris and solid contaminants out of bearings; such matter is removed by filtration at another location in the lube oil system.

Oil Tank :

Gas Turbine **trip** is triggered: 1- If the oil level continues to rise and the level switch signals level >>MAX. This level can only be reached if a leak in the lube oil cooler allows water to flow into the lube oil system. 2- If the oil level in the tank drops below setting of level switch <MIN, due to a leak. 3-If the fire protection system triggers shutdown of the main and auxiliary lube oil pumps as well as the jacking oil pump & starts up the emergency oil pump, which has a lower capacity.



Lube Oil Pressure Monitoring: Bearing oil supply pressure is monitored by three pressure transducers. Pressure switch switches on the DC power supply directly and thus enables emergency oil pump startup even in the event of an I&C system failure. Gas turbine **trip** is triggered if at least two of following three signals are issued: □□ Lube oil pressure declines below setting of pressure switch (example, 1.5 bar). □□ Lube oil supply pressure, measured by pressure transducer, declines below limit (for example, 1.5bar) for longer than (for example, 3s)

Lifting Oil System Task: At low turbine speeds, lube oil alone does not form an adequate hydrodynamic lubricating film. Jacking oil at high pressure (approx. 140 bar) is forced into pockets in the bearing shells below the shaft journals. The shaft is lifted and floats hydrostatically on a film of oil. Jacking oil pump and associated redundant pump are vane pumps driven by a three-phase electric motor.

Shaft Turning Gear: It comprises hydraulic motor that is connected to a drive pinion. The drive pinion is permanently meshed with a second pinion mounted on the free end of a swing arm. Hydraulic cylinder actuator pivots the swing arm inward to mesh the pinion at the free end thereof with a gear ring mounted on the intermediate shaft that connects the gas turbine to the generator. Spring force returns the swing arm to its disengaged position.

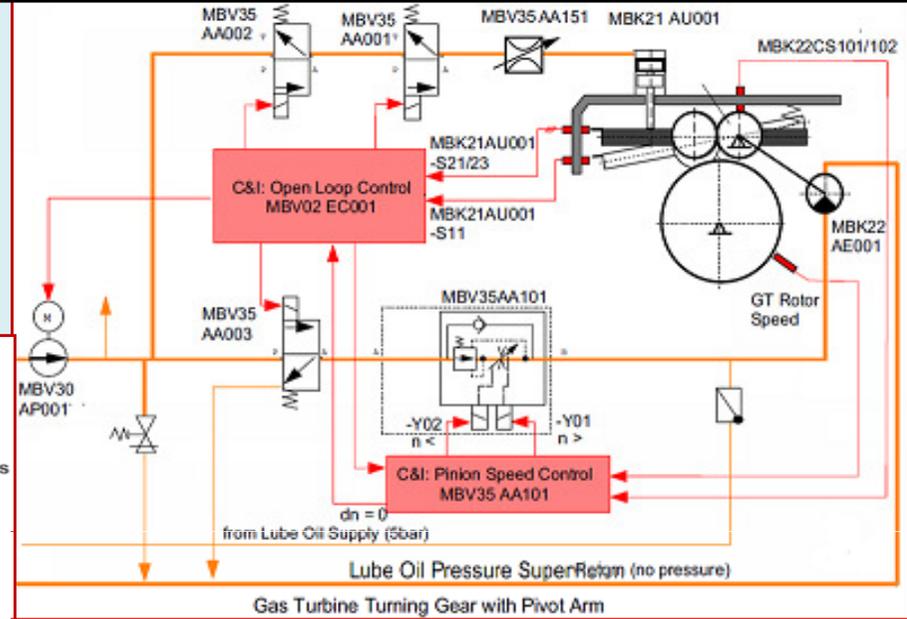
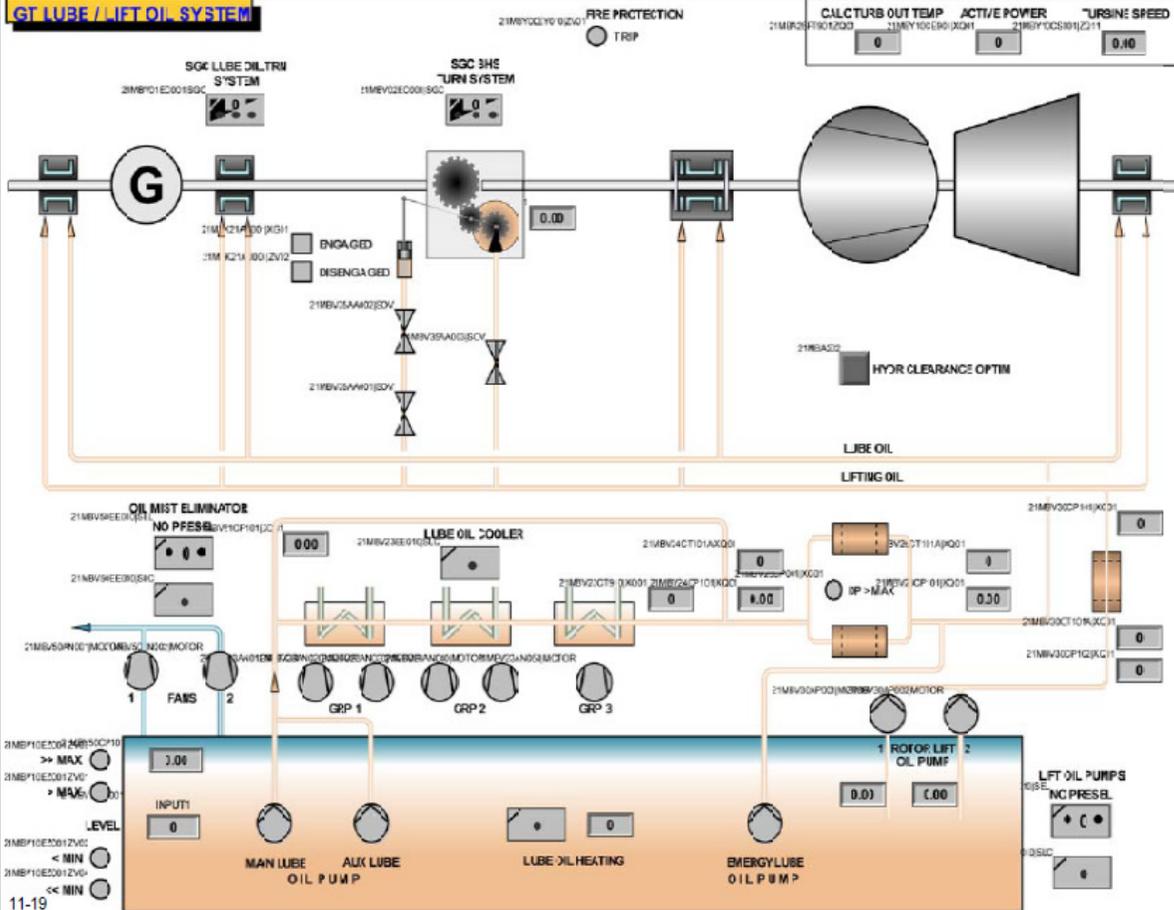
Program "Operation":

The STARTUP program for SGC Lube Oil/Turning Gear Operation has the task of automatically preparing the components of the lube oil system and the turning gear for operation of the gas turbine. In the course of this process the hardware-based function implementing startup of the emergency lube oil pump in response to a drop in lube oil pressure is tested.

SGC Lube Oil/Turning Gear Operation (MBV01 EC001)

- S 1 -Switch off SLC Lube Oil Heating
- S 2
S 3 -Startup test for emergency oil pump via ECO relay (only on turning gear operation or shutdown)
- S 4
S 7 -Switch-on check of main, auxiliary and emergency lube oil pumps
- S 4
S 7 -Switch off turning gear
- S 4
S 7 -Switch off auxiliary and emergency lube oil pump if main lube oil pump is functional
- S 8 -Switch on jacking oil pump
- S 9 - SLC Lube Oil Cooler ON
- S 10 -Steady-state step, lube oil system in operation
- S 10 -Checkback to SGC Gas Turbine "LUBE OIL SYSTEM READY"

GT LUBE / LIFT OIL SYSTEM



Program "Standstill":

The shutdown program of the SGC Lube Oil/Turning Gear Operation controls operation of the turning gear for the gas turbine-generator. Pressure-dependent startup functions for the auxiliary and emergency lube oil pumps are tested two hours into cooldown turning.

SGC Lube Oil/Turning Gear Operation (MBV01 EC001)

- S 51 -Switch on jacking oil pump
- S 52 -Startup turning gear
- S 52 -2 hours of cooldown turning
- S 53 -Close compressor air intake damper
- S 53 -Switch off SLC Lube Oil Coolers
- S 53 -Switch on compressor standstill dryer
- S 54 -Pressure-dependent startup test on auxiliary LOP
- S 56 -Pressure-dependent startup test on emergency LOP
- S 57 -Permanent turning mode

STARTUP PROGRAM:

- S1 - Close shutoff valve
- S1 - Close engaging valves
- S1 - Decrease flow control valve setting (to minimum)
- S2 - Branch: Start turning gear operation from GT standstill?
- S3 - Open shutoff valve
- S3 - Increase flow control valve setting (to maximum)
- S3 - Monitor speed rise for hydraulic gear motor
- S4 - Wait for synchronism between gearwheel on GT shaft and pinion of turning gear
- S5 - If necessary, decrease flow control valve setting
- S6 - Open engaging valves
- S6 - Monitor engaging process
- S7 - Increase flow control valve setting (to maximum)
- S7 - Monitor speed rise for hydraulic gear motor
- S8 - Steady-state turning gear operation
- S9 - Wait for reliable standstill of turbine
- S10 - Decrease flow control valve setting (to minimum)
- S11 - Open engaging valves

SHUTDOWN PROGRAM

- S51 - Close shutoff valve
- S51 - Close engaging valves
- S51 - Monitor disengaging process
- S52 - Decrease flow control valve setting (to minimum), Turning gear operation terminated
- S53 - 24 hours waiting time
- S54 - Increase flow control valve setting