



ROYAL INSTITUTE  
OF TECHNOLOGY

# THERMAL POWER PLANT SIMULATOR TPP 200 LABORATORY EXERCISE

## TUTORIAL N1: ROLLING UP OF TURBINE TRAIN AND CONNECTION OF GENERATOR TO THE GRID

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## **INTRODUCTION**

Tutorial N1 consists of two exercises: the first exercise is for training with the TPP simulator software, which makes the students familiar to the simulator system gives a practical feeling of running a thermal power plant. The second one is for training with rolling up of turbine train and connection of generator to the grid. The theoretical background for the exercise N1.2 is also available in the tutorial.

Following exercises are available in the tutorial:

- 1. Exercise N1.1 for training: General handling of the TPP simulator**
- 2. Exercise N1.2: Rolling up of turbine train and connection of generator to the grid**

## Theoretical background for the Exercise N2: Rolling up of turbine train and connection of generator to the grid

### Control the shaft speed

It is assumed that before starting the turbine, the operator will first familiarise himself with the general piping layout and the operating characteristics of the unit, after which he will proceed as follows:

1. Inspect the governor mechanism and oil where necessary.
2. If the drain ahead of the throttle valve has been closed for any reason, again open until all water of condensation has been removed.
3. Now open the throttle valve to 5% to set the rotor in motion.
4. As soon as the turbine is rolling, observe vibrations and wait until equilibrium will be established.
5. Increase the governor set point to 10 % wait until the vibrations are less than 20% to minimize stresses on the shaft and then increase the governor set point to 20 %.
6. When the vibration is lower than 30%, indicating evenly heated turbine rotor, increase the governor set point from 20 to 40%. Be careful not to set the speed range 1700-1900 rpm, which are the critical speed ranges.
7. Increase the governor set point further to reach normal speed.
8. When normal operating speed is reached the turbine is ready to load.

The rotor absorbs the torque produced in the rotating blades from the expansion of the steam and transmits it through the coupling at the ends to the following shaft and eventually to the generator. Rotor speeds for the HP and IP elements of high pressure, high temperature designs are typically 3000 rpm, 50 Hz. The LP elements generally operate at the same speed although in some instances, to obtain additional exhaust-annulus area, the LP elements are on a separate shaft and rotate at 1500 rpm.

### Synchronising and connection of main circuit-breaker

#### Circuit breaker

In power plants, switching is achieved with a circuit breaker. Before the circuit breaker is closed to connect two live generating systems, both voltages and frequencies must be the same, and in particular, the two AC waveforms must be exactly in phase. If they are not, with the inertia of several large generators behind it,

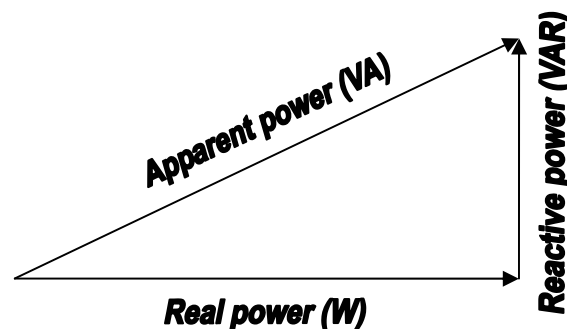
the utility system will jerk the plant generator into phase is a fraction of a second, shearing the generator shaft or much worse. The business of correctly closing a circuit breaker that connects to AC systems is known as synchronizing and it may be done manually, under relay supervision, or fully automatically.

### Voltage control

The output voltage of an alternator running at rated speed, and not connected to other alternators, is a function of the excitation. On a single unit, the level of field excitation can be changed manually with a rheostat. For alternators connected to parallel, it is virtually impossible to control the field excitation level manually to compensate for changes in the reactive power flow. Voltage regulators are used to regulate the excitation of an alternator and thus the output voltage or reactive power output. Voltage regulators usually sense only one phase, but for more accuracy, three-phase voltage sensing may be desirable.

### The power factor

The power factor is a way of representing the extent to which alternating current drawn by the plant is out of phase with the voltage. It is expressed as the ratio (or percentage) of real power (watts) to apparent power (volts\*amperes). Most industrial plants have a power factor somewhere between 70 and 95 percent.



It is convenient to divide the apparent power into two vector components: real power and reactive power. Both components are important in power generation and must be metered and controlled separately.

### Synchronization

*Manual synchronization.* A synchronizing panel will originally contain two voltmeters, two frequency meters and a synchroscope and/or synchronizing lights. One voltmeter and one frequency meter monitor the incoming machine and the others monitor the running machine. The synchroscope pointer indicates the phase angle between the two generator voltages. Synchronizing lights usually serve as backup to the synchroscope.

*Automatic synchronization.* Many types of automatic synchronizers have been designed to replace some of or all the manual synchronizing functions. On large machines, there are primary backups in manual synchronizing schemes to block closing of the circuit breaker too far out of synchronism. Highly accurate and reliable automatic synchronizing relays are available with adjustable ranges to monitor both synchronism and the voltage levels of the machines being synchronized.

## **Oil firing**

As soon as ignition has taken place, the oil and air mixture must be adjusted to produce a stable flame. At this point it is best to have a flame slightly yellow, indicating a deficiency of air. The operator must learn how to adjust the fuel and air supply to obtain the lemon-colored flame required the starting up period. After the correct flame conditions have been obtained, the boiler is brought up to temperature slowly as with other fuels.

It is essential when burning fuel oil that the operator know the equipment and attend to certain details to assure satisfactory operation. The burners must be regulated to prevent the flame from striking the boiler heating surface or furnace walls. If this precaution is not taken, localized heating will cause a burned out tube or rapid deterioration of the furnace wall. It is important to ignite burners in 1, 3, 2 and 4 sequence. The reason of this procedure is to have uniform temperature distribution in the furnace.

Care and adjustment are necessary in regulating the air supply to the furnace. The usual procedure is to supply a steam or primary air with atomized oil and after the combustion has started to introduce the additional requirements as secondary air.

## **Change to coal firing**

With the system of pulverization, each boiler is equipped with one or more pulverizing mills through which the coal passes on its way to the burners. The coal is fed to these pulverizing mills by automatic control, to meet the steam demand. No separate drying is necessary since warm air from an air preheater is supplied to the pulverizer mill where drying takes place. This stream of primary air carries the fine coal from the pulverizer mill through the burners and into the furnace. Combustion starts as the fuel and primary air leave the burner tip. The secondary air is introduced directly into the furnace, where it mixes with the coal and primary air. The velocity of the primary and secondary air creates the necessary turbulence, and combustion takes place with the fuel in suspension.

Control of the mill output is accomplished by the damper located in the primary air fan inlet. This damper serves as a fuel regulator and may be operated by the boiler automatic combustion control. The feeder output is regulated by the coal level in the mill cylinder.

The pulverizers may be directly connected to the motor drive and operated at high speed. Control of pulverizer output is accomplished by varying the coal feed and the flow of primary air, either by hand or by automatic control.

The secondary air is supplied under pressure by the forced draft fan. It is important to adjust the primary air pressure to prevent the flame from striking the furnace walls and boiler tubes.

Once the start sequence is finished and all burners are operative on coal, then it is possible to shut off burners operated on the oil.

## Exercise N1.1 for training: Handling the simulator

### Objectives

1. Press "Initial Conditions" on the keyboard. [Shift F6]
2. Select "Block connected".
3. Start the simulator with "Running" [F1]. Check that the clock is running (top of the left corner).
4. Press "Picture Directory" on the keyboard [Home].
5. Select picture MD 260, "Main Steam Lines".
6. Check that steam data in the steam main line is approx. 30 bar, 330 °C Main Steam Line take the steam from superheater 3 in the boiler to the main steam valve at the HP- turbine. Read and write down the data on the line close to the HP- turbine.
7. Select picture MD 300 (Between IP- and LP- turbines on MD 260).
8. Check that the power is about 30 MW. (Numbers on the Generator)
9. Press "Picture Directory" at the keyboard [Home].
10. Select picture MD 170.
11. Check that all four burners on level D are running and that the pressure in the furnace is close to -20 mm H<sub>2</sub>O.
12. Go to picture MD 180. (On the right side from the "Coal Silo")  
Take in the flames by pressing the button on "Plane D" in the display module.
13. Open the controller for O<sub>2</sub> in flue gas by pressing "C" in "Oxygen Controller" [CTR1801]. Check that the set point is 2 % and that the actual value is stable.
14. Read and write down the contents of CO in flue gas on the display for "Carbon Mono Oxide" and note the value.
15. Decrease the set point for O<sub>2</sub> to 1 % (set value and press "Enter") and find out how much the content of CO will increase. Press F8 to go to "Alarm Log Summary Display". Click on the blinking value to reset the alarm for high content of CO. Note the value of CO when it is stable. Reset the set point for O<sub>2</sub> to 2.1 %
16. Freeze the simulation [F2].
17. Go to "Initial Conditions" [Shift F6] and select "Cold Plant".

18. Start the simulation with “Running” [F1].
19. Press “Picture Directory” [Home]. Select picture MD 100, “Fuel Oil system”.
20. Start preheating of the oil in the tank by opening (right click) the valves V01023 and V01024 (bottom of the left corner: to check mouse over) and switch the temperature controller into “Auto”.
21. Drain some water from the tank by opening “HFO service tank bottom drain valve” (at the bottom of Fuel Oil Service Tank).
22. Read the oil temperature in the tank. Check that the temperature is slowly increasing.
23. Stop simulation with “Freeze” [F2].
24. Go to “Initial Conditions”, select “Block Connected” and start the simulation with “Running” [F1].
25. Read and note steam pressure and generator power on picture MD 300 and fuel consumption (at the bottom: fuel oil flow G01850) on MD 200.
26. Start all four burners on plane C (MD 160). Be careful with the pressure in the furnace (should not be high). Do not ignite a new burner (wait some time) if the pressure is high on the positive side. Start with burner 1 (press “start” on the control panel) and followed by 3 -2 -4.
27. Select “Initial Conditions” and freeze the simulation. Increase the simulation speed to 5. Start simulation again with “Running” [F1].
28. Press “Picture Directory” [Home]
29. Select “Pen Recorder” (MD 130).
30. Click on 'Tagname' and write the tagnumber (P03006) **Note: Block Letters**. The Variable will be searched in the database.
31. Select the limits 0 and 100 bar and start the plotting of the variable by clicking at the button for “Channel 1”. Repeat the procedure for variable E03812 (Generator Power) on “Channel 2”.
32. Increase the firing intensity to 25 % on picture MD 190. The increasing takes place by writing the value for fuel oil (25 %) on BLM (Block Load Master Controller Output). Check that the value for fuel oil increase from 9 t/h into 15 t/h.
33. Read the fuel consumption on page MD 200.
34. Follow how the steam pressure and the generator power will increase. Look at

page MD 300 and the plotting on “Pen Recorder”. Read the values when the plant is stabilized.

35. Freeze the simulation [F2].

## **Exercise N1.2: Rolling up of turbine train and connection of generator to the grid**

### **Objectives:**

#### **Control the shaft speed**

1. Press "Initial Conditions" on the keyboard [Shift F6].
2. Select "Ready for rolling up".
3. Start the simulator with "Running" [F1].
4. Press "Picture Directory" on the keyboard [Home].
5. Select picture MD 300, "Steam Turbines".
6. Increase turbine governor set point to 5 % (press INCR/DECR to adjust the right value). Observe opening of all safety shut-off valves and steam extraction valves. Observe turbine speed. Select picture MD 380 (bottom under the generator) and observe that the generator excitation is not activated (grey colour of generator excitation).
7. Increase governor set point to 10 %. Observe turbine speed increase to approximately 1100 rpm.
8. Watch turbine vibrations (at the right upper corner). When vibrations are less than 20% on the indicator, increase governor set point to 20%. This should give a final turbine speed of about 1500 rpm.
9. When the vibration is lower than 30%, indicating evenly heated turbine rotor, increase the governor set point from 20 to 40%. Be careful not to set the speed range 1700-1900 rpm, which are the critical speed ranges.
10. Increase the governor set point to approximately 68%. When the speed is above 2800 rpm, observe automatic stopping of electric LO pumps (bottom on the left corner). Select picture MD 380 and observe activation of the generator excitation.
11. Increase governor set point approximately to 3005 rpm,. In order to achieve this value press INCR/DECR. Do it step by step not to miss the right speed. Remember speed of the shaft increasing not in parallel with governor speed value. It has some time delay.

#### **Synchronizing and connection of main circuit-breaker**

1. Select picture MD 300

2. Increase the generator excitation (press INCR) until the voltage at the main circuit-breaker is equal to the line voltage (press INCR one again to stop increase of the voltage), and the synchronoscope indicates "VOLT OK".
3. When the voltage and frequency is correct, connect circuit-breaker (press CONN). Synchronizing is automatic. (MD380/X3832)
4. Immediately after connection, increase turbine load by increasing the governor set point to 80% in order to avoid return power trip of the main circuit-breaker. (MD300)
5. Frieze simulation [F1].
6. Select "Initial Conditions" and change "simulation speed ratio" form 1 to 3. Set appropriate speed ratio in the "simulator speed ratio" section and press [Enter].
7. Start simulation with "Running" [F2].

### **Load rising (oil burners)**

1. Increase the firing intensity to 25% (15t/h) on picture (MD190). Set block load master controller output to 25% and press [Enter].
2. Ignite the burners on the Plane C in sequence 1, 3, 2, 4. (MD160) To ignite the burner press "Start".
3. Increase the firing intensity to 35% (MD 190).

### **Connection of auxiliary circuit-breaker (Block Binding)**

1. Reduce HP bypass steam press control minimum position from 12% to 0% type the value and press [Enter] (MD260/C12618). To find and to check the HP bypass steam press control valve (C12618) use "mouse over" function.
2. Stop steam dumping to direct heater by setting LP bypass steam pressure controller (Z22603) from AUTO to MAN (to find use mouse over function). Set value of 0 % and press [Enter].
3. Increase governor set point to 100%. (MD300)
4. Check MVAR readout and adjust generator excitation if necessary (MD380).
5. Check that the generator power is higher than auxiliary block load and connect auxiliary circuit-breaker. (MD380/X03835)

6. Check cos-phi and adjust the generator excitation if required. Normal cos-phi is 0.9 - 0.95. (MD380)

### **Change to coal firing**

1. Check the preliminary air supply to coal mill D, open the primary air fan shut-off valve (V01720). Activate the start sequence for coal mill Plan D on the operator-panel (X01761).
2. When the start sequence is finished and all burners are operative on coal, then shut off burners 1 to 4 by pressing "Stop" buttons.
3. Repeat the procedure for burner on Plane C.
4. Observe and adjust the oxygen controller. Normal set point on coal firing is 3,5%.
5. Increase the firing intensity to 45%.
6. Freeze simulation.