Simulation of Coal Fired Power Plant v2025

Richard J Smith
richardsmith@asia.com

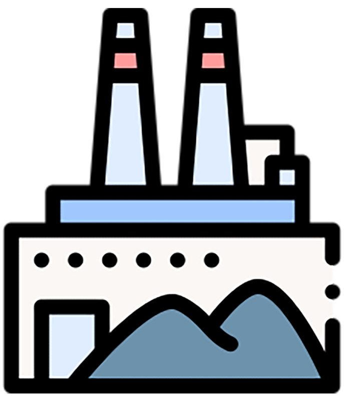
27 June 2025

Disclaimer

This document is provided by Richard J Smith 'as is' and 'with all faults'. The provider makes no representations or warranties of any kind concerning the safety, suitability, inaccuracies, typographical errors, or other harmful components of this document and software.

The sole purpose of this document is to provide a guide to the accompanying application.

Use the information contained at your own risk.



Contents

1 Introduction **5**
- 1.1 KKS . . . 5
- 1.2 Open/Close, On/Off conventions . . . 7

2 Simulator layout **9**
- 2.1 Initial screen display when application opened . . . 9
- 2.2 Top bar . . . 9
- 2.3 Right panel . . . 10
- 2.4 Bottom bar . . . 10
- 2.5 Main area of screen . . . 11
- 2.6 Trends . . . 11

3 Functional Description of Systems **13**
- 3.1 Auxiliary . . . 15
  - 3.1.1 Electrical Supplies . . . 15
  - 3.1.2 Water Treatment Plant (WTP) . . . 18
  - 3.1.3 Instrument Air (IA) . . . 19
  - 3.1.4 Fuel Oil Supply . . . 20
  - 3.1.5 Auxiliary Boiler . . . 21
  - 3.1.6 Closed Cooling Water (CCW) . . . 22
  - 3.1.7 Cooling Water (CW) . . . 24
- 3.2 Boiler . . . 25
  - 3.2.1 Main Steam system . . . 25
  - 3.2.2 Air Systems . . . 27
  - 3.2.3 Fuel Control . . . 30
  - 3.2.4 Feedwater Pumping (FWP) . . . 33
  - 3.2.5 Electrostatic Precipitator (ESP) . . . 35
- 3.3 Turbine . . . 36
  - 3.3.1 Turbine Steam System . . . 36
  - 3.3.2 Turbine supervisory . . . 37
  - 3.3.3 Lube Oil Systems . . . 40
  - 3.3.4 Gland steam and Vacuum Systems . . . 42
  - 3.3.5 Condensate Extraction Pump (CEP) . . . 44
  - 3.3.6 Control Oil . . . 46
  - 3.3.7 Generator . . . 48

4 Start-up Procedure **50**
- 4.1 First steps . . . 50
  - 4.1.1 Selecting the level of difficulty . . . 50
  - 4.1.2 Power on . . . 50
- 4.2 General/Miscellaneous information . . . 52
  - 4.2.1 Furnace purge . . . 53
  - 4.2.2 Reset Turbine TRIP . . . 54
  - 4.2.3 Turbine trip . . . 55
  - 4.2.4 Boiler run-back . . . 57
  - 4.2.5 Recovering from a Turbine trip . . . 57
  - 4.2.6 Boiler trip . . . 58
  - 4.2.7 Plant trip . . . 60
  - 4.2.8 Alarms and Events . . . 61
- 4.3 Cold Start . . . 63
- 4.4 Shutdown (normal) . . . 66
- 4.5 Warm Start . . . 68
- 4.6 Hot Start . . . 70

5 Alarms and Trips **72**
- 5.1 Boiler . . . 72
- 5.2 Turbine . . . 72
- 5.3 Auxiliaries . . . 73

6 Instructor/Trainer Window Usage **74**
6.1 Sim RUN/PAUSE . . . 74
6.2 Scenarios . . . 74
6.3 Faults . . . 74

A List of equipment **77**

B Screenshots **85**

C Thermodynamics **107**

D Plant systems not covered **108**

E Revision History **110**

F Known issues **111**

G Figures **112**

Acknowledgements

Whilst writing the associated application and preparing this documentation and various tutorial videos, I have managed to combine my hobby of computer programming and my years working at various power plants around the world for my own enjoyment and satisfaction.

Whilst I am happy of the outcome, I do realise that many features are missing or could be improved. It may be in the future I will take another look at this program and update/improve it further.

I would like to acknowledge the following people and/or programming utilities that both inspired me and allowed this program to be written.

All the great training provided by the New Zealand Electricity Department/Electricorp/Genesis Energy during my time as a young technician.

Some great coal fired power plants around the world that allowed me to contribute and share knowledge, including Huntly - New Zealand, Paiton - Indonesia, MapTaPhut - Thailand, Manjung - Malaysia, Babelan - Indonesia, Koniambo - New Caledonia.

Roger Meier's DataPlot Classes (https://opensource.the-meiers.org) which is used throughout this application for basic trending.

Christian Schmitz MBS (MonkeyBread Software)) Chart Director plugin used for various gauges/instruments.

Application icon created by Freepik and avialable at FlatIcon.

Application files and this user guide can found on GitHub at `https://github.com/Richard66NZ/CoalSIMv2`

Tutorial videos can be found on YouTube at `https://www.youtube.com/@RichardSmith-zc9zi`

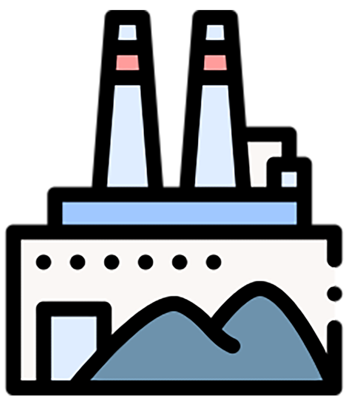


Figure 1: Power plant icons created by Freepik - Flaticon

1 Introduction

This simulation represents a rather basic model of a 150MW (gross) single unit superheated Rankine cycle power plant with a pulverised coal fired boiler.

The aim is to perform a cold start of the boiler and turbine and once synchronised to the electrical grid increase load to the unit maximum of approx. 150 MW. Once this load is reached a score will be given on your performance, taking into account the fuel usage, auxiliary power consumption and any environmental limits that have been exceeded. To achieve a perfect score of 100% may require a few attempts.

Additionally this simulator can be used as a basic training tool, allowing unit start up, shut down and responses to various faults to be trialled.

This document is intended as a very simple guide to teach you operation of a small coal fired power generation plant. This information is organised as follows;

Firstly this document will detail some of the information you will need to understand the screens that represent the ACME power plant Unit 1. This will include a short introduction to a plant coding system (KKS in this case) which allows all items of plant to be identified (helps reduce confusion and mistakes in a real plant). Then some information on colour coding and what it means in relation to plant equipment status.

Secondly we will cover the layout of the screens and the various displays of information and controls.

Thirdly this document includes a functional description of each system so that you may understand the function and operation of each.

Next we have a step by step procedure on how to successfully start and shut down the unit.

Finally we have an appendix with various other information they may be of use to you when operating this plant.

1.1 KKS

The KKS system (Kraftwerk-Kennzeichen-System in German or factory numbering system in English) is a classification system for the complete power plant and its components and provides a common language for the designer, the manufacturer and the user.

It is used at many power plants around the world to identify the various components, such as pumps, valves, pressure vessels, electrical supplies and instrumentation in a logical and standard manner.

KKS will be used throughout the accompanying software application and also within this user guide to identify plant components - so it is a good idea that you become familiar with it.

A typical KKS code for an item of plant machinery is as below;

1MAV10AP001

This is broken down as follows;

1 - Unit 1

MAV Can be further broken down into;

- **M** Main machine
- **A** Steam turbine
- **V** lubricant supply system

10 location of item within this system

AP Pump

001 First pump in this system at this location

So in summary the KKS code 1MAV10AP001 refers to the Unit 1, main steam turbine lubricating pump. If two lubricating pumps are fitted in parallel then the other can be referred to as 1MAV10AP002 or even 1MAV11AP001.

In addition to M referring to Main machine, the following codes are also used in this simulation;

A - Grid and distribution systems

B - Power transmission and auxiliary power systems

E - conventional fuel supply

G - Water supply and disposal

H - conventional heat generation

L - Steam, water, gas cycles

M - Main machine sets

P - Cooling water system

Q - auxiliary systems

Also other than AP for pump, the following equipment keys are also used;

AA - valve, damper, etc

AC - heat exchanger

AE - Turning, driving, lifting and slewing device

AN - Compressor units, fans

AP - Pump units

AV - combustion equipment

BB - Storage equipment (vessels, tanks)

CE - Electrical variables (current, voltage, power, frequency)

CF - flow rate

CK - time

CL - level

CP - pressure

CS - velocity, speed

CT - temperature

CY - vibration

GH - Electrical and instrument installation units (cubicles, boxes)

GS - Switchgear equipment

GT - Transformer equipment

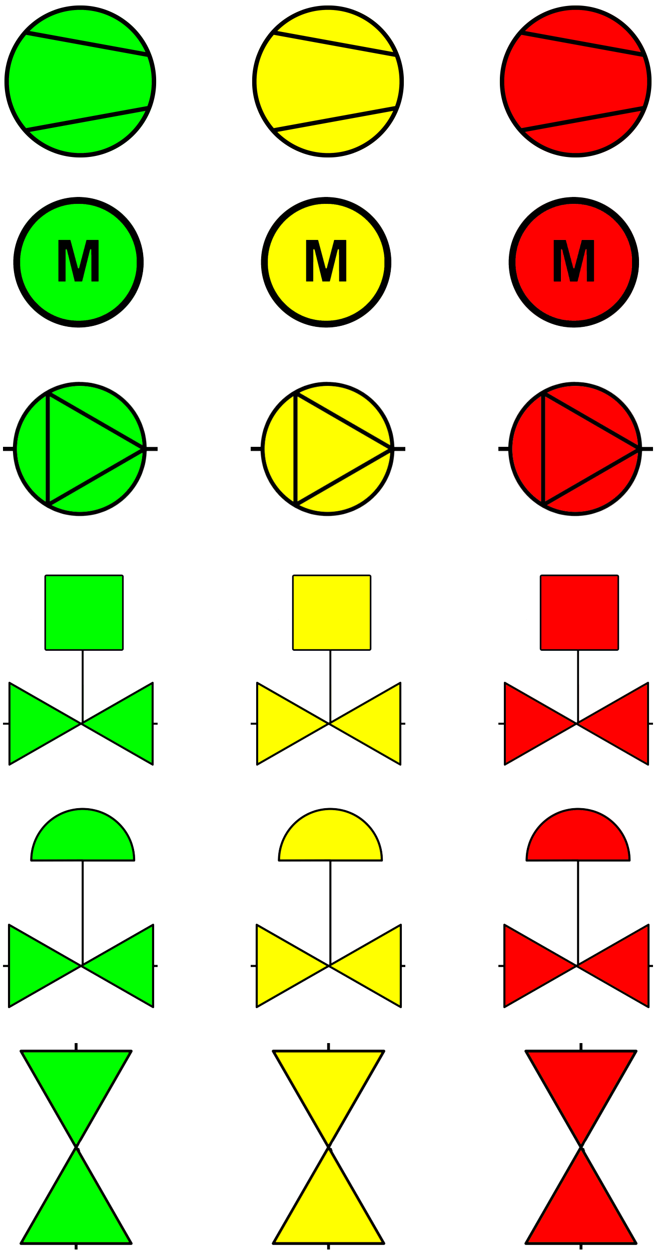
A complete list of KKS codes used in this simulation is provided in appendix A.

For further information on the KKS coding system please search on-line.

1.2 Open/Close, On/Off conventions

When using a screen to represent physical action in the real world, we must agree on a standard to clearly show when a valve is open or closed, or even in fault. For this simulation the colour RED is used to show that a valve is OPEN or that a pump/fan/motor is running. Conversely the colour GREEN means that a valve is CLOSED or that a pump/fan/motor is shutdown.

If the pump, motor, circuit breaker is coloured YELLOW, then is in in fault and will need resetting.



whilst above the colour RED indicated that a valve is OPEN for instance, when it comes to electrical system it is the opposite (i.e. a RED circuit breaker indicated it is closed.

It is better then not to think about if an item of equipment is OPEN or CLOSED, etc, but better to think of it being In Service and Out of Service.

Therefore if an item of plant (Pump, motor, valve or circuit breaker) is In Service it will be shown in RED, whilst if Out of Service it will be shown in GREEN.

2 Simulator layout

2.1 Initial screen display when application opened

This is the screen presented when the application is run. It consists of a number of parts/panels, some that stay fixed throughout the simulation and others that will change depending on the stage of the simulation or the buttons the user presses.

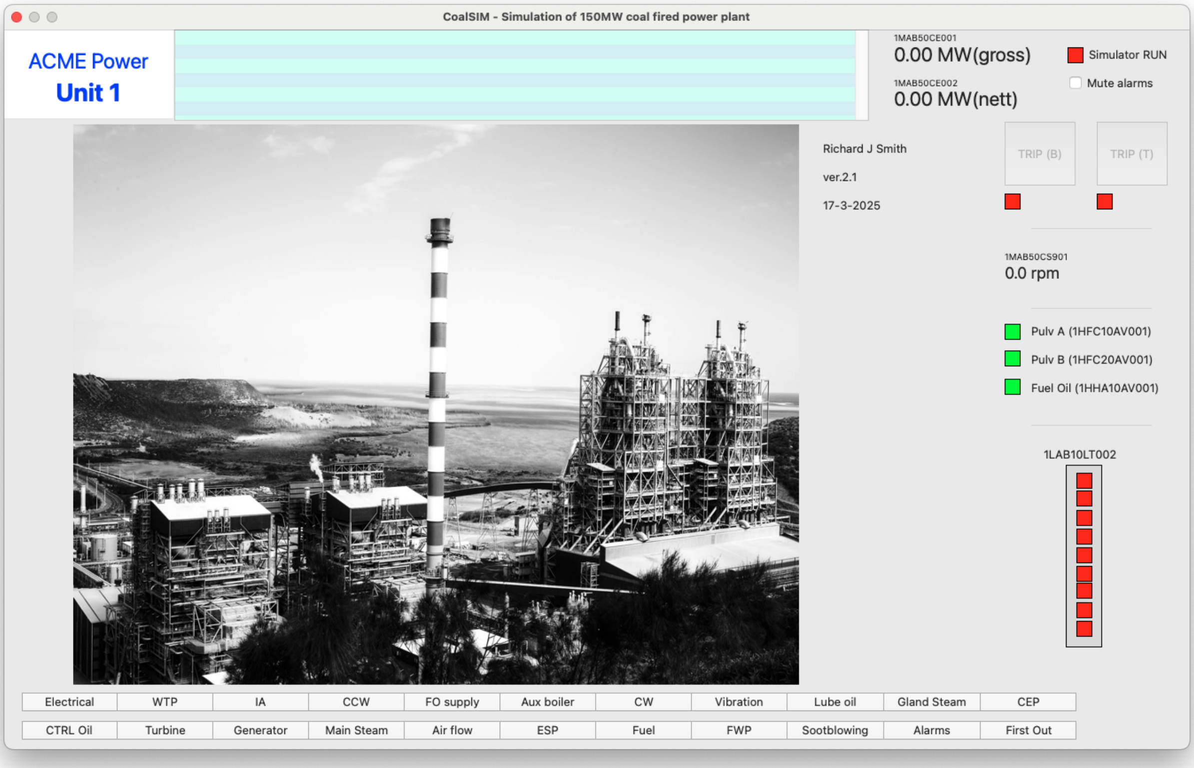


Figure 2: Application opening screen

2.2 Top bar

Firstly on the top bar we have the power station name on the left side (in this case ACME Power Unit 1). The ACME power plant has been designed as a station consisting of 4 units, however only the first has been built to date.

In the middle of the top bar is a small alarm/event list. This will display the latest 6 or so plant alarms or events (i.e. an alarm is a warning from the control system that something is not right. An event is some action, such as starting a pump, etc). For a larger display of alarm and event we have a dedicated screen, which will be shown latter.

Then on the right side of the top bar we have the load generated by our Power plant. This consists of two values, the gross power which is the total output from the Unit 1 generator, and the nett power which is the gross minus the power needed to run the units fans, pumps and motors. Whilst we may make 150MW of electricity at full load from the generator, we can only sell about 140MW to the customer. The other 10MW is used by ourselves.

Note: above each of the two power indications there is a small label with a KKS code (1MAB50CE001 for gross power and 1MAB50CE002 for nett). This is the first occurrence of KKS coding in the simulation, but will not be the last.

Finally far to the right side we have an indication of when the simulation is running RED or paused GREEN and a mute alarm checkbox. This can be useful when the audible alarms get a bit annoying, however be careful muting this as you may miss an important alarm.

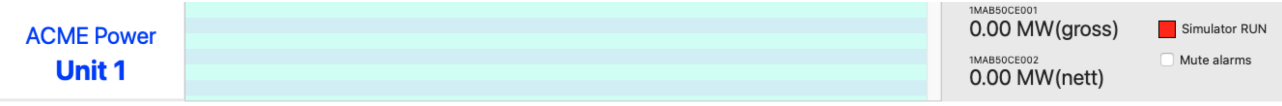


Figure 3: Top bar of application window

2.3 Right panel

Down the right side of the screen runs a panel with a few more useful items. At the top we have the manual trip buttons for Boiler on the left and Turbine on the right. Pressing either will immediately trip the boiler or turbine. Note: Tripping the boiler will also result in a turbine trip. Below each trip button is a small indication box which are shown as RED in this case. This means both the boiler and turbine are currently in a tripped state. To reset the boiler trip we must start the furnace fans and purge the boiler. To reset the turbine trip we must have the boiler in service and steam temperature, pressure and flow at the correct values.

Below this we have a reading 1MAB50CS901 which is the unit steam turbine rotating speed. This will initially be zero and will increase to 30rpm once the turbine turning gear is on. After resetting the turbine trip this will ramp up to 3000rpm before the generator is synchronised to the electrical grid.

Next we have a visual representation of the fuel burners that are currently in operation. Whilst this information can also be found on the Fuel screen, it is always handy to have it in front of your face at all time. First is Coal pulveriser A and Coal pulveriser B followed by the Fuel Oil (FO) burner. Their current colour of GREEN indicates all burners are currently stopped. Note: whilst in this list it shows Coal pulveriser A above pulveriser B, in the actual furnace they are lettered from the bottom.

Finally we have a visual representation of 1LAB10LT002, which after some practice you will instantly know is the boiler steam drum level indication. This is always an important device to refer to, as if the level is too high it can result in water carrying over from the steam drum and travelling to the turbine, whilst if too low can result in boiler water tubes overheating. Bother instances are dangerous and expensive to repair.

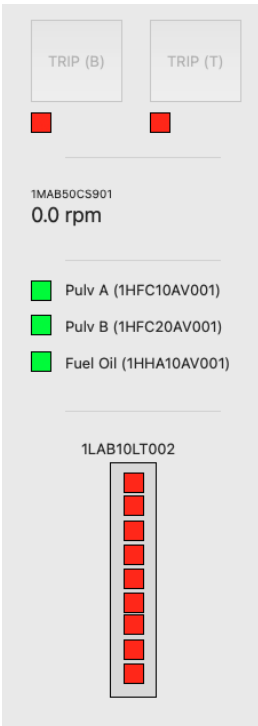


Figure 4: Right side panel of application window

2.4 Bottom bar

On the bottom of the screen we have two rows of page/screen selector buttons. Pressing any of these will change the main are of screen into a display for the requested system. Sometimes the label is rather descriptive (e.g. Electrical will take you tot he electrical systems screen), whilst sometime abbreviations are used, such as IA for

Instrument Air, CW for Cooling Water, CCW for Closed Cooling Water, ESP for ElectroStatic Precipitator, etc.

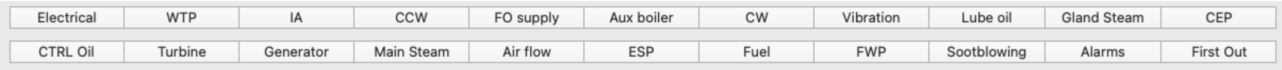
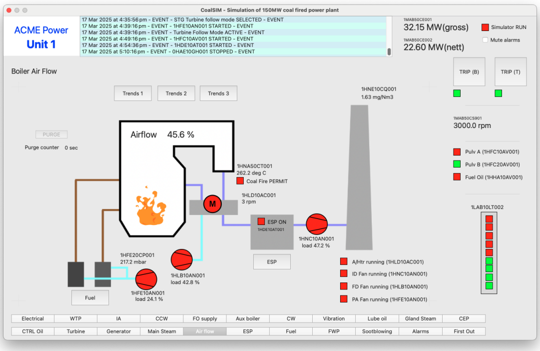


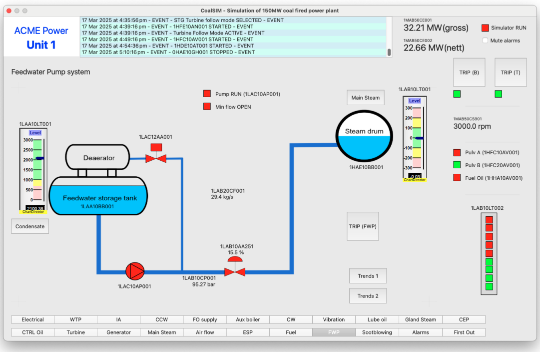
Figure 5: Bottom bar of application window

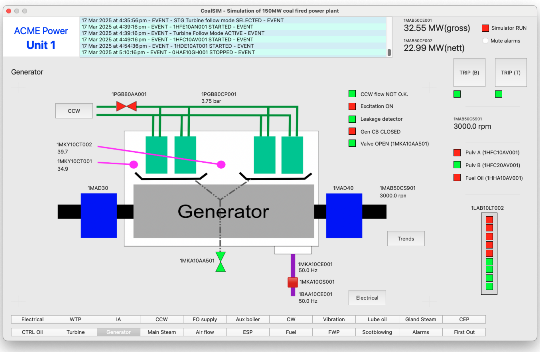
2.5 Main area of screen

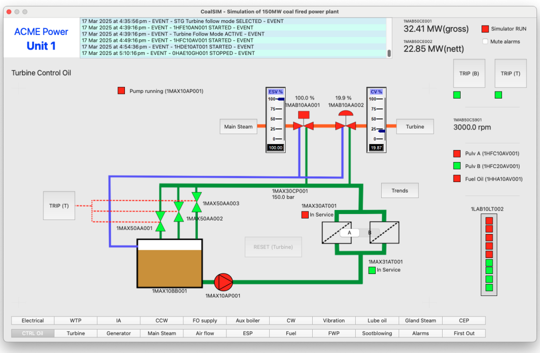
Depending on the button that is pressed on the button bar at the bottom of the screen, the main area will change to display different parts/systems of the power station.

A few example screens are shown below, but the full list of screenshots can be found in appendix B.









2.6 Trends

Many of the system screens have additional buttons so that you can quickly navigate to another screen that may be related to the system you are currently looking at, or can in some cases redirect you to a trend screen.

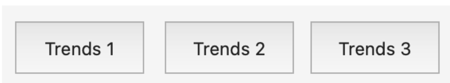


Figure 6: Buttons to redirect to a screen displaying system parameter trends

These trend screens can display a maximum of 4 variables and are very useful in monitoring plant conditions. A button labelled 'RETURN' is situated at the top right of the trend display and this will return you to the previous screen when pressed.

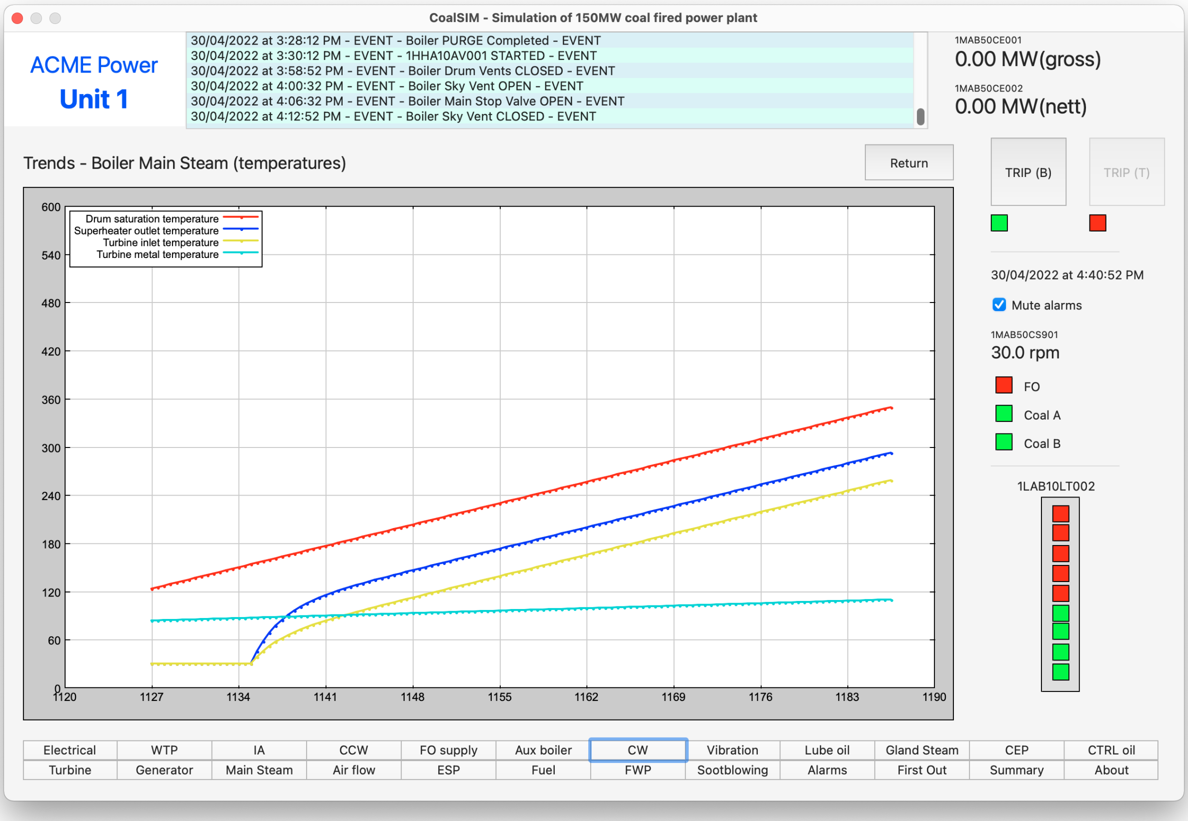


Figure 7: Typical trend screen display

3 Functional Description of Systems

Power (electricity) generation in a coal fired power station usually follows what is called the Rankine cycle with the addition of a superheat section and sometimes a reheat section. The ACME power station unit 1 utilises a Rankine superheat cycle as shown below.

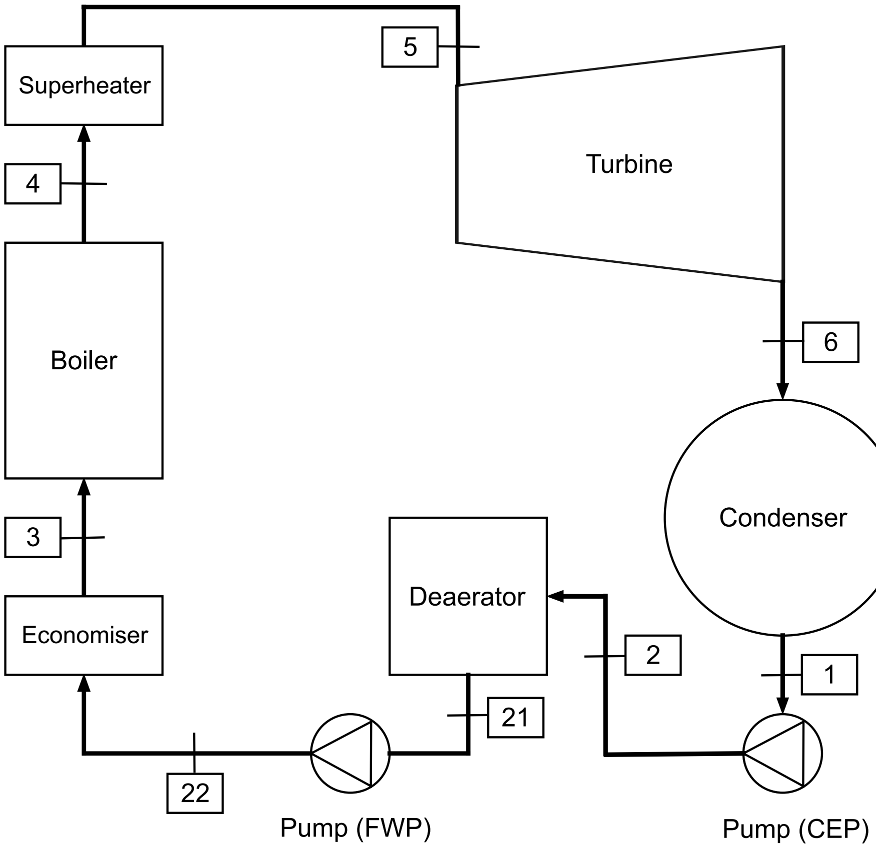


Figure 8: Rankine cycle diagram of ACME unit 1 plant.

The main cycle consists of heating water in the boiler until it is convert to steam. Transporting this steam to the superheater where more heat is added to raise its temperature (in this case to approx. 540 deg C). From the superheater the steam then travels down the steam legs (just large pipes really) to the turbine. The steam enters the turbine and the heat contained is converted to rotary motion (i.e. the steam spins the turbine around). The steam exhaust from the turbine drops down to the condenser, where it is cooled and changes back to the liquid state (i.e. water). This water is then pumped back to the boiler (in our example it is first pumped to the Deaerator and from there further pumped to the boiler. Thus completing the cycle.

To support the above cycle we need many other items/equipment. This equipment can be broken down into different areas, as follows;

Auxiliary equipment required;

1. An electrical system to provide power to the plant motors, pumps and fans, etc and also to allow electricity generated by Unit 1 to be distributed onto the country wide electrical grid and to the consumers.
2. A water treatment plant (WTP) to make the required very clean water used in the boiler.
3. A compressed air supply as many of the plant valves, dampers, etc are pneumatically controlled/actuated.
4. A closed cooling water (CCW) system to provide cooling water to various components. When motors are run they generate heat and a cooling system is then required to remove this heat. Also the main generator gets very hot and is also provided with coolers supplied from the CCW system.
5. A supply of fuel oil (this can be any grade, but common is now usually diesel fuel as it is easy to obtain). We must have a storage tank of fuel available sufficient to start the unit and also a pump to distribute it to all the units and also the auxiliary boiler.

6. A supply of coal from usually a large coal stockpile (not modelled in this simulation).

Boiler equipment required;

1. Fans to provide air to the furnace for combustion (Forced Draught fan) and extract the flue gas from the furnace (Induced Draught fan) and deliver them to the chimney (stack).
2. A fuel oil burner used to start the boiler and raise pressure and temperature and also support the igination of coal.
3. Some coal pulveriser to crush the supplied coal.
4. An additional fan to blow the coal from the coal pulveriser to the furnace (Primary Air fan).
5. A rotary Airheater which takes some heat from the boiler exhaust flue gases and transfers it to the air supply from the Forced Draught fan. This improves the boiler efficiency.
6. An Electrostatic Precipitator (ESP) that removed dust particles from the boiler exhaust flue gas. This is an environmental necessity to prevent visible smoke at the chimney.
7. A sampling system to measure chimney emissions and check the effectiveness of the ESP.
8. A system to clean the furnace walls and superheater tubing of coal ash deposits (Sootblowing system). If this is not done then it will restrict heat transfer and lower unit efficiency.
9. A burner tilt system to point the burners either up or down inside the furance so as to control the steam outlet temperature. Point them down to reduce this temperature and up to increase it.

Turbine equipment required;

1. A Lubricating Oil system to provide lubrication and cooling to the turbine and generator bearings.
2. A system to monitor and record the vibration and temperatures at each bearing to prevent damage.
3. A Turning gear system to allow rotation of the turbine/generator shaft before startup (to ensure straightness of the shaft) and after shutdown (to prevent uneven cooling and possible rubbing between the rotor and casing).
4. A Jacking oil system to help lift the turbine/generator rotor during turning gear or low speed operation to prevent a wipe of the white metal bearings.
5. A condenser under the turbine to extract heat from the exhaust steam and convert it to water.
6. A Cooling Water pump to provide river water to the condenser.
7. A vacuum system to remove air from the turbine condenser so that it operates in a vacuum (i.e. approx. 50mbar absolute pressure or -950mbar gauge pressure). This is done to extract more work from the steam and increases unit efficiency.
8. A gland steam system to seal the turbine rotor where it passes through the casing at either end.
9. A Condensate Extraction pump (CEP) to take the cooled water from the condenser and pump it to the Dearator vessel.
10. A Dearator for removing oxygen from the water and providing a large reservoir of water in the system
11. A Feedwater pump (FWP) to take the water from the deaerator and pump it to the high pressure needed to feed back to the boiler.

All the above equipment is modelled in this simulation and each component will be described in more detail in the next section.

3.1 Auxiliary

3.1.1 Electrical Supplies

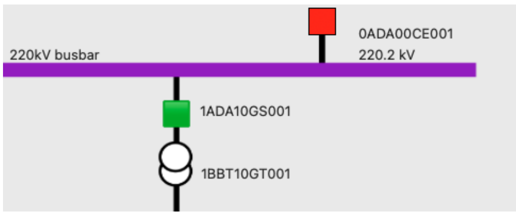
The ACME power plant has a main 220kV (220000 volt) busbar that is sized to support power generation from four unit of 150MW each. This 220kV busbar is connected via to overhead transmission lines to the countries electrical grid system. Each line is equipped with a power flow meter (0ADA00CE003 and 0ADA00CE005) which show the import/export of power.

Currently as only one unit at ACME power has completed construction (Units 2 - 4 are still waiting financing) their are only 2 other connections to this busbar.

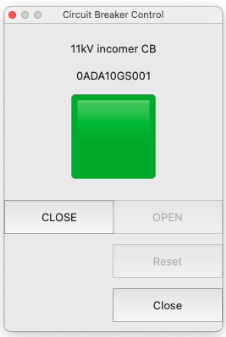
Firstly the generator output terminals are connected through circuit breaker (1MKA10GS001) and step up transformer (1BAT10GT001) to the left end of the 220kV busbar.This provides a route for the power geenrated by Unit 1 to the 220kV busbar and out onto the countries electrical grid.

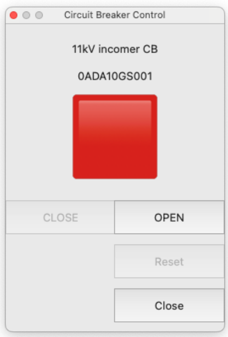
Secondly another connection through circuit breaker (1ADA10GS001) and transformer (1BBT10GT001) takes power from the 220kV busbar and supplies the Unit 1 11kV Switchboard. This switchboard has 9 connections, 8 of which supply electricity to run 11kV motors (i.e. CEP pump, FWP pump, ID fan, FD fan, PA fan, Pulv A, Pulv B, CW pump) and 1 connection via transformer (1BFT10GT001) to the unit 1 400V switchboard which supplies power to smaller items (i.e. lighting, small electric motors, air conditioning, coffee machine, etc).

To close circuit breaker (1AFA10GS001) and back feed power to the 11kV switchboard, click on the Circuit breaker symbol shown as a GREEN square in screenshot below.



This will open up a Circuit Breaker Control faceplate window as shown below left. Just press the CLOSE button[1]

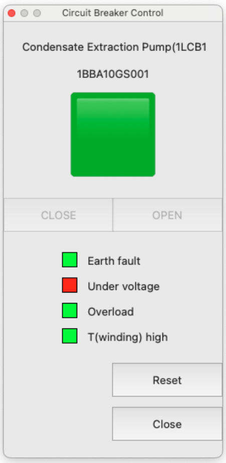


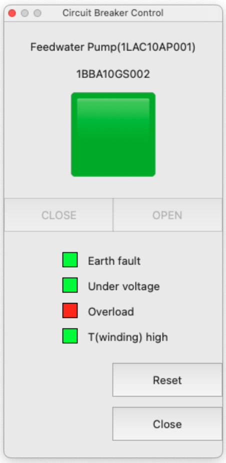


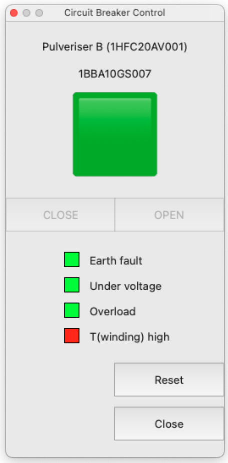
It can occurs that either the main generator circuit breaker (1MKA10GS001) or any of the 8 motor feed circuit breakers (1BBA10GS001 - 1BBA10GS008) are in fault condition, If this is the case then just click on the affected circuit breaker symbol and its related Circuit Breaker Control faceplate window will open.

On this control panel you have indication of various faults, such as Earth Fault, Reverse Power, Over Current, Under Voltage, Winding temperature HIGH, etc. BY pressing the "Reset" button these faults can be cleared and the affected motor or generator can be used again.

[1] Once this circuit breaker is closed you will start to be charged for any electricity consumed.







A screenshot of simulator DCS screen related to this system can be found on page 85.

Alarms and trip levels associated with this system;

- Condensate Extraction Pump motor EARTH FAULT TRIP
- Condensate Extraction Pump motor UNDERVOLTAGE TRIP
- Condensate Extraction Pump motor OVERLOAD TRIP
- Condensate Extraction Pump motor WINDING TEMP HIGH TRIP
- Feedwater Pump motor EARTH FAULT TRIP
- Feedwater Pump motor UNDERVOLTAGE TRIP
- Feedwater Pump motor OVERLOAD TRIP
- Feedwater Pump motor WINDING TEMP HIGH TRIP
- Induced Draught Fan motor EARTH FAULT TRIP
- Induced Draught Fan motor UNDERVOLTAGE TRIP
- Induced Draught Fan motor OVERLOAD TRIP
- Induced Draught Fan motor WINDING TEMP HIGH TRIP
- Forced Draught Fan motor EARTH FAULT TRIP
- Forced Draught Fan motor UNDERVOLTAGE TRIP
- Forced Draught Fan motor OVERLOAD TRIP
- Forced Draught Fan motor WINDING TEMP HIGH TRIP
- Primary Air Fan motor EARTH FAULT TRIP
- Primary Air Fan motor UNDERVOLTAGE TRIP
- Primary Air Fan motor OVERLOAD TRIP
- Primary Air Fan motor WINDING TEMP HIGH TRIP
- Pulveriser A motor EARTH FAULT TRIP
- Pulveriser A motor UNDERVOLTAGE TRIP
- Pulveriser A motor OVERLOAD TRIP
- Pulveriser A motor WINDING TEMP HIGH TRIP
- Pulveriser B motor EARTH FAULT TRIP

- Pulveriser B motor UNDERVOLTAGE TRIP
- Pulveriser B motor OVERLOAD TRIP
- Pulveriser B motor WINDING TEMP HIGH TRIP
- Cooling Water Pump motor EARTH FAULT TRIP
- Cooling Water Pump motor UNDERVOLTAGE TRIP
- Cooling Water Pump motor OVERLOAD TRIP
- Cooling Water Pump motor WINDING TEMP HIGH TRIP

Instrument fitted on this system include;

- 220kV incomer 1 0ADA00CE003 indication power (MW) flow.
- 220kV incomer 2 0ADA00CE005 indication power (MW) flow.
- 220kV bus voltage 0ADA00CE001 indication voltage.
- Generator running Hz 1BAA10CE001 indication frequency.
- Generator incoming Hz 1MKA10CE001 indication frequency.
- 11kV bus voltage 1BBA10CE001 indication voltage.
- CEP pump supply 1BBA10GS001 circuit breaker status open/closed.
- FWP pump supply 1BBA10GS002 circuit breaker status open/closed.
- ID fan supply 1BBA10GS003 circuit breaker status open/closed.
- FD fan supply 1BBA10GS004 circuit breaker status open/closed.
- PA fan supply 1BBA10GS005 circuit breaker status open/closed.
- Pulv A supply 1BBA10GS006 circuit breaker status open/closed.
- Pulv B supply 1BBA10GS007 circuit breaker status open/closed.
- CW pump supply 1BBA10GS008 circuit breaker status open/closed.
- Generator synchronising CB 1MKA10GS001 circuit breaker status open/closed.
- 11kV board supply CB 1ADA10GS001 circuit breaker status open/closed.
- 220/11kV Unit supply transformer 1BBT10GT001
- 220/11kV generator transformer 1BAT10GT001
- 415V unit supply switchboard 1BFB10GH001
- 11lV/415V unit supply transformer 1BFT10GT001
- 415V unit supply switchboard voltage 1BFB10CE001 indication voltage.
- Water Treatment Plant supply 1BFB10GS023 circuit breaker status open/closed.

Pre-requisites for back energising the Unit 1 11kV switchboard include;

- 220kV busbar energised.

3.1.2 Water Treatment Plant (WTP)

This station is equipped with an ion exchange water treatment plant which takes water from the local river and processes it until it is suitable for use in a high pressure boiler. This processed water is called demineralised (Demin) water.

The operation of the water treatment plant is not modelled in this simulation, however the produced demin water is store in the demin water tank (0GHC10BB001) which can be found on the WTP simulator screen. This tanks level will fluctuate depending on usage and supply from water treatment plant.

The current demin tank level is shown on level indicator (0GHC10CL001) in meters.

The demin tank is equipped with a single demin distribution pump (0GCF10AP001) which will distribute demin water to all ACME Power station units.

This distribution pump can be started/stopped by clicking on the GREEN pump symbol. Once started on the Pump Control faceplate window the pump discharge pressure will be displayed on gauge (0GCF10CP001).

Normal demin distribution pump discharge pressure is approximately 8.5 barg.

A screenshot of simulator DCS screen related to this system can be found on page 86.

Alarms and trip levels associated with this system;

- WTP Protection OFF - loss of electrical supply
- Demin Pump Protection OFF - loss of electrical supply
- Demin Demin Forwarding Pump Protection OFF - WTP out of service
- Demin Supply Pressure LOW $<$ 4.0 bar

Instrument fitted on this system include;

- Demin tank level 0GCF10LT001.
- Demin forwarding pump (0GCF10AP001) indication on/off.
- Demin pump discharge pressure 0GCF20CP001.

Pre-requisites for starting the WTP plant include;

- Power supply from 400V switchboard available.

Pre-requisites for starting the Demin supply pump include;

- Power supply from 400V switchboard available for pump 0GCF10AP001.
- WTP plant running

3.1.3 Instrument Air (IA)

The ACME Power station is equipped with an instrument air system to supply air to all pneumatic control valves, damper, etc.

This system takes normal atmospheric air and compresses it to a pressure of approximately 9 barg. Moisture is also removed from the air so that all valves/dampers/etc operate in a smooth an precise manner.

The single instrument air compressor (0SCA10AN001) can be started/stopped using the IA compressor control faceplate and will indicate the air discharge pressure on gauge (0SCA10CP001).

Compressed and dry air from the compressor is stored in a local air receiver (0SCA20BB001) from which it is distributed to all ACME Power station units.

A screenshot of simulator DCS screen related to this system can be found on page 87.

Alarms and trip levels associated with this system;

- IA Compressor Protection OFF - loss of electrical supply
- IA Compressor Protection OFF - no CCW cooling
- IA Pressure LOW <7.5 bar
- IA Pressure LOW LOW <6.5 bar (30001)

Instrument fitted on this system include;

- Compressor (0SCA10AN001) indication on/off.
- Compressed air supply pressure 0SCA30CP001.

Pre-requisites for starting the IA compressor include;

- Power supply from 400V switchboard available compressor 0SCA10AN001.
- CCW system for motor cooling.

3.1.4 Fuel Oil Supply

The ACME Power station is equipped with a single fuel oil tank (0EGC10BB001) to provide fuel oil for startup of each station main boiler and also the station auxiliary boiler.

The fuel oil tank can be filled from road tankers, however in this simulation it will always show a constant level[2]. This level is shown on level indicator (0EGC10CL001) in meters.

The fuel oil tank is equipped with a single fuel oil distribution pump (0EGC10AP001) which will distribute fuel oil to all ACME Power station units plus the auxiliary boiler.

This distribution pump can be started/stopped using the FO pump control faceplate and will indicate the pump discharge pressure on gauge (0EGC10CP001).

Normal FO distribution pump discharge pressure is approximately 10.5 barg.

A screenshot of simulator DCS screen related to this system can be found on page 89.

Alarms and trip levels associated with this system;

- FO Forwarding Pump Protection OFF - loss of electrical supply
- FO Forwarding Pump Protection OFF - loss of IA supply
- FO Supply Pressure LOW <9.5 bar
- FO Supply Pressure LOW LOW <8.5 bar
    - If only Fuel oil burner in service TRIP boiler (30002)
    - If Coal pulveriser also in service then TRIP FO burner only

Instrument fitted on this system include;

- FO tank level 0EGD30LT001.
- FO delivery pump (0EGC10AP001) indication on/off.
- FO delivery pump discharge pressure 0EGD10CP001.
- FO supply to auxiliary boiler (0EGD65AA101) indication open/closed.
- FO supply to Unit 1 (1EGD20AA101) indication open/close.
- FO supply to Unit 2 (2EGD20AA101) indication open/close.
- FO supply to Unit 3 (3EGD20AA101) indication open/close.
- FO supply to Unit 4 (4EGD20AA101) indication open/close.
- FO pressure control valve (0EGC10AA251) position.

Pre-requisites for starting the Fuel Oil Forwarding system include;

- Power supply from 400V switchboard available for pump 0EGC10AP001.
- IA compressed air for various actuators.

[2]Whilst the supply of FO is unlimited you will still be charged for the amount you use during a boiler start up.

3.1.5 Auxiliary Boiler

The ACME Power station is equipped with a single ACME brand auxiliary boiler. This boiler is necessary to provide steam to the turbine gland steam system on a unit cold start when steam from the unit main steam system is not available. Once steam is available from the unit main steam system the auxiliary boiler can be shut down.

The auxiliary boiler can be started/stopped using the auxiliary boiler (0QHA10GH001) control faceplate. Just click on the auxiliary boiler fan (0HAE10AN001) and the associated faceplate will open.

To start the auxiliary boiler fuel oil must be available from the fuel oil distribution pump (0EGC10AP001) and atomising air for the burner from the instrument air compressor (0SCA10AN001).

In the real world a small auxiliary boiler such as this would take a number of hours to start up to be ready to supply superheated steam to the unit turbine gland steam system, however in this simulation that time is accelerated and steam will be available in a matter of seconds.

A screenshot of simulator DCS screen related to this system can be found on page 90.

Alarms and trip levels associated with this system;

- Auxiliary Boiler Protection OFF - loss of electrical supply
- Auxiliary Boiler Protection OFF - loss of IA supply
- Auxiliary Boiler Protection OFF - FO supply Pressure LOW

Instrument fitted on this system include;

- Forced air fan (0HAE10AN001) indication on/off
- Fuel oil supply valve (0EGD65AA251) indication open/closed
- Auxiliary boiler discharge valve (0LBG10AA001) indication open/closed

Pre-requisites for starting the Auxiliary Boiler include;

- Power supply from 400V switchboard available for forced air fan 0HAE10AN001.
- IA compressed air for various actuators and burner atomising air.
- Fuel oil supply system running.

3.1.6 Closed Cooling Water (CCW)

Each individual unit at the ACME Power station is equipped with its own closed cooling system to provide a means to cool various plant systems, including;

- Generator
- Lube Oil cooler
- Control oil cooler
- Air heater oil cooler
- MV motors (CEP, FWP, PA, FD, ID fans, CW pump, Pulv A, Pulv B)
- LV motors (IA compressor, various other small pumps)

The CCW system consists of a single pump (1PGA10AP001), a fin fan cooler equipment with 24 fans and distribution pipework to all the required consumers.

The complete CCW system can be started/stopped using the CCW control faceplate (Click on CCW pump symbol) and will indicate the water pressure on gauge (1PGB20CP001).

As more MV motors and other consumers are started the heat input into the CCW system will increase. To compensate for this, the fin fan cooling fans will automatically start and stop to keep the system temperature within limits.

Any small leakage from this system will be topped up from the demin distribution pump (0GCF10AP001).

A screenshot of simulator DCS screen related to this system can be found on page 88.

Alarms and trip levels associated with this system;

- CCW Pump Protection OFF - loss of electrical supply
- CCW Head Tank LOW
- CCW Head Tank LOW LOW (TRIP CCW pump 1PGA10AP001)

Instrument fitted on this system include;

- CCW pump (1PGA10AP001) indication on/off.
- CCW pump discharge pressure 1PGB20CP001.
- CCW head tank level low 1PGB30LS001.
- CCW head tank filling valve (1GHC10AA201) indication open/closed.
- CCW fan (1PGA10AN001) indication on/off.
- CCW fan (1PGA10AN002) indication on/off.
- CCW fan (1PGA10AN003) indication on/off.
- CCW fan (1PGA10AN004) indication on/off.
- CCW fan (1PGA10AN005) indication on/off.
- CCW fan (1PGA10AN006) indication on/off.
- CCW fan (1PGA20AN001) indication on/off.
- CCW fan (1PGA20AN002) indication on/off.
- CCW fan (1PGA20AN003) indication on/off.
- CCW fan (1PGA20AN004) indication on/off.

- CCW fan (1PGA20AN005) indication on/off.
- CCW fan (1PGA20AN006) indication on/off.
- CCW fan (1PGA30AN001) indication on/off.
- CCW fan (1PGA30AN002) indication on/off.
- CCW fan (1PGA30AN003) indication on/off.
- CCW fan (1PGA30AN004) indication on/off.
- CCW fan (1PGA30AN005) indication on/off.
- CCW fan (1PGA30AN006) indication on/off.
- CCW fan (1PGA40AN001) indication on/off.
- CCW fan (1PGA40AN002) indication on/off.
- CCW fan (1PGA40AN003) indication on/off.
- CCW fan (1PGA40AN004) indication on/off.
- CCW fan (1PGA40AN005) indication on/off.
- CCW fan (1PGA40AN006) indication on/off.
- Generator CCW supply valve (1PGB80AA001) indication open/closed.

Pre-requisites for starting the CCW system include;

- Power supply from 400V switchboard available for pump 1PGA10AP001.
- Power supply from 400V switchboard available for fans 1PGA10AN001 - 1PGA40AN006 (total 24 fans).
- RECOMMENDED - Demin pump (0GCF10AP001) in service.

3.1.7 Cooling Water (CW)

Steam existing from the turbine exhaust after doing work within the turbine is at a pressure of approx. 50 mbar (absolute) and 33 deg C (Note: because of the vacuum present steam can exist at this temperature). To convert this back to water we must remove its latent heat which we accomplish in the condenser.

The condenser hangs beneath the turbine and collects the exhaust steam which then passes over the many cooling tubes inside (can be 5000 tubes or more). Inside these tubes is cooling water from the local river and the heat to convert the steam back to water is transferred to this cooling water. By removing latent heat from the steam and giving it to the cooling water, the steam is converted back to water and the cooling water discharge is slightly hotter than the suction.

The cooling water flow necessary is rather large (approx. $3m^3/s$ in this case) so a large 11kV pump (1PAB10AP001) is provided. It sucks water from the nearby local river, passes it through the condenser tubes and dumps it back to the river downstream slightly warmer.

Due to environmental consideration, it is only permissible to raise the river water temperature slightly. During normal full load operation this is approx. 5 deg C, but during some events such as a boiler runback to 50% load, this temperature may be higher.

An alarm will sound if this differential temperature (1PAC40CT901) is >6 deg C and a further alarm will occur if it is >7 deg C. Above this higher valve a report will be required as to why you have exceeded the local government resource consent limits and a deduction will be made from your performance score on the Summary page.

A screenshot of simulator DCS screen related to this system can be found on page 91.

Alarms and trip levels associated with this system;

- CW Pump Protection OFF - loss of electrical supply
- Vacuum Pump Protection OFF - loss of electrical supply
- Vacuum Pump Protection OFF - loss of IA supply
- CW Pump Protection OFF - no CCW cooling
- Vacuum Pump Protection OFF - Gland Steam not available
- CW Delta T HIGH >6 deg C
- CW Delta T HIGH HIGH >7 deg C

Instrument fitted on this system include;

- Cooling water pump (1PAB10AP001) indication on/off.
- Cooling water condenser inlet temperature 1PAC10CT001
- Cooling water condenser outlet temperature 1PAC40CT001
- Condenser inlet/outlet differential temperature 1PAC40CT901. Note this is a calculated value from the two above thermocouples
- Condenser absolute pressure 1MAG10CP001

Pre-requisites for starting the main Cooling Water system include;

- Power supply from 11kV switchboard available for pump 1PAB10AP001.
- CCW system for motor cooling.

3.2 Boiler

ACME Power unit 1 is equipped with a pulverised coal fired natural circulation sub-critical pressure boiler. It includes the following components/systems;

3.2.1 Main Steam system

From the feedwater pump discharge the feedwater is lead to the boiler. In this simulation we do not have high pressure feedwater heaters so the water flow directly from pump discharge to the economiser inlet.

As the feedwater passes through the economiser it is absorbing heat from the boiler backpass area. Eventually the feedwater exits the economiser and enters the steam drum.

The cold (relative to the water already in the drum) feedwater then travels down the boiler downcomer pipes to the boiler bottom headers. There it is distributed into all the boiler waterwall tubes and travels upwards back to the steam drum gaining heat from the furnace burners.

It is now a water/steam mixture and as it enters the drum the cooler water is again directed to the downcomer pipes whilst the steam is separated off and lead to the superheater section.

The steam travels through the superheater gaining further heat and increasing its temperature above the saturation temperature (i.e. superheating it).

During the steams flow through the superheater water can be injected into it to control the final superheater outlet temperature. This injection system is called the de-superheating sprays.

A further method to control the superheater outlet temperature is by using the burner tilt control. This either tilts up or down the burner nozzles (1 oil and 2 coal nozzles all tilting together) so as to direct the fuel either upwards into the furnace where superheater outlet temperature will increase or downwards where heat absorption into the waterwalls will increase, but superheater outlet temperature will decrease.

Once the steam exists the superheater it can travel three different paths.

1. Startup Sky vent
2. Turbine bypass valve to condenser
3. Turbine steam inlet

Once boiler firing of fuel, either oil or coal is started a steam flow path must exist or the metal of the superheater tubes will overheat. During startup after oil firing has started but before condenser vacuum is created the only flow path available is to the boiler startup sky vent which harmlessly vents the steam produced to atmosphere.

Once a vacuum exists in the condenser the boiler main stop valve can be opened and the steam will then flow through the turbine bypass valve to the condenser. At this stage the boiler sky vent will close.

Once the boiler pressure, temperature and steam flow have reached values that are compatible with the requirements of the turbine (this depends on the type of startup - Cold, Warm or Hot) the turbine trip can be reset and steam will flow to the turbine and it will increase in rotation speed up to 3000 rpm.

When the turbine has reached 3000 rpm and the generator synchronised to the electrical grid the generator power output will increase until minimum load is achieved.

At this stage 'Turbine Follow Mode' should be selected on the Turbine Steam page and the generator load will increase until the turbine bypass valve is fully closed.

The addition of further fuel into the boiler, will result in an increase in steam flow and a corresponding increase in generator power output.

A screenshot of simulator DCS screens related to this system can be found on page 92.

Alarms and trip levels associated with this system;

- Boiler Outlet Temperature HIGH >545 deg C
- Boiler Outlet Temperature HIGH HIGH >555 deg C (20003)
- Boiler Drum Pressure HIGH >165 bar (Boiler safety valve OPEN)
- Boiler Drum Pressure HIGH HIGH >170 bar (20014)
- Boiler drum level LOW <-200mm
- Boiler drum level LOW LOW <-300mm (20011)
- Boiler pressure rate of increase HIGH
  - >0.25 bar/min with Fuel Oil only
  - >0.8 bar/min with Coal pulveriser running
- Boiler pressure rate of increase HIGH HIGH (20005)
  - >0.3 bar/min with Fuel Oil only
  - >0.9 bar/min with Coal pulveriser running
- Boiler temperature rate of increase HIGH
  - >2.0 deg C/min with Fuel Oil only
  - >2.5 deg C/min with Coal pulveriser running
- Boiler temperature rate of increase HIGH HIGH (20004)
  - >6.0 deg C/min with Fuel Oil only
  - >8.0 deg C/min with Coal pulveriser running

Instrument fitted on this system include;

- Steam drum level 1LAB10LT001
- Steam drum water temperature 1HAE10CT001
- Steam drum vent valve (1HAE15AA001) indication open/close.
- Steam drum safety valve (1LBH10AA401) indication open/close.
- Superheater outlet temperature 1LBA30CT001.
- Superheater outlet pressure 1LBA30CP001.
- Boiler main stop valve (1LBH20AA101) indication open/close.
- Boiler startup vent valve (skyvent) 1LBH10AA151 position.
- Sootblowing supply isolation valve (1HCB10AA001) indication open/close.
- Gland steam supply isolation valve (1LBA50AA001) indication open/close.
- Steam leg temperature 1LBA50CT001.
- Steam leg pressure 1LBA50CP001.
- Steam leg drain valve (1LBA50AA501) indication open/close.
- Turbine inlet steam temperature 1LBA60CT001.
- Turbine inlet steam pressure 1LBA60CP001.
- Turbine inlet steam flow 1LBA50CF001.
- Condenser pressure 1MAG10CP001.
- Turbine emergency stop valve (ESV) 1MAB10AA001 position.
- Turbine bypass valve 1MAN20AA251 position.

3.2.2 Air Systems

The furnace needs a constant supply of air to support combustion and in this case is of the balanced draught type. This means air blown into the furnace by the FD (Forced Draught) fans is sucked out by the ID (Induced Draught) fans. A slight negative air pressure is maintained in the furnace to prevent hot gasses leaking out.

For initial operation during startup then this air supply is sufficient to support the fuel oil burner.

Once a furnace backpass temperature >250 deg C is achieved then it is possible to start the PA (Primary Air) fan. The function of this fan is too feed air to each coal pulveriser to transport the pulverised coal to the furnace

As fuel oil or coal feeder speed is increased then the boiler air flow will also increase to ensure their is always sufficient oxygen to support combustion.

Additional a rotary type airheater is installed after the boiler backpass, the function of which is to remove heat from the boiler exhaust flue gas (which would be wasted heat exhausting from the chimney) and transfer that heat to the air entering the furnace. The result is an increase in boiler efficiency.

A screenshot of simulator DCS screens related to this system can be found on page 93.

Alarms and trip levels associated with this system;

- Air Heater Protection OFF - loss of electrical supply
- ID Fan Protection OFF - loss of electrical supply
- FD Fan Protection OFF - loss of electrical supply
- PA Fan Protection OFF - loss of electrical supply
- ID Fan Protection OFF - loss of IA supply
- FD Fan Protection OFF - loss of IA supply
- PA Fan Protection OFF - loss of IA supply
- ID fan Protection OFF - AHTR not running
- FD fan Protection OFF - ID fan not running
- Boiler Air Flow Controller Protection OFF
- Air Heater Protection OFF - no CCW cooling
- ID Fan Protection OFF - no CCW cooling
- FD Fan Protection OFF - no CCW cooling
- PA Fan Protection OFF - no CCW cooling
- Boiler ID fan load HIGH >100%
- Boiler FD fan load HIGH >100%
- Boiler Air Flow low <25%
- Boiler Air Flow low <20% (20007)
- Boiler Air Flow HIGH >98%
- Boiler Air Flow HIGH >102% (20008)
- Boiler PA Duct Pressure LOW <150 mbar
- Boiler PA Duct Pressure LOW LOW <100 mbar (20006)
- ID fan inlet temperature HIGH >148 deg C
- ID fan inlet temperature HIGH HIGH >150 deg C (ID fan protection OFF)

- Stack particulate emission HIGH >35mg/Nm3
- Stack particulate emission HIGH HIGH >50mg/Nm3

Instrument fitted on this system include;

- Air heater (1HLD10AC001) indication on/off.
- ID fan (1HNC10AN001) indication on/off.
- FD fan (1HLB10AN001) indication on/off.
- PA fan (1HFE10AN001) indication on/off.
- Boiler backpass temperature 1HNA50CT001
- Air Heater rotation speed 1HNA10AC001
- ID fan load 1HNC10AN001
- FD fan load 1HLB10AN001
- PA fan load 1HFE10AN001
- PA duct pressure 1HFE20CP001
- Boiler total airflow
- ESP (1HDE10AT001) indication on/off.
- Stack opacity measurement 1HNE10CQ001

Pre-requisites for starting the Rotary Airheater include;

- Power supply from 400V switchboard available for air heater motor 1HLD10AC001.
- IA compressed air for various dampers and actuators.
- CCW system for motor/gearbox cooling.

Pre-requisites for starting the ID Fan include;

- Power supply from 11kV switchboard available for fan 1HNC10AN001.
- IA compressed air for various dampers and actuators.
- CCW system for motor cooling.
- Airheater running.

Pre-requisites for starting the FD Fan include;

- Power supply from 11kV switchboard available for fan 1HLB10AN001.
- IA compressed air for various dampers and actuators.
- CCW system for motor cooling.
- ID fan running.

Pre-requisites for placing Air Flow on AUTO include;

- Airheater running.
- ID fan running.
- FD fan running.

Pre-requisites for starting the Furnace PURGE include;

- Boiler steam drum level is not in alarm.
- Fuel oil supply pressure is good.
- Furnace air flow rate is good.

Pre-requisites for starting the PA Fan include;

- Power supply from 11kV switchboard available for fan 1HFE10AN001.
- IA compressed air for various dampers and actuators.
- CCW system for motor cooling.
- Furnace backpass temperature >250deg C.

3.2.3 Fuel Control

Each ACME Power station boiler is equipped with 1 × oil burner for startup and 2 × coal pulveriser for full load operation.

The fuel oil burner can operate from approximately 10% to 100% fuel oil flow and is supplied from the fuel oil distribution pump (0EGC10AP001). This burner is used for initial startup of the boiler until sufficient furnace backpass temperature is reached to allow starting of the PA (Primary Air) fan.

During startup the rate of increase of boiler pressure and temperature must be closely watched to ensure the rate is not too fast. Careful control of the fuel oil burner is required to prevent a rate of rise that will result in a boiler trip.

Once the PA fan has been started and the fan discharge duct pressure is above alarm point then it is possible to start one or both coal pulverisers.

Whilst the heat output from the single fuel oil burner is low and only enough to achieve steam flow of approximately 17 kg/s (which is approximately 15 MW power generation), each coal pulveriser has enough heat output for 50% load. Hence 2 × coal pulveriser in service with maximum feeder speed will give enough heat input to achieve steam flow of approximately 134 kg/s (which is approximately 150 MW power generation - i.e. full load)

Each coal pulveriser is fed by raw coal from a coal bunker positioned above it. This coal bunker can only store a limited amount of coal and its level will decrease depending on coal feeder rate for each pulveriser. When required these coal bunkers can be refilled by requested coal supply from the fuel handling yard. The fuel supply conveyors upstream of the coal bunkers is not modelled in this simulation except that we can request a top up of the coal bunkers and after a short delay to start the fuel handling equipment the coal bunker levels will start to increase.

Let the coal bunker level get too low and the associated coal pulveriser will stop. This can cause a full unit trip so pay attention to the fuel supplies.

Maintaining a stable flame when burning coal, especially at low coal feeder speeds can be a problem so some limits are put in place to prevent a possible loss of ignition and subsequent reignition of unburned fuel causing an explosion.

Either the coal pulversier burner elevation can be above a certain minimum speed or it can be supported by an adjacent fuel oil burner elevation in service or by another coal pulveriser burner also above a certain minimum speed.

Lower limits on Coal Pulveriser feeder speeds are as follows;

With only 1 Coal Pulveriser in service and no Fuel Oil support;
Alarms

- <50% - Unsupported Coal Pulveriser In Service <50% Feeder Speed
- <50% - Unsupported Coal Pulveriser In Service - Start Oil Support

Trip

- <40% - Unsupported Coal Pulveriser In Service <40% Feeder Speed (20009)

With 2 Coal Pulveriser in service and no Fuel Oil support;
Alarms

- <40% - Coal Pulveriser's In Service <40% Feeder Speed
- <40% - Coal Pulveriser's In Service - Start Oil Support

Trip

- <30% - Coal Pulveriser's In Service <30% Feeder Speed
    - Coal Pulveriser A <30% Feeder Speed (Pulv A Trip)

- Coal Pulveriser B <30% Feeder Speed (Pulv B Trip)

With 1 or 2 Coal Pulverisers in service plus Fuel Oil support ON; Alarms

- Coal Pulveriser A minimum Feeder Speed 25%
- Coal Pulveriser B minimum Feeder Speed 25%

In the event that a turbine trip is actuated in many cases the boiler can continue to operate (i.e. a turbine trip does not always cause a boiler trip). When the turbine inlet valve trips close the generator circuit breaker will open and power generation will stop, however the turbine bypass valve will open and direct the steam to the turbine condenser.

As the turbine bypass valve is not designed for full load steam flow the boiler fuel firing will be reduced automatically to a safe level.

If both coal pulveriser burners are in operation then one coal pulveriser will shut down and the other will reduce to 50% feeder speed. If only one pulveriser is in service it will just reduce to 50% feeder speed.

A screenshot of simulator DCS screens related to this system can be found on page 95.

Alarms and trip levels associated with this system;

- Pulveriser A Protection OFF - loss of electrical supply
- Pulveriser B Protection OFF - loss of electrical supply
- Pulveriser A Protection OFF - loss of IA supply
- Pulveriser B Protection OFF - loss of IA supply
- Pulveriser A Protection OFF - no CCW cooling
- Pulveriser B Protection OFF - no CCW cooling
- FO supply pressure <8.5 bar (30002)
- Coal Bunker A level LOW <1.0m
- Coal Bunker A level LOW LOW <0.0m (Pulv A protection OFF)
- Coal Bunker B level LOW <1.0m
- Coal Bunker B level LOW LOW <0.0m (Pulv B protection OFF)
- Coal Pulveriser B TRIP - Boiler RUNBACK
- Coal Pulveriser A RUNBACK to 50%
- Coal Pulveriser B RUNBACK to 50%
- Unsupported Coal Pulveriser In Service <50% Feeder Speed
- Unsupported Coal Pulveriser In Service - Start Oil Support
- Unsupported Coal Pulveriser In Service <40% Feeder Speed (20009)
- Coal Pulveriser's In Service <40% Feeder Speed
- Coal Pulveriser's In Service - Start Oil Support
- Coal Pulveriser's In Service <30% Feeder Speed
- Coal Pulveriser A <30% Feeder Speed (Pulv A Trip)
- Coal Pulveriser B <30% Feeder Speed (Pulv B Trip)
- Coal Pulveriser A minimum Feeder Speed 25%
- Coal Pulveriser B minimum Feeder Speed 25%

- Boiler Loss of Fuel TRIP (20010)

Instrument fitted on this system include;

- Coal Pulv A (1HFC10AV001) indication on/off.
- Coal Pulv B (1HFC20AV001) indication on/off.
- Oil Burner ON (1HHA10AV001) indication on/off.
- FO supply block valve (1EGD20AA101) indication open/closed.
- FO supply control valve (1HHA10AA251) indication open/closed.
- FO flow controller 1HHA10CQ001
- Bunker A 1HFA10BB001
- Bunker B 1HFA20BB001
- Bunker A level 1HFA10LT001
- Bunker B level 1HFA20LT001
- PA fan (1HFE10AN001) indication on/off.
- Pulv A speed controller 1HFB10CQ001
- Pulv B speed controller 1HFB20CQ001
- Burner Tilt controller 1HFD10FG001A
- Burner tilt position (1HFD10FG001B) indication.
- Request to fill button - FILL (REQUEST)
- Wait filling indication Wait Filling (F WAIT)
- Boiler TRIP button - TRIP (B)
- Pressure rate of rise indication.
- Temperature rate of rise indication.

Pre-requisites for starting the Boiler Fuel Oil Burner include;

- IA compressed air for various dampers and actuators.
- Fuel oil supply system running.
- Boiler purge completed successfully.

Pre-requisites for starting a Coal Pulveriser include;

- Power supply from 11kV switchboard available for coal pulveriser 1HFC10AV001 or 1HFC20AV001.
- IA compressed air for various dampers and actuators.
- CCW system for motor cooling.
- Primary Air duct pressure >150mbar.
- Fuel oil burner in service for 1st coal pulveriser start.

3.2.4 Feedwater Pumping (FWP)

To complete the delivery of water from the Condensate system back to the boiler steam drum we have the feedwater pump and associated equipment.

Firstly the water stored in the Deaerator and Feedwater Storage tank (1LAA10BB001) acts as a reservoir of water ready to be supplied to the boiler. Also the Deaerator other main purpose is to help with the removal of any dissolved gases (especially oxygen) in the feedwater as these can cause corrosion in the boiler.

From the Deaerator and Feedwater Storage tank water is fed down to the main Feedwater pump (1LCA10AP001) which then pumps it at high pressure (>160 bar) up to the boiler steam drum.

To protect the pump from overheating and always ensure that a flow of water exists in the pump, a minimum flow valve (1LAC12AA001) is fitted. This will open at low flow and close at high flows to maintain this minimum flow.

To maintain the Steam drum level at its desired setpoint (NWL is 0.0mm as the level in this vessel is measure $\pm$ from the centre line) we have a flow control valve fitted after the FWP pump. This valve (1LAB10AA251) will modulate to control the Steam Drum level at setpoint. Also when starting the system it will maintain a constant flow of approx. 25 kg/s to initially fill the pipework and Steam Drum to its normal working level.

When starting the system, the FWP pump (1LAC10AP001) will run and the minimum flow valve (1LAC12AA001) will immediately open to ensure flow. Once the Steam Drum level control valve (1LAB10AA251) is placed in AUTO mode (located on Feedwater pump faceplatex) the Steam Drum level will start to increase up to its normal working level. Eventually when the feedwater flow is sufficient to the Steam Drum, the minimum flow valve will close.

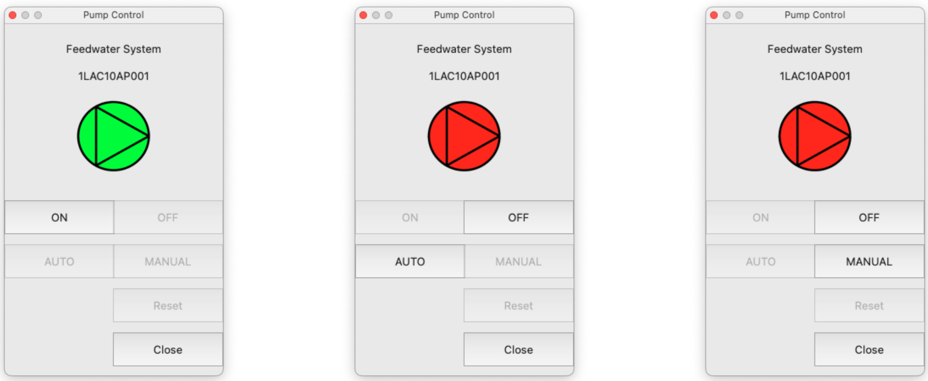


Figure 9: Feedwater Pump ON/OFF and Steam drum level control AUTO selection.

A screenshot of simulator DCS screen related to this system can be found on page 96.

Alarms and trip levels associated with this system;

- Feedwater Pump Protection OFF - loss of electrical supply
- Feedwater Pump Protection OFF - loss of IA supply
- Feedwater Pump Protection OFF - no CCW cooling
- Deaerator level LOW <1000mm
- Deaerator level LOW LOW <400mm (FWP protection OFF)

Instrument fitted on this system include;

- Feedwater storage tank level (1LAA10LT001) measurement.
- Feedwater pump (1LAC10AP001) indication on/off.
- Feedwater pump discharge pressure (1LAB10CP001).

- Feedwater pump minimum flow valve (1LAC12AA001) indication open/closed.
- Feedwater flow to steam drum (1LAB20CF001) measurement.
- Steam drum level (1LAB10LT001) measurement.

Pre-requisites for starting the FWP pump include;

- Power supply from 11kV switchboard available for pump 1LAC10AP001.
- IA compressed air for various actuators.
- CCW system for motor cooling.
- DA level >400mm.

3.2.5 Electrostatic Precipitator (ESP)

To reduce pollution from coal combustion (in this case visual smoke) an electrostatic precipitator is fitted. This uses high voltage to charge the flue gas dust particles and subsequently capture them, greatly reducing the dust particles escaping from the chimney.

The high voltages involved in the ESP however present a risk of explosion if any unburnt fuel oil makes it to this area. Therefore the ESP will automatically turn off if the oil burner control is $> 20\%$

Not operating the ESP at high boiler loads will result in exceeding the allowable limits for chimney opacity. Exceeding these limits will result in a penalty in your final score.

A screenshot of simulator DCS screen related to this system can be found on page 94.

Alarms and trip levels associated with this system;

- ESP Protection OFF - loss of electrical supply
- Fuel Oil burner flow >20% (ESP protection OFF)

Instrument fitted on this system include;

- ID fan (1HNC10AN001) indication on/off.
- ESP fields (1, 2 and 3) indication on/off.
- Emitting rapping gear (1HDE10AT001A) indication on/off
- Collecting rapping gear (1HDE10AT001B) indication on/off
- Stack Opacity indication 1HNE10CQ001

Pre-requisites for starting the ESP include;

- Power supply from 400V switchboard available for ESP fields 1, 2 and 3.
- Power supply from 400V switchboard available for ESP emitting rapping motor 1HDE10AT001A.
- Power supply from 400V switchboard available for ESP collecting rapping motor 1HDE10AT001B
- Fuel Oil control demand <20%.
- Boiler TRIP reset.

3.3 Turbine

ACME Power unit 1 is equipped with a 150 MW class single cylinder multi stage machine. It includes the following components/systems;

3.3.1 Turbine Steam System

The turbine is fitted with a single steam entry with ESV (Emergency Stop Valve) and CV (Control Valve), plus a turbine bypass valve to allow steam conditions from the boiler to be matched with the required turbine conditions before allowing steam to enter the turbine.

A screenshot of simulator DCS screen related to this system can be found on page 103.

Alarms and trip levels associated with this system;

- Turbine steam flow LOW <10 kg/s
- Turbine steam flow LOW LOW <9 kg/s (10014)
- Turbine/Generator load below MINIMUM LOAD <15 MW for X seconds (10018)
- Turbine/Generator REVERSE POWER (10017)
- Boiler Emergency Push Button (10021)
- Bypass valve opening HIGH - reduce boiler load
- Bypass valve opening HIGH HIGH (10019)[3]

Instrument fitted on this system include;

- Turbine inlet steam temperature 1LBA60CT001
- Turbine inlet steam pressure 1LBA60CP001
- Turbine inlet steam flow 1LBA50CF001
- Turbine ESV valve 1MAB10AA001
- Turbine CV valve 1MAB10AA002
- Turbine bypass valve 1MAN20AA251
- Turbine speed 1MAB50CS901
- Generator gross power 1MAB50CE001

[3] If the turbine bypass valve is open >110% for X seconds a turbine trip will occur. This best solution is to reduce boiler firing rate (either FO or Coal flow) which will drop the steam flow and allow the bypass valve to reduce its opening percentage.

3.3.2 Turbine supervisory

The steam turbine needs to be monitored at all times, but especially during run up to 3000 rpm to ensure no damage is done to it. Included in the installed sensors are instruments to measure the rotor metal temperature, bearing vibrations (both vertical and horizontal), bearing metal temperatures, expansion of the turbine rotor, shaft position and rotor speed.

The turbine white metal bearings are its most sensitive and easily damaged part so each of these four bearings is fitted with a vibration probe that will measure vertical acceleration, another to measure horizontal vibration and finally a thermocouple to measure bearing metal temperature.

Horizontal vibration readings at low speed (30 - 500 rpm) are a good indication of shaft straightness (the shaft can become bent by gravity if allowed to sit in the one position for too long).

Vertical vibration readings are more useful at higher speed (1000 - 3000 rpm) and will spike during the turbine run up when the turbine is passing through the critical speed range (usually around 2300 rpm).

Bearing metal temperature readings are useful as an increase is a indication that something is not right and should be investigated promptly.

Next the rotor metal temperature measurement is not actually a direct reading from the turbine rotor (that is hard to do as it is rotating). So therefore this is a calculated value using the main steam inlet temperature, the gland steam temperature, the outer turbine casing temperature and time. If the turbine is on turning gear with gland steam system off, this temperature will slowly reduce until down to ambient conditions (30 deg C in our case). This temperature is used by the turbine controller to determine if the next startup of the turbine will be considered a Cold, Warm or Hot start, as follows;

Turbine rotor metal temperature;

- <250 deg C - Cold start
- >250 deg C and <450 deg C - Warm start
- >450 deg C - Hot start

As the turbine is run up to 3000 rpm and heated by the main steam the metal that makes up the casing and the rotor will expand and cause a lengthening of the turbine. The casing and rotor will expand at differing rates due to the mass of the casing being much larger than the rotor. The expansion of the casing is measured as overall expansion (1MAD50FY001), whilst the difference between rotor and casing expansion is measured as Differential expansion (1MAD50FY002).

Additionally as the steam flow increases through the turbine as the load goes up to maximum the force pushing the rotor away from the steam inlet will also increase. This causes the rotor to move relative to the casing and bearing as is measured as Shaft Position (1MAD50FT003).

Finally we need to measure the speed of the turbine rotor accurately. To do this 3 separate speed probes are installed (1MAB50CS001/002/003) and the average reading is used (1MAB50CS901). If one speed probe has a reading that disagrees with the other two, it will be voted out and the average will just be then of the two remaining probes.

Before resetting the turbine trip signal and starting the turbine run up to 3000 rpm, the turbine rotor turning gear must be ON. It should be run for a time before turbine run up to ensure the rotor is straight (observe the bearing horizontal vibrations whilst at 30 rpm - turning gear speed. If they are high then the rotor needs longer on turning gear).

However once you are ready, the the turbine run up has started, it will follow the following sequence;

- >34 rpm - Turbine Turning Gear - DISENGAGED
- >990 rpm Turbine Turning Gear Motor OFF
- >1080 rpm Turbine Jacking Oil Pump OFF
- >2940 rpm Generator Excitation ON

- >2999 rpm Turbine at Full Speed (FSNL)
- Auto Synchronising ON
- Generator CB CLOSED
- Load increased to Minimum load

Once minimum load is reached, you will find that the turbine bypass valve (1MAN20AA251) is still slightly open.

To enable the turbine control system (which controls the turbine Control Valve (1MAB10AA002) to open or close to raise or lower the power generated) we must first close this bypass valve.

By selecting the Turbine CTRL mode to - Turbine MW AUTO, the turbine bypass valve will automatically close slowly to force this extra steam flow through the turbine (turbine load will also increase slightly during this time). Once the turbine bypass valve is fully closed the STG mode light - Turbine follow will be lit. This indicated the turbine load will now follow the boiler load. If you increase the fuel flow to the boiler, the steam flow will increase, the turbine CV will open and the generator output power will also increase. Conversely if you reduce the boiler fuel flow then the generator output power will reduce.

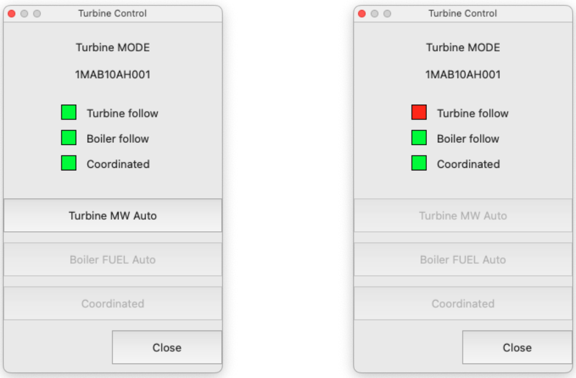


Figure 10: Turbine Control faceplate.

A screenshot of simulator DCS screen related to this system can be found on page 98.

Alarms and trip levels associated with this system;

- Turbine steam flow LOW <10 kg/s
- Turbine steam flow LOW LOW <9 kg/s (10014)
- Turbine/Generator load below MINIMUM LOAD <15 MW for X seconds (10018)
- Turbine/Generator REVERSE POWER (10017)
- Turbine NDE bearing 1MAD10 Vertical vibration HIGH >5 mm/s
- Turbine NDE bearing 1MAD10 Vertical vibration HIGH HIGH >12 mm/s (10001)
- Turbine DE bearing 1MAD20 Vertical vibration HIGH >5 mm/s
- Turbine DE bearing 1MAD20 Vertical vibration HIGH HIGH >12 mm/s (10001)
- Generator DE bearing 1MAD30 Vertical vibration HIGH >5 mm/s
- Generator DE bearing 1MAD30 Vertical vibration HIGH HIGH >12 mm/s (10001)
- Generator NDE bearing 1MAD40 Vertical vibration HIGH >5 mm/s
- Generator NDE bearing 1MAD40 Vertical vibration HIGH HIGH >12 mm/s (10001)
- Turbine Emergency Push Button (10021)

Instrument fitted on this system include;

- Turbine rotor temperature 1MAB10CT005
- Turbine NDE bearing vibrations vertical 1MAD10CY001
- Turbine NDE bearing vibrations horizontal 1MAD10CY002
- Turbine NDE bearing temperature 1MAD10CT001
- Turbine DE bearing vibrations vertical 1MAD20CY001
- Turbine DE bearing vibrations horizontal 1MAD20CY002
- Turbine DE bearing temperature 1MAD20CT001
- Generator DE bearing vibrations vertical 1MAD30CY001
- Generator DE bearing vibrations horizontal 1MAD30CY002
- Generator DE bearing temperature 1MAD30CT001
- Generator NDE bearing vibrations vertical 1MAD40CY001
- Generator NDE bearing vibrations horizontal 1MAD40CY002
- Generator NDE bearing temperature 1MAD40CT001
- Turbine overall expansion 1MAD50FY001
- Turbine differential expansion 1MAD50FY002
- Turbine shaft position 1MAD50FT003
- Turbine speed 1 1MAB50CS001
- Turbine speed 2 1MAB50CS002
- Turbine speed 3 1MAB50CS003
- Turbine speed combined 1MAB50CS901

3.3.3 Lube Oil Systems

The turbine/generator shafts are supported by 4 bearings; turbine NDE (non-drive end) bearing, turbine DE (drive end) bearing which is a combined journal and thrust bearing, generator DE bearing and generator NDE bearing.

All bearings are supplied with lubricating oil from the lube oil pumping system. This consist of a main lube oil pump that supplies oil to all 4 bearings at a discharge pressure of 3.1 bar. This pump needs to run continuously whilst the turbine is rotating to ensure no damage to the white metal journal bearings.

In the event that the lube oil pump trips, the turbine will immediately trip and the DC (direct current) lube oil pump will start. This pump is supplied with power from a bank of batteries so will work even in the event of a station power blackout. The DC pump is only intended to supply lubricating oil whilst the turbine/generator shaft runs down from 3000 rpm to zero speed.

If the AC lube oil pump is unavailable to run then the DC lube oil pump will start and run until the turbine rotor metal temperature is <120 deg C.

Additionally a jacking oil pump is also fitted that supplies lubricating oil at high pressure to the bottom of each journal bearing to provide upward support at low rotor speed. This jacking oil supply is only needed below a shaft speed of approximately 900 rpm and will stop automatically when rotor speed exceeds 1080 rpm.

Finally a motorised turning gear system is provided to rotate the turbine/generator shaft at low speed (30 rpm) to ensure an even cool down of the shaft after operation and to ensure straightness of the shaft before startup.

A screenshot of simulator DCS screen related to this system can be found on page 99.

Sequence of events as turbine speed increases on start up;

- >34 rpm - Turbine Turning Gear - DISENGAGED
- >990 Turbine Turning Gear Motor OFF
- >1080 Turbine Jacking Oil Pump OFF

Sequence of events as turbine speed decreases on shut down;

- <920 Turbine Jacking Oil Pump ON
- <500 Turbine Turning Gear Motor ON
- <2 rpm turning gear - ENGAGED

Alarms and trip levels associated with this system;

- Lube Oil Pump Protection OFF - loss of electrical supply
- Turbine Jacking Oil Pump Protection OFF - AC LO Pump not running
- Turbine Turning Gear Protection OFF - AC LO Pump not running
- Turbine DC Lube Oil Pump RUN

Instrument fitted on this system include;

- Lube Oil Pump Protection OFF - loss of electrical supply
- Jacking Oil Pump Protection OFF - loss of electrical supply
- Turning gear Protection OFF - loss of electrical supply
- AC lube oil pump (1MAV10AP001) indication on/off.

- DC lube oil pump (1MAV12AP001) indication on/off.
- Lube oil supply pressure (1MAV15CP001)
- Jacking oil pump (1MAV20AP001) indication on/off.
- Jacking oil supply pressure to turbine bearings (1MAV25CP001)
- Steam turbine rotor metal temperature (1MAB10CT005).
- Turning gear motor (1MAK10AE001) indication on/off.
- Turning gear engaged indication.
- Turbine shaft speed (1MAB50CS901).

Pre-requisites for starting the AC Lube Oil pump include;

- Power supply from 400V switchboard available for pump 1MAV10AP001.
- IA compressed air for various actuators.
- CCW system for oil cooler.

Pre-requisites for starting the Jacking Oil pump include;

- Power supply from 400V switchboard available for pump 1MAV20AP001.
- IA compressed air for various actuators.
- Lube oil pump 1MAV10AP001 running.

Pre-requisites for starting the turbine Turning Gear motor include;

- Power supply from 400V switchboard available for motor 1MAK10AE001.
- Lube oil pump 1MAV10AP001 running.
- Jacking oil pump 1MAV20AP001 running.

Pre-requisites for selecting the DC Lube oil pump to AUTO include;

- Power supply from 110V DC switchboard available for motor 1MAV12AP001 (Note: has this is a battery supply it is always available).

3.3.4 Gland steam and Vacuum Systems

Due to the high pressure steam within the turbine near the DE bear and the near complete vacuum at the turbine NDE end, a means is needed to seal these areas and prevent leakage either in or out. For this purpose with have the Gland Steam/Sealing system.

Steam is provide either from the Auxiliary boiler via valve 0LBH10AA001 during startup or from the Unit Main Steam via valve 1LBA50AA001 at all other times, and when the system is running maintains a seal steam pressure of approx. 350 mbar. The control valve 1MAW10AA001 control this supply of gland steam.

Any excess seal steam or main steam leakage from the DE of the turbine is extracted back to the gland steam (GS) condenser, where liquid is drained off and any steam extracted by the gland steam extraction fan (1MAW10AN001) and vented to atmosphere.

The gland steam system should be operated at all times that the condenser is under vacuum conditions.

To increase efficiency and extract the maximum amount of work from the steam in the turbine the turbine exhaust (and condenser) is kept in a vacuum (pressure approx 50mbar absolute). This vacuum is maintained by the reduction in volume of the steam exhausting from the turbine when it is converted to water in the condenser, but when first starting the unit this vacuum must be made by operating the condenser Vacuum pump (1MAJ10AP001). This pump will continue in normal operation as it also functions to remove any non-condensible gases from the condenser space.

The vacuum pump can only be started when gland steam pressure is >250 mbar.

The vacuum that can be achieved in the condenser is a function of the cooling water temperature. At a cooling water inlet temperature of about 30 deg C a vacuum of -950 mbar is possible (i.e. 50 mbar absolute).

A screenshot of simulator DCS screen related to this system can be found on page 100 and page 91.

Alarms and trip levels associated with this system;

- Gland Steam Exhauster Fan Protection OFF - loss of electrical supply
- Gland Steam Exhauster Fan Protection OFF - loss of IA supply
- Gland Steam Protection OFF - Steam supply Pressure LOW
- Gland Steam Protection OFF - Turning gear OFF
- Condenser Pressure HIGH >250 mbar
- Condenser Pressure HIGH HIGH >400 mbar (10013)
- Condenser Pressure HIGH HIGH HIGH >600 mbar (20013)

Instrument fitted on this system include;

- Main Steam isolation valve (1LBA50AA001) indication open/closed.
- Auxiliary boiler isolation valve 0LBH10AA001) indication open/closed.
- Steam available indication (GS supply AVAIL).
- Gland steam pressure control valve (1MAW10AA251) position.
- Gland steam pressure 1MAW20CP001
- Turbine rotor metal temperature 1MAB10CT005
- Gland steam exhauster fan (1MAW10AN001) indication on/off.

Pre-requisites for starting the gland steam system include;

- Power supply from 400V switchboard available .

- IA compressed air for various actuators.
- steam supply available from either;
  - Auxiliary boiler via valve 0LBH10AA001, or.
  - Boiler main steam leg via valve 1LBA50AA001
- Main CW pump running.
- Turbine speed >2rpm.

Pre-requisites for starting the condenser Vacuum pump include;

- Power supply from 400V switchboard available ejector pump 1MAJ10AP001.
- IA compressed air for various actuators.
- Gland steam pressure >250mbar.

3.3.5 Condensate Extraction Pump (CEP)

After the steam is exhausted from the back end of the steam turbine it falls into the condenser where the cooling water flowing through the condenser tubing will remove the latent heat and convert this steam back to water (usually referred to as condensate water or just condensate). This condensate collects in the bottom of the condenser in a space called the hotwell.

To maintain the cycle and the flow of steam from the boiler, this water must be returned to the boiler steam drum and in our station it is done in two steps. Firstly it is pumped from the condenser up to the Deaerator and then, secondly from the Deaerator it is pumped up to the steam drum. It is done in this way as it is very hard to design a single pump to go from the suction pressure of approx. 50 mbar (absolute) in the condenser up to the 160 bar discharge required to feed water to the steam drum.

So therefore, for the first step our station has a condensate extraction pump (CEP pump - 1LCB10AP001) that extracts condensate water from the hotwell and pumps it up to the Deaerator and feedwater storage vessel (1LAA10BB001).

To protect the pump from overheating and always ensure that a flow of water exists in the pump, a minimum flow valve (1LCB12AA001) is fitted. This will open at low flow and close at high flows to maintain this minimum flow.

To maintain the Deaerator level at its desired setpoint (approx. 2100mm) we have a flow control valve fitted after the CEP pump. This valve (1LCA10AA251) will modulate to control the Deaerator level at setpoint. Also when starting the system it will maintain a constant flow of approx. 25 kg/s to initially fill the pipework and Deaerator to its normal working level.

When first starting the condensate system the boiler and turbine are not running. As no steam is therefore returning from the steam turbine and converting to water in the condenser to feed the CEP pump the hotwell level would soon drop to zero. To provide this filling water and also to top up any leakages in the whole cycle a condenser filling valve (1GHC10AA301) is fitted that supplies water from the Demin water pump (0GCF10AP001).

When starting the system, the CEP pump (1LCB10AP001) will run and the minimum flow valve (1LCB12AA001) will immediately open to ensure flow. Once the Deaerator level control valve (1LCA10AA251) is placed in AUTO mode (located on the CEP pump faceplate) the Deaerator level will start to increase up to its normal working level. Eventually when the condensate flow is sufficient to the Deaerator, the minimum flow valve will close.

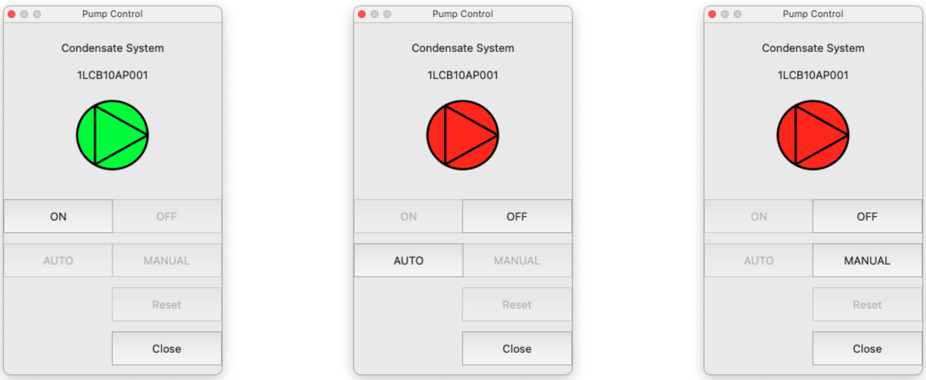


Figure 11: Condenate Extraction Pump ON/OFF and Deaerator level control AUTO selection.

A screenshot of simulator DCS screen related to this system can be found on page 101.

Alarms and trip levels associated with this system;

- CEP Pump Protection OFF - loss of electrical supply
- CEP Pump Protection OFF - loss of IA supply
- CEP Pump Protection OFF - no CCW cooling
- Hotwell level LOW <300mm

- Hotwell level LOW LOW <250mm (CEP protection OFF)
- Deaerator level LOW <1000mm
- Deaerator level LOW LOW <400mm (FWP protection OFF)

Instrument fitted on this system include;

- Condenser hotwell level 1LCA10BB001
- Condenser filling valve (1GHC10AA301) position open/closed.
- Condensate Extraction pump (1LCB10AP001) indication running on/off.
- Condensate Extraction pump discharge pressure 1LCA10CP001
- Condensate Extraction pump minimum flow valve (1LCB12AA001) indication open/closed.
- DA level control valve (1LCA10AA251) position.
- Condensate flow 1LCA20CF001
- DA feedwater tank level 1LAA10LT001

Pre-requisites for starting the CEP pump include;

- Power supply from 11kV switchboard available for pump 1LCB10AP001.
- IA compressed air for various actuators.
- CCW system for motor cooling.
- Hotwell level >250mm.

3.3.6 Control Oil

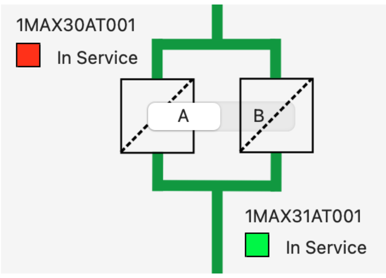
A hydraulic oil system is provided for control of the turbine ESV (Emergency Stop Valve 1MAB10AA01) and CV (Control valve 1MAB10AA002). It is generally known as the Control Oil system and consists of the following components;

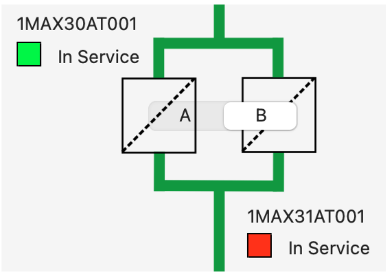
- Stainless steel tank (1MAX10BB001) to contain a reservoir of hydraulic oil.
- High pressure pump (1MAX10AP001) to provide the hydraulic oil at approx. 150 bar pressure to the turbine valves.
- Duplex filter (A side - 1MAX30AT001 and B side - 1MAX31AT001) for ensuring the hydraulic oil supplied is clean and contains no foreign matter that could damage the valve control solenoids. Note: this filter can be swapped from A to B side whilst the turbine is running.
- Supply of hydraulic oil to each valve (1MAB10AA001 and 1MAB10AA002).
- Leakoff line to drain excess hydraulic oil fromt he valves back to the reservoir tank.
- 3 x trip valves (1MAX50AA001/002/003) to reduce the hydraulic oil pressure suddenly.

Both the ESV valve (1MAB10AA001) and CV valve (1MAB10AA002) are spring close valves, so loss of hydraulic oil pressure will cause both to close quickly (rather large and strong springs are fitted).

All the events that intend to cause a turbine trip (see list and details on page 72 below) work by sending a signal to the 3 trip valves (1MAX50AA001/002/003) to OPEN. This will dump the hydraulic oil back to the reservoir tank, reducing the oil pressure and causing the ESV and CV to close quickly - thus tripping the turbine.

As the in service filter becomes blocked over time, the pump discharge pressure (1MAX30CP001) will reduce. If you receive the alarm "Control oil pressure LOW" it means the pump discharge pressure is already <145 bar and you should consider changing the filter to the other side (e.g. if A side in service and receive low pressure alarm then change selection to B side in service).





If this alarm is ignored then eventually a turbine trip will occur when the pump discharge pressure (1MAX30CP001) is <143 bar.

A screenshot of simulator DCS screen related to this system can be found on page 102.

Alarms and trip levels associated with this system;

- Control Oil Pump Protection OFF - loss of electrical supply
- Control Oil Pressure LOW <145 bar
- Control Oil Pressure LOW LOW <143 bar (10016)

Instrument fitted on this system include;

- Control Oil pump discharge pressure (after filters) 1MAX30CP001
- Turbine ESV valve opening 2MAB10AA001
- Turbine CV valve opening 1MAB10AA002

Pre-requisites for starting the Control Oil pump include;

- Power supply from 400V switchboard available for pump 1MAX10AP001.
- IA compressed air for various actuators.

Pre-requisites for resetting the Turbine TRIP signal include;

- CW pump on.
- Control Oil pump on.
- Boiler MFT is false.
- Main steam temperature before turbine (1LBA60CT001) is ±20 deg C from target start temperature (Cold = 400, Warm = 430, Hot = 460 deg C).
- Main steam flow (1LBA50CF001) >15 kg/s
- DC lube oil pump selected to AUTO run.

3.3.7 Generator

The ACME brand generator installed at our site is of the 2-pole cylindrical rotor type with a rotating rectifier excitation system (not modelled). Having 2-pole means it rotates at 3000 rpm and as such no gearbox is required and it can be directly coupled to the steam turbine.

At the generator output terminals, frequency is measured (1MKA10CE001) along with voltage and current (not shown on screen). These valves are used when synchronising the generator to the electrical grid and closing the generator Circuit Breaker (1MKA10GS001).

Four coolers are fitted at the top of the generator casing to help remove the heat from this system. They are supplies from the CCW system and fitted with a flow switch to ensure adequate cooling. This system is only required when the generator is producing electricity so is fitted with an isolation valve (1PGB80AA001) that open only when circuit breaker (1MKA10GS001) is closed.

The air flow within the generator circulates through these coolers and the temperature in (Warm gas 1MKY10CT002) and temperature out (Cold gas 1MKY10CT001) are monitored.

Occasionally water can leak from these coolers and trays are fitted under them to catch any liquid. Once the liquid is sufficient an alarm will be generated and the tray's must be manually drained by opening the casing drain valve (1MKA10AA501). Failure to do this can lead to a high level of liquid in the casing and eventual trip of the generator.

A screenshot of simulator DCS screen related to this system can be found on page 104.

Alarms and trip levels associated with this system;

- CCW cooling flow LOW
- CCW cooling flow LOW LOW (10024)
- Generator Warm Gas temperature (1MKY10CT002) HIGH
- Generator Warm Gas temperature (1MKY10CT002) HIGH HIGH (10022)
- Generator liquid in casing level HIGH
- Generator liquid in casing level HIGH HIGH (10023)
- Generator Circuit Breaker closing TIMEOUT HIGH
- Generator Circuit Breaker closing TIMEOUT HIGH HIGH (10015)
- Turbine REVERSE POWER (10017)

Instrument fitted on this system include;

- Casing drain (1MKA10AA501) indication open/closed.
- CCW isolation valve (1PGB80AA001) indication open/closed.
- Generator synchronising CB (1MKA10GS001) indication open/closed.
- Turbine speed 1MAB50CS901
- Generator running Hz 1BAA10CE001
- Generator incoming Hz 1MKA10CE001
- CCW pressure 1PGB80CP001
- Generator cold gas temperature 1MKY10CT001
- Generator hot gas temperature 1MKY10CT002
- CCW flow NOT OK indication
- Excitation ON indication

- Leakage detector indication

Pre-requisites for starting the generator include;

- CCW system for generator coolers.
- Steam turbine speed at 3000 rpm.

4 Start-up Procedure

4.1 First steps

4.1.1 Selecting the level of difficulty

This simulator can be set up to start from cold boiler/turbine conditions in either EASY or HARD mode.

If the EASY setting is selected;

1. Boiler temperature rate of change is not limited (no alarms and no boiler trip).
2. Boiler pressure rate of change is not limited (no alarms and no boiler trip).

However if HARD setting is selected, then;

1. Boiler temperature rate of change is limited. For firing on fuel oil only limits are; alarm=2 deg C/min, trip=2.5 deg C/min. For coal firing these limits increase to; alarm=6 deg C/min, trip=8 deg C/min.
2. Boiler pressure rate of change is limited. For firing on fuel oil only limits are; alarm=0.25 bar/min, trip=0.3 bar/min. For coal firing these limits increase to; alarm=0.8 bar/min, trip=0.9 bar/min.

In either mode, various faults, alarms and annoyances can be introduced from the Trainer Window Fault page. This will be discussed in section 6 - Instructor/Trainer Window Usage.

4.1.2 Power on

Select the Electrical button on the bottom button bar.

On the screenshot below you can see the Electrical Systems page as it appears when first starting the application. Electricity is available on the 220kV busbar (this is connected to the main country electrical grid and not a part of this simulation), but out Unit 1 generator is off (circuit breaker 1MKA10GS001 is OPEN) and power to our unit 11kV board is also off (1ADA10GS001 is OPEN).

Before we can generate some electricity to feed into the country electrical grid, we need to take some back to start all the motors, pumps and fans on our boiler, turbine and auxiliary system. All the power we need can be provided from our unit 11kV board.

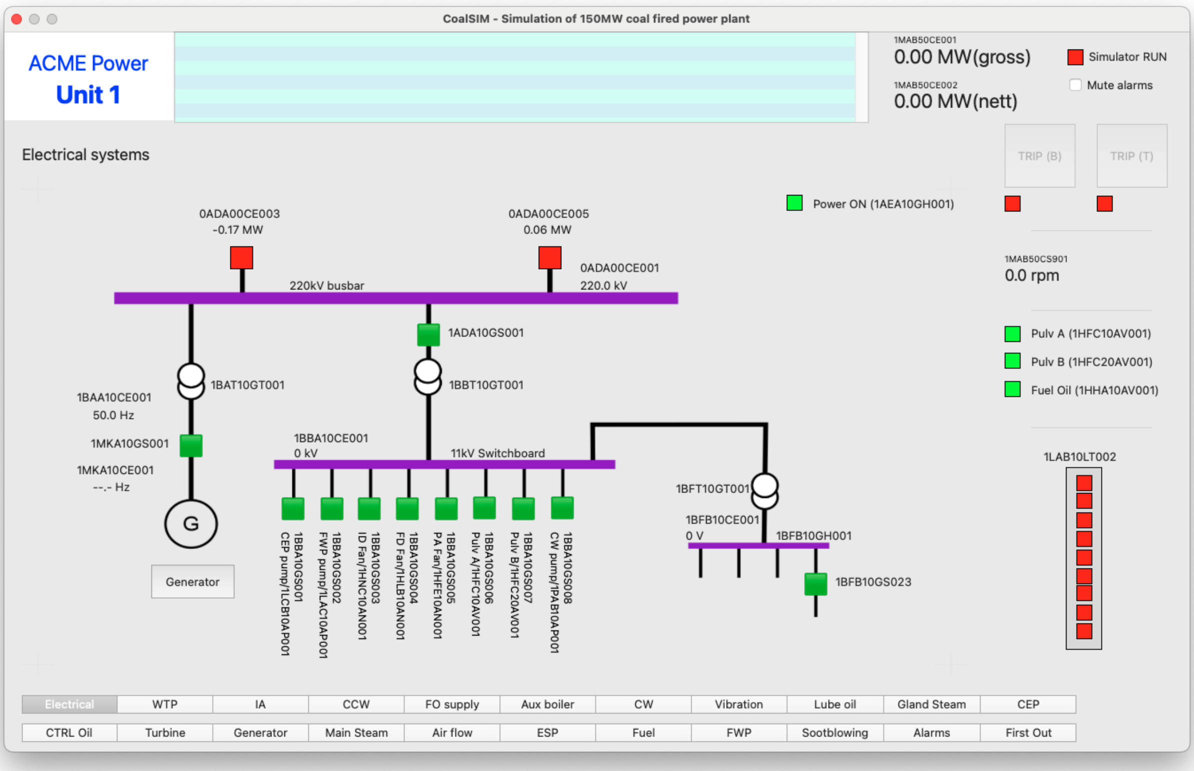
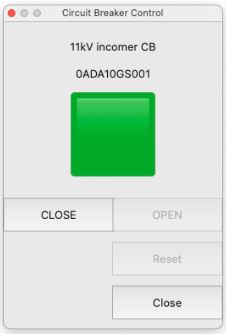
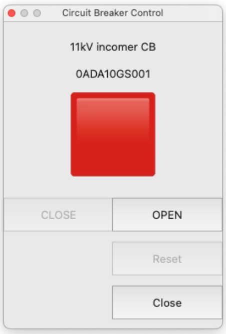


Figure 12: Electrical systems screen - 11kV board de-energised

Click on the Circuit breaker symbol (1ADA10GS001) and a Circuit Breaker Control faceplate will open.



Click the "CLOSE" button with your mouse.



This will cause circuit breaker 1ADA10GS001 to CLOSE and back feed electricity through transformer 1BBT10GT001 to the unit 11kV board. Note 11kV board voltage (1BBA10CE001) will increase from 0kV up to a value around 11.1kV. Also this will cause electricity to be provided via transformer 1BFT10GT001 to the 400V electrical board (1BFB10GH001). Now power is available to all our motors, pumps and fans.

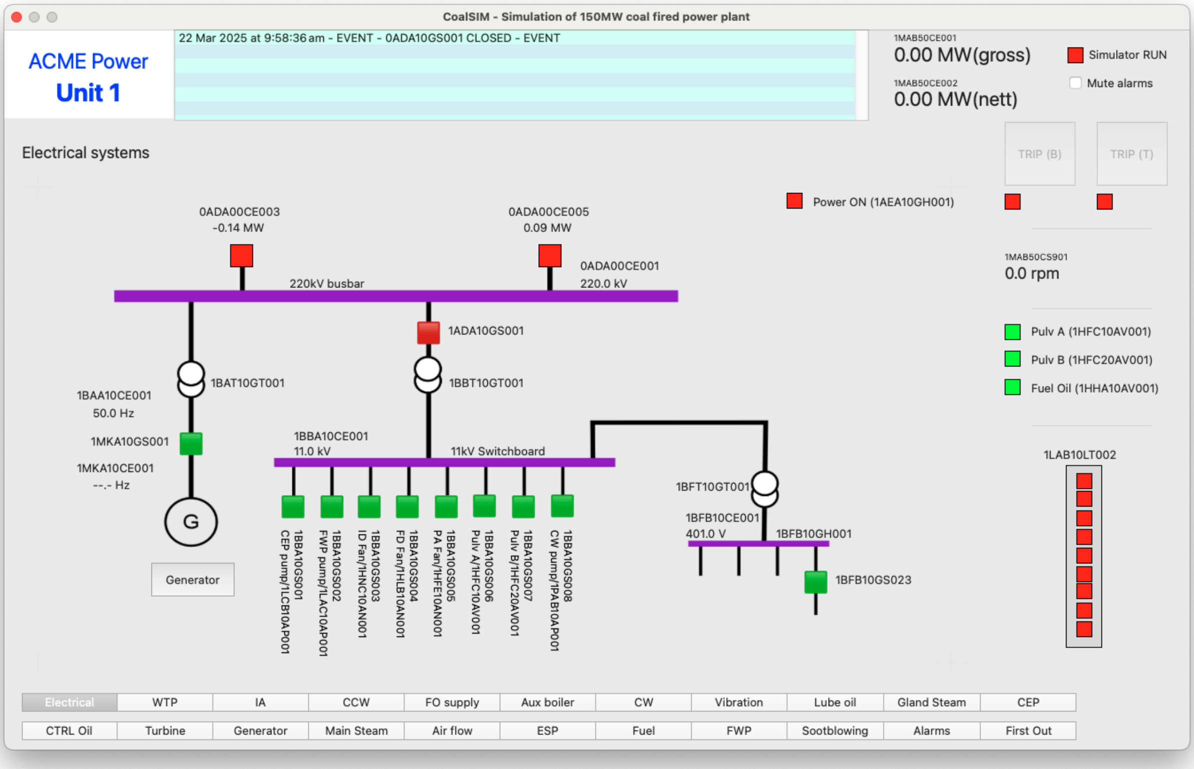


Figure 13: Electrical systems screen - 11kV board LIVE

Now that you have power available please continue the unit startup by following the Cold Start procedure on page 63.

4.2 General/Miscellaneous information

- The ACME power plant unit 1 has been fully commissioned and after a shutdown of a few weeks is ready for startup and to prove that it can reliably reach maximum load within its design parameters. All plant equipment except the main 220kV busbar is off and will need starting in the correct sequence if this startup is to be successful.

- As the turbine/generator shaft has been stationary for a lengthy time it is likely that the rotor has sagged (i.e. essentially both the turbine and generator rotors are long pieces of metal supported between two bearings and the force of gravity will cause the metal to sag). If the turbine/generator is run to 3000 rpm in this condition the bearing vibrations will be very high. To remove this sag a number of hours (typically 12-24 hours in real life) is required with the turbine turning gear ON to remove any sags. A clear indication that the rotors have a sag is high horizontal vibrations at turning gear speed or during the early stages of turbine run up.

- Turbine starts are generally separated in 3 differing categories depending on the metal temperature of the turbine rotor. This is done to ensure that when steam is introduced to the turbine it is at the same or slightly higher temperature than the rotor metal. The three categories at this site are Cold, Warm and Hot.

  - Cold start (rotor metal temperature <250 deg C).
  - Warm start (rotor metal temperature >250 and <450 deg C)
  - Hot start (rotor metal temperature <450 deg C).

  A turbine with a cold rotor metal temperature requires a long, gradual run up process to limit the stress in the large metal forging that is the rotor (i.e. rotor with hot surface temperature but cold centre has high stress). A hot start however can be much quicker as the rotor is more evenly warm. A warm start fits somewhere between the two.

  Each start type has its own requirements for steam temperature and pressure from the boiler to start the turbine run up.

  - Cold starts require a steam temperature of 400 deg C ±20.
  - Warm starts require a steam temperature of 430 deg C ±20.
  - Hot starts require a steam temperature of 460 deg C ±20.

  Deviate too far from these target temperatures and damage can be done to the turbine, resulting in a reduced lifetime. Also a penalty will be incurred on your final score.

  - Cold starts require a steam pressure of 90 bar.
  - Warm starts require a steam pressure of 110 bar.
  - Hot starts require a steam pressure of 120 bar.

  Boiler steam outlet pressure is automatically controlled by the turbine bypass valve during startup conditions so you will not be required to match this manually. Also you will not be penalised if it is outside the range.

  When attempting to attain the required main steam temperature on a Warm or Hot startup, remember that the maximum steam outlet temperature attainably with fuel oil is only approx. 400 deg C, whilst a coal flame burns much hotter. Select your fuel usage and percentage fuel oil and/or coal flow to reflect the steam temperature you require (e.g. more coal feeder speed and less fuel oil control valve opening leads to higher flame temperature and therefore higher main steam temperature).

  After a normal shutdown or the turbine has tripped you will initially have a very hot rotor metal temperature. The turbine turning gear must remain in operation as the rotor cools to ensure it is cooling evenly. If you restart the turbine directly then the rotor temperature will still be in the Hot start region. After a few hours (in the real world) the temperature will drop down and any attempted starts will be in the

Warm start region. Eventually the rotor temperature will drop below 250 deg C and the start up will be considered to be in the Cold start region.

When the rotor metal temperature drops below 120 deg C then it is considered safe to turn off the turbine turning gear, jacking oil and lube oil systems.

4.2.1 Furnace purge

Before fuel oil can be started it is a requirement to purge the furnace. This means running the furnace fans at a certain load for a set time to ensure the furnace does not have any potentially flammable/explosive gases left over from the previous shutdown and/or trip.

This requirement is specified in NFPA 85 2001 edition section 2.5.2.4.1 Prefiring Cycle item (9) The purge shall be at least eight air changes. Airflow during the period of opening the damper and returning it to light-off position shall be permitted to be included in computing the time for eight air changes.

For this particular boiler a purge at 40% air flow for 20 seconds is all that is required. It is not possible to start any fuel oil or coal burners until the furnace has been successfully purged.

Requirements to Purge the furnace;

- Boiler steam drum level is not in alarm.
- Fuel oil supply pressure is good.
- Furnace air flow rate is good.

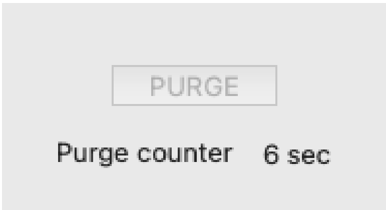


Figure 14: Furnace purge in progress with 6 seconds remaining.

Once the furnace purge timer reaches zero seconds remaining, the following will occur;

- Boiler MFT will RESET.
- Fuel Oil burner isolation/trip valve (1EGD20AA101) will OPEN.
- It will now be possible to start the boiler Fuel oil burner (1HHA10AV001).

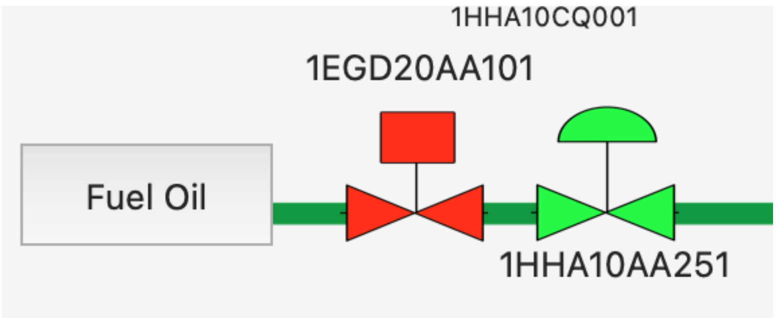


Figure 15: Fuel Oil burner isolation/trip valve (1EGD20AA101) after Purge completed.

4.2.2 Reset Turbine TRIP

The turbine trip signal is active until all the systems/equipment have been started to allow the turbine to be run-up and operated in a safe manner. When all the requirements on the list below are satisfied, the turbine RESET button can be pressed and the turbine will then automatically run-up to 3000rpm, synchronise and increase load to minimum (approx. 15MW).

Requirements to Reset Turbine trip;

- CW pump on.
- Control Oil pump on.
- Boiler MFT is false.
- Main steam temperature before turbine (1LBA60CT001) is ±20 deg C from target start temperature (Cold = 400, Warm = 430, Hot = 460 deg C).
- Main steam flow (1LBA50CF001) >15 kg/s
- DC lube oil pump selected to AUTO run.
- Turbine turning gear engaged.

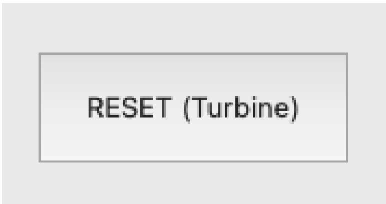


Figure 16: Ready to RESET turbine trip and run-up the turbine.

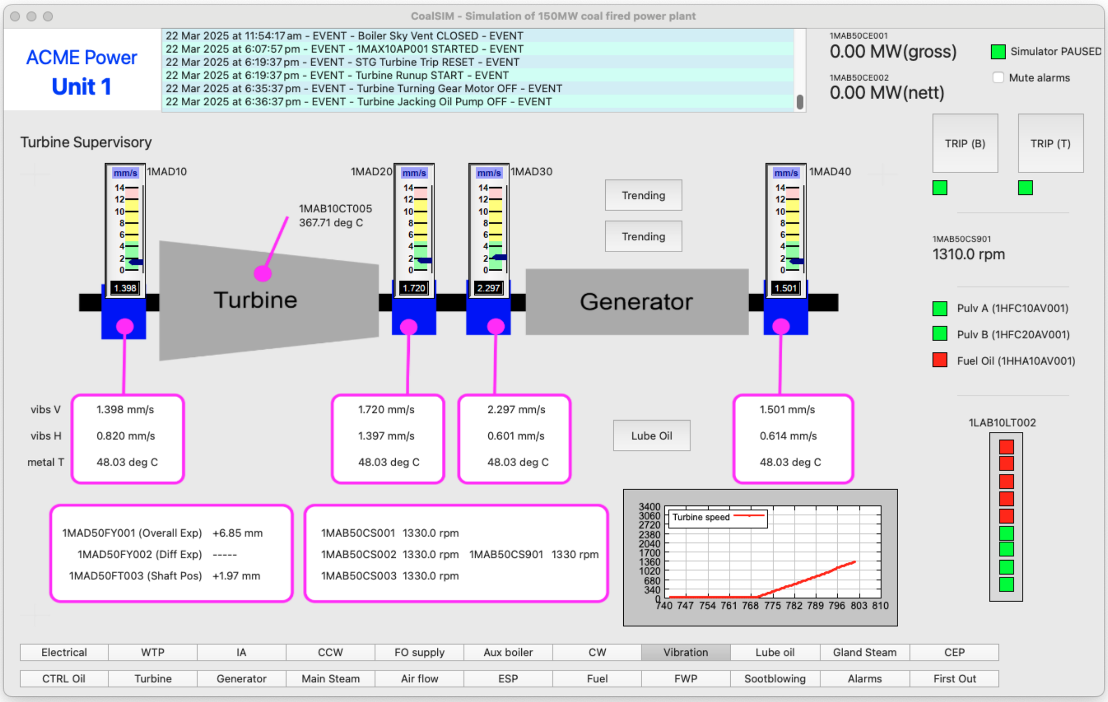


Figure 17: Turbine in the process of run up to 3000 rpm.

4.2.3 Turbine trip

When a turbine trip occurs, the following action will be taken automatically by the boiler/turbine control system;

- Control oil trip valves (1MAX50AA001/002/003) will open and reduce the hydraulic oil pressure in the control oil system.
- Turbine ESV valve (1MAB10AA001) will CLOSE.
- Turbine CV (1MAB10AA002) will CLOSE.
- Generator circuit breaker (1MKA10GS001) will OPEN and electricity generation will stop.
- Turbine bypass valve (1MAN20AA251) will OPEN.
- Turbine speed (1MAB50CS901) will reduce to zero and then turning gear motor will engage and boost speed back to 30rpm for cooling of turbine.
- If two coal pulveriser are in service then;
  - Coal pulveriser B (1HFC20AV001) will TRIP.
  - Coal pulveriser A (1HFC10AV001) will runback in speed to 50%.
- If only a single pulveriser is in service then;
  - Coal pulveriser in service (1HFC10AV001 or 1HFC20AV001) will runback in speed to 50%.

The cause of the turbine trip (or any unit/plant trip) can be found on the First Out screen, as shown below. Note: Whilst the First Out screen is always a good place to start to look for the cause of trip it does not provide the whole answer. For example if the cause of trip shown is "Boiler Air Flow LOW" we just know that the air flow was less than 20% for some reason. However by looking at the Alarm page we can see before the alarm for air flow low we have an additional alarm for ID Fan TRIP. So the cause is the ID Fan trip, but the First Out screen just reports it as low air flow.

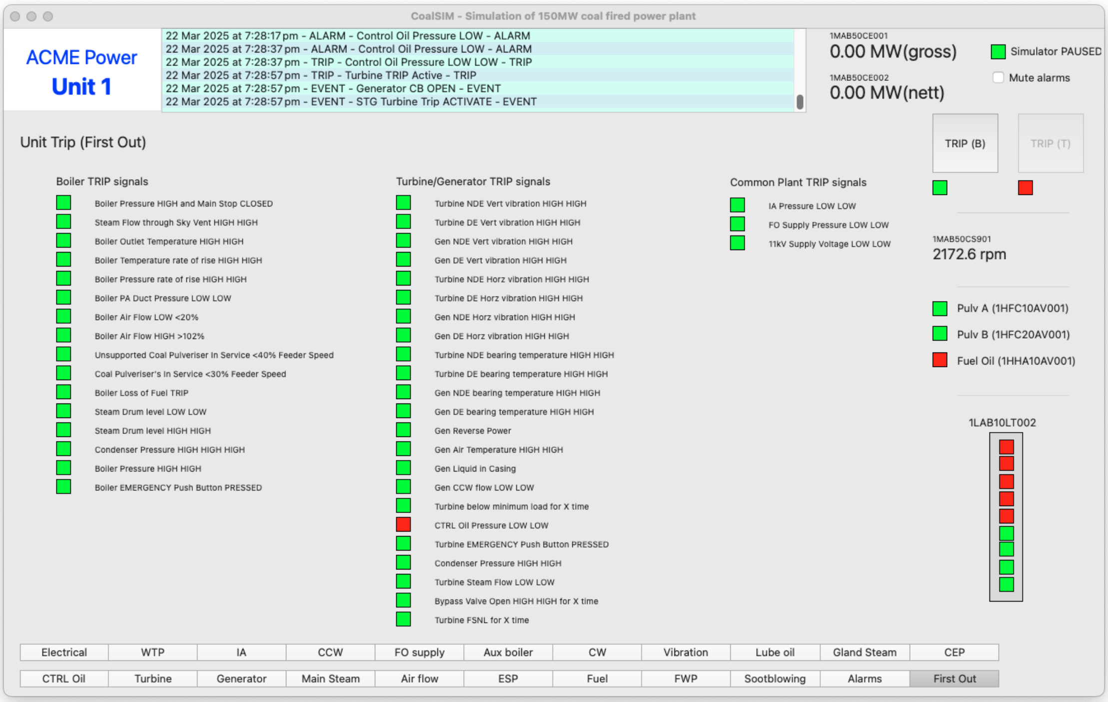


Figure 18: First Out screen showing a Turbine TRIP.

The following alarms will cause a Turbine TRIP;

10001 Turbine NDE Vert vibration HIGH HIGH

10002 Turbine DE Vert vibration HIGH HIGH

10003 Gen NDE Vert vibration HIGH HIGH

10004 Gen DE Vert vibration HIGH HIGH

10005 Turbine NDE Horz vibration HIGH HIGH

10006 Turbine DE Horz vibration HIGH HIGH

10007 Gen NDE Horz vibration HIGH HIGH

10008 Gen DE Horz vibration HIGH HIGH

10009 Turbine NDE bearing temperature HIGH HIGH

10010 Turbine DE bearing temperature HIGH HIGH

10011 Gen NDE bearing temperature HIGH HIGH

10012 Gen DE bearing temperature HIGH HIGH

10013 Condenser Pressure HIGH HIGH

10014 Turbine Steam Flow LOW LOW

10015 Turbine at FSNL for X time

10016 Control Oil Pressure LOW LOW

10017 Reverse Power

10018 Turbine trip as below minimum load for X time

10019 bypass valve opening HIGH HIGH

10021 Turbine Emergency Push Button

10022 Generator warm air temperature HIGH HIGH

10023 Generator liquid in casing alarm

10024 Generator CCW flow LOW LOW

4.2.4 Boiler run-back

Any of the above Turbine trips will also in addition to tripping the turbine, result in a runback of the boiler. This is required as the bypass valve (1MAN20AA251) is only rated for 50% of full load steam flow.

If 2 Coal pulveriser are in service then the runback will be undertaken by;

- Tripping Coal pulveriser B
- Reducing Coal pulveriser A feeder speed to 50%

If only 1 Coal pulveriser is in service then the runback will be undertaken by;

- Reducing the running Coal pulveriser feeder speed to 50%

4.2.5 Recovering from a Turbine trip

Once the turbine has tripped its speed will drop and run down to near zero rpm. During this time the cause of the trip should be investigated and any issues found corrected.

Additionally fuel (both fuel oil and coal) should be adjusted to reduce turbine bypass valve opening and lower cooling water delta T (1PAC40CT901) below alarm values.

Once the turbine turning gear has engaged and the speed has returned to 30 rpm adjustment of burner tilt position (1HFD10GF001a) and selection of burners in service should be undertaken so as to attain the desired main steam temperatures for what should be a Hot start of the turbine.

When steam temperature is sufficient the Turbine Trip signal can be RESET and the turbine will run up to 3000 rpm and synchronise (The Hot start procedure on page 70 from step 20 can be used as a guide for this turbine restart).

4.2.6 Boiler trip

A boiler trip or MFT (Main Fuel Trip) can be either of the SOFT or HARD type. SOFT type results in the extinguishing of the flame in the furnace (all burners OFF), however the boiler fans will continue to run. A furnace purge will be required before restarting the firing.

A HARD type will also extinguish the flame in the furnace, but also trip the PA, ID and FD fans. To restart firing the fans must be restarted and the furnace purged.

Both the HARD and the SOFT type will also send a signal to the turbine control system to cause a Turbine TRIP.

The types of boiler trips that will cause a HARD type trip are;

20001 Boiler Pressure HIGH and Main Stop CLOSED

20002 Steam Flow through Sky Vent HIGH HIGH

20007 Boiler Air Flow low <20%

20008 Boiler Air Flow HIGH >102%

20021 boiler push button pressed

20015 Coal Pulveriser's In Service <30% Feeder Speed

The types of boiler trips that will cause a SOFT type trip are;

20003 Boiler Outlet Temperature HIGH HIGH

20004 Boiler Temperature rate of rise HIGH HIGH

20005 Boiler Pressure rate of rise HIGH HIGH

20006 Boiler PA Duct Pressure LOW LOW

20009 Unsupported Coal Pulveriser In Service <40% Feeder Speed

20010 Boiler Loss of Fuel TRIP

20011 Steam Drum level LOW LOW

20012 Steam Drum level HIGH HIGH

20013 Condenser Pressure HIGH HIGH HIGH - boiler trip and bypass

20014 Boiler pressure HIGH HIGH

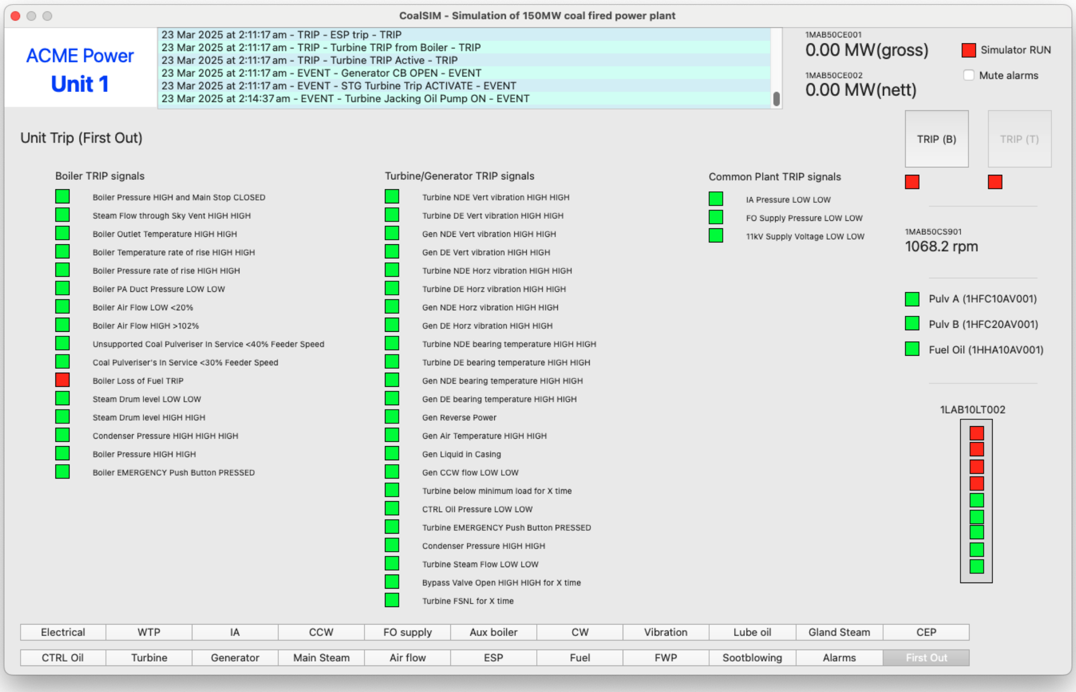


Figure 19: First Out screen showing a Boiler TRIP.

4.2.7 Plant trip

A number of system are implemented at ACME power that service the entire plant, not just Unit 1. We have a common Instrument air supply system, a common main fuel oil tank and distribution pump and a common electrical system.

If any of the following alarms are received, whilst they may not directly cause a boiler or turbine trip, they will still result in a unit trip (e.g. 11kV board voltage LOW - will cause all fan motors to stop);

30001 IA Pressure LOW LOW

30002 FO Supply Pressure LOW LOW

30003 11kV board Voltage LOW

4.2.8 Alarms and Events

Whenever an item of plant is started and/or stopped an event is raised. A list of these events can be seen on the Alarm and Event page.

In addition to the events, alarms can also be generated whenever a system parameter is outside the normal operating range. All these alarms and events can be listed together or separately using the radio buttons below the main list.

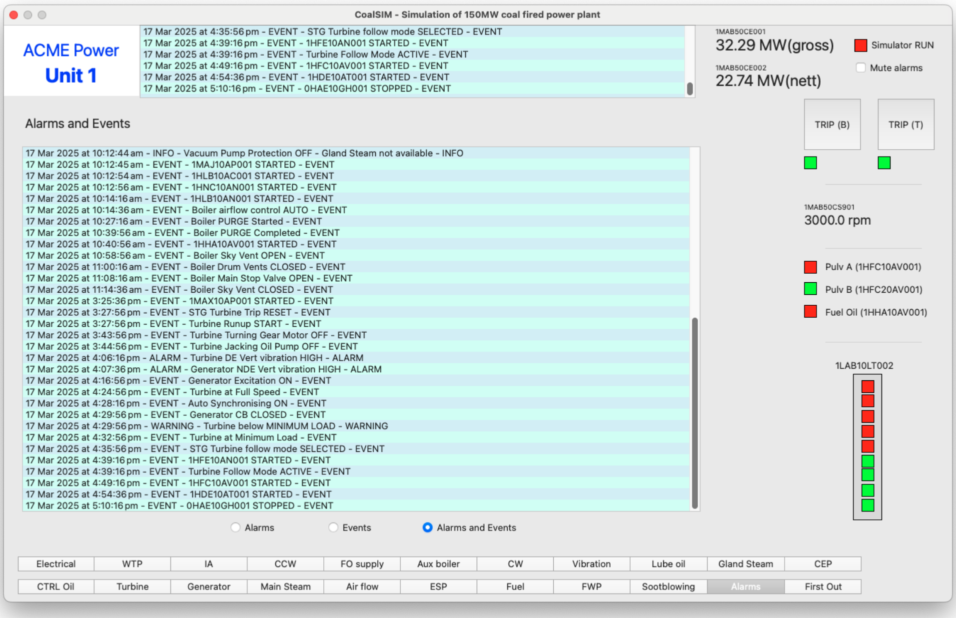


Figure 20: Alarms and Events shown together.

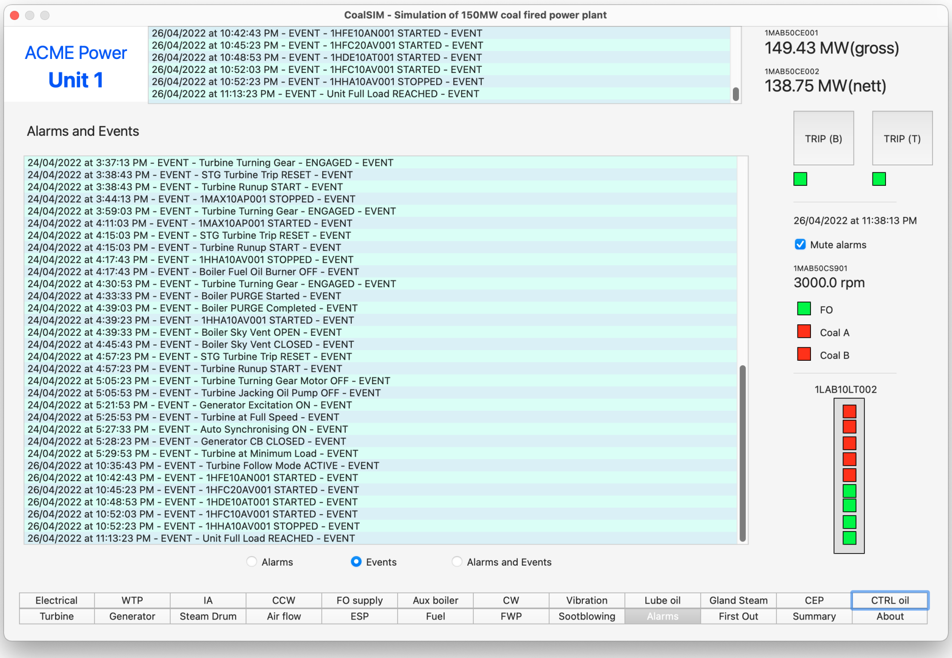


Figure 21: Events only shown.

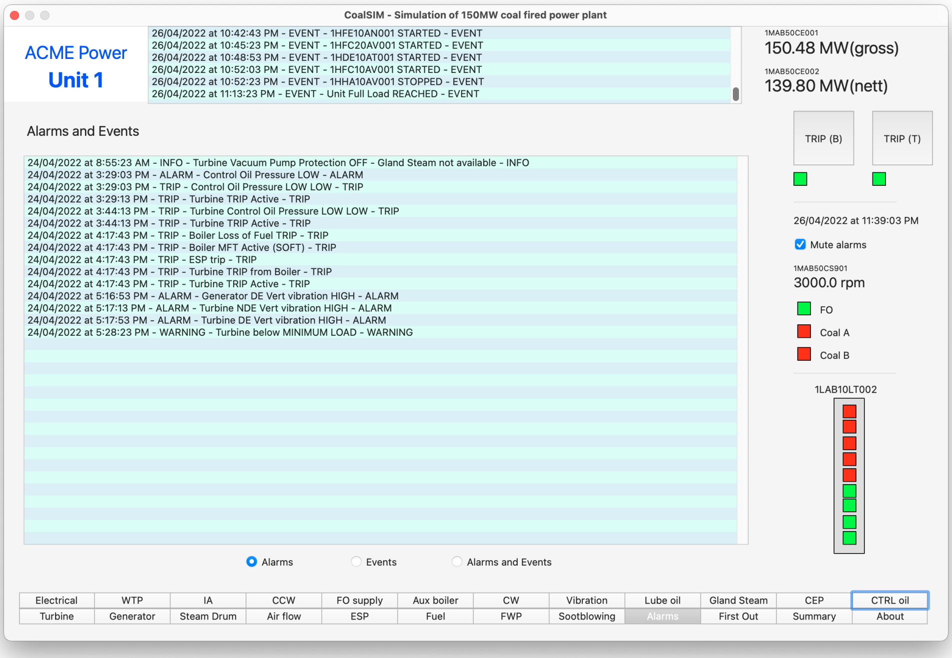


Figure 22: Alarms only shown.

4.3 Cold Start

A cold start is defined as one in which the turbine rotor metal temperature (1MAB10CT005) is <250deg C.

The main outline of a cold start is as follows;

- Start the plant auxiliary systems.
- Put the turbine on turning gear.
- Fill the deaerator and steam drum with water.
- Start the gland steam system and pull a vacuum in the condenser.
- Start boiler fans and purge the boiler.
- Light off the fuel oil burner.
- Increase boiler steam temperature, pressure and flow until matching the steam turbine requirements.
- Run up the steam turbine to 3000 rpm.
- Synchronise the generator.
- Select Turbine follow mode.
- Start coal pulverisers to increase unit load.

A step by step procedure so as to accomplish a cold start is below and this should be followed as closely as possible to achieve the best possible score.

1. CLOSE circuit breaker 1ADA10GS001 to backfeed power to 11kV electrical board 1BBA10 (0AEA10GH001 ON).
2. CLOSE circuit breaker 1BFB10GS023 to supply power to Water Treatment Demin Plant. Plant will auto start and produce demineralised water (0GCF10GH001 ON).
3. START demin forwarding pump 0GCF10AP001.
4. START closed cooling water (CCW) system (1PGA10AP001 ON). Note: this will start the demin circulating pump (1PGA10AP001), start the first of 24 cooling fans (1PGA10AN001), place the cooling fan start/stop control to automatic and place the CCW system filling valve (1GHC10AA201) to automatic.
5. START plant instrument air system (0SCA10AN001 ON). Note: this will take a few seconds to reach normal IA system pressure.
6. START plant fuel oil supply system (0EGC10AP001 ON). Note: this will start the fuel oil forwarding pump (0EGC10AP001) and once discharge pressure has reached a certain valve select pressure control valve (0EGC10AA251) to automatic control.
7. START the auxiliary boiler (0QHA10GH001 ON). Note: this will start the auxiliary boiler forced draught fan (0HAE10AN001), open fuel valve (0EGD65AA251) and ignite the burner. Once boiler pressure is sufficient the boiler main stop valve (0LBG10AA001) will open.
8. START turbine lube oil and place turning gear in operation;
   (a) START turbine lube oil pump (1MAV10AP001 ON)
   (b) START turbine jacking oil pump (1MAV20AP001 ON)
   (c) START turbine turning gear (1MAK10AE001 ON). Note: turning gear motor will engage to turbine shaft and increase turbine rotor to approx. 30 rpm
9. START condensate extraction system;
   (a) START condensate extraction pump (1LCB10AP001 ON). Note: pump (1LCB10AP001) will start and minimum flow valve (1LCB12AA001) will open to ensure an adequate flow through the pump to prevent damage.

   (b) SELECT condensate extraction pump controller to AUTO (LCB (CEP-AUTO)). Note: this will fill deaerator (1LAA10BB001) to a level of approx. 2100mm. The flow control valve (1LCA10AA251) will operate on auto to control this level. The hotwell filling valve (1GHC10AA301) will also operate in auto to ensure adequate water level in condenser hotwell.

10. START feedwater system;

    (a) START feedwater pump (1LAC10AP001 ON). Note: pump (1LAC10AP001) will start and minimum flow valve (1LAC12AA001) will open to ensure an adequate flow through the pump to prevent damage.

    (b) SELECT feedwater pump controller to AUTO (LAC (FWP-AUTO)). Note: this will fill steam drum (1HAE10BB001) to its normal working 0mm. The flow control valve (1LAB10AA251) will operate on auto to control this level.

11. START condenser cooling water pump (1PAB10AP001 ON).

12. START gland steam system;

    (a) SELECT gland steam CONTROL VALVE (1MAW10AA251) to AUTO. Note: if steam supply from either auxiliary boiler (0LBH10AA001) or boiler main steam (1LBA50AA001) is available then gland steam supply valve (1MAW10AA251) will change to auto control and increase the gland steam pressure (1MAW20CP001) up to its setpoint of approx. 350 mbar. Gland steam exhauster fan (1MAW10AN001) will also start at this time.

13. START condenser vacuum pump (1MAJ10AP001 ON). Note: this will cause the condenser vacuum breaker valve (1MAG10AA401) to close and slowly reduce condenser pressure down to it normal operating pressure. Approx. 50 mbar.

14. START furnace fans;

    (a) START air heater (1HLD10AC001 ON). Air heater speed should be around 3 rpm.
    (b) START induced draught fan (1HNC10AN001 ON).
    (c) START forced draught fan (1HLB10AN001 ON).
    (d) SELECT forced draught fan controller to AUTO. Note: this will cause ID and FD fans to increase in load until boiler airflow is around 30%.

15. PURGE the furnace (PURGE button). Note: this will cause the ID and FD fans to increase in load to >40% and start the purge counter. Once the purge counter has reached zero the furnace fan loading will return to previous values. At the end of furnace purge (20 seconds with boiler airflow >40%) the boiler TRIP signal is reset.

16. START fuel oil burner (1HHA10AV001 ON). Note: once fuel oil burner flame is lit, the burner can be controlled by adjusting the controller (1HHA10CQ001). Increase this controller slowly to raise boiler pressure and temperature, however be mindful of boiler limits on rate of increase for these values.

17. As boiler steam pressure and temperature rise the following will occur in succession;

    (a) steam drum vent valve (1HAE15AA001) will CLOSE when pressure >1.5 bar.
    (b) boiler startup vent valve (skyvent 1LBH10AA151) will OPEN when boiler pressure >2 bar to ensure adequate steam flow through boiler superheater section to prevent overheating.
    (c) boiler main stop valve (1LBH20AA101) will OPEN to pressurise the steam legs. Note: this will be prevented if condenser vacuum is too high.
    (d) steam leg drain valve (1LBA50AA501) will OPEN to drain any accumulated water in these pipes.
    (e) turbine bypass valve (1MAN20AA251) will OPEN and control in automatic to keep boiler pressure at approx. 90 bar. Boiler start up vent valve (skyvent 1LBH10AA151) will CLOSE.
    (f) at a steam leg pressure of >10 bar the steam leg drain valve (1LBA50AA501) will CLOSE.
    (g) at a steam leg pressure of >20 bar the steam supply valve to gland steam (1LBA50AA001) will OPEN.

18. Once gland steam in available from main steam (1LBA50AA001), the auxiliary boiler can be shut down (0QHA10GH001 OFF).

19. When the following turbine steam inlet condition are met the turbine can be started;

(a) main steam temperature (1LBA60CT001) 400±20 deg C.
(b) main steam pressure (1LBA60CP001) 90±10 bar.
(c) main steam flow rate (1LBA50CF001) >15 kg/s. Note: if steam flow rate is too low, increase fuel oil burner controller (1HHA10CQ001) slowly to 100%.

20. START turbine control oil pump (1MAX10AP001 ON).

21. RESET turbine trip. Note: turbine ESV valve (1MAB10AA001) will open to 100% and CV valve (1MAB10AA002) will open sufficient to accelerate turbine rotor to 3000rpm.

22. As the turbine rotor speed increases the following will occur in succession;

    (a) turbine turning gear will disengage as turbine rotor speed increases above 34 rpm.
    (b) turbine turning gear motor will STOP when rotor speed is >990 rpm.
    (c) turbine jacking oil pump (1MAV20AP001) will STOP when rotor speed is >1080rpm.
    (d) turbine rotor will travel through its critical speed around 2600 rpm. Pay close attention to rotor vibrations during this time.
    (e) generator excitation will auto ON at a turbine speed >2940 rpm.
    (f) turbine rotor will reach and stabilise at 3000 rpm.
    (g) generator Auto Synchronising will ON after a short time delay.
    (h) once generator synchronising circuit breaker (1MKA10GS001) has closed, turbine CV valve (1MAB10AA002) will open sufficiently to load turbine to minimum continuous load of approx. 15 MW (gross).

23. SELECT Turbine CTRL mode to "Turbine MW AUTO". Note: turbine bypass valve (1MAN20AA251) will drive close which will cause turbine CV (1MAB10AA002) to open slightly and turbine MW (1MAB50CE001) to increase. Once turbine bypass valve (1MAN20AA251) is fully CLOSED steam turbine will be in TURBINE FOLLOW mode (this means any change in boiler fuel flow will directly result in a change in turbine output).

24. START primary air fan (1HFE10AN001 ON). Note: starting of primary air fan (1HFE10AN001) is only possible once furnabce backpass temperature (1HNA50CT001) is >250 deg C. Once primary air duct pressure (1HFE20CP001) is >150 mbar it will be possible to start a coal pulveriser.

25. START coal pulveriser B (1HFC20AV001 ON). Note: pulveriser B coal flow controller (1HFB20CQ001) will automatically go to 16 t/hour coal flow.

26. START electrostatic precipitator (1HDE10AT001 ON). Note: ESP will not start if fuel oil flow is >20%. Reduce fuel oil firing if necessary.

27. INCREASE pulveriser B coal flow controller (1HFB20CQ001) to 20 t/hr.

28. START coal pulveriser A (1HFC10AV001 ON). Note: pulveriser A coal flow controller (1HFB10CQ001) will automatically go to 16 t/hour coal flow.

29. STOP fuel oil burner (1HHA10AV001 OFF).

30. INCREASE pulveriser A and pulveriser B coal flow controller (1HFB10CQ001 and 1HFB20CQ001) to 40 t/hr each. This should be done slowly whilst being mindful of boiler limits on rate of increase for pressure and temperature.

31. ADJUST furnace burner tilt angle (1HFD10GF001a) to ensure superheater outlet temperature (1LBA30CT001) does not exceed design values (design = 540 deg C; alarm = 545 deg C; trip = 555 deg C).

32. STOP plant fuel oil supply system (0EGC10AP001 OFF).

33. Increase boiler fuel firing until unit full load (approx. 150 MW gross) is reached.

4.4 Shutdown (normal)

1. REDUCE pulveriser A and pulveriser B coal flow controller (1HFB10CQ001 and 1HFB20CQ001) to 20 t/hr each. This should be done slowly whilst observing the generator MW output (1MAB50CE001).
2. START plant fuel oil supply system (0EGC10AP001 ON). Note: this will start the fuel oil forwarding pump (0EGC10AP001) and once discharge pressure has reached a certain valve select pressure control valve (0EGC10AA251) to automatic control.
3. START fuel oil burner (1HHA10AV001 ON). Note: once fuel oil burner flame is lit, the burner can be controlled by adjusting the controller (1HHA10CQ001). For now leave controller at 10%.
4. REDUCE pulveriser A coal flow controller (1HFB10CQ001) to 10 t/hr.
5. STOP pulveriser A (1HFC10AV001 OFF).
6. REDUCE pulveriser B coal flow controller (1HFB20CQ001) to 10 t/hr.
7. STOP pulveriser B (1HFC20AV001 OFF).
8. STOP electrostatic precipitator (1HDE10AT001 OFF)
9. MONITOR generator MW output (1MAB50CE001) as it reduces.
10. MONITOR when MW output (1AMB50CE001) is below zero the turbine will TRIP on REVERSE POWER (code - 10017).
11. As the turbine rotor speed decreases the following will occur in succession;
    (a) turbine jacking oil pump (1MAV20AP001) will START when rotor speed is <1500 rpm.
    (b) turbine turning gear motor will START when rotor speed is <500 rpm.
    (c) turbine turning gear will ENGAGE as turbine rotor speed is <2 rpm.
12. STOP fuel oil burner (1HHA10AV001 OFF). Note: this will result in a boiler TRIP.
13. RESET generator circuit breaker (1MKA10GS001) reverse power relay.
14. If immediate restart is not planned then continue;
    (a) STOP condenser vacuum pump (1MAJ10AP001 OFF). Note: this will stop the condenser vacuum pump (1MAJ10AP001) and open the condenser vacuum breaker valve (1MAG10AA401) and vacuum will quickly dissipate.
    (b) STOP gland steam system (1MAW10GH001 OFF). Note: gland steam control valve (1MAW10AA251) will CLOSE and gland steam exhauster fan (1MAW10AN001) will STOP. Gland steam pressure (1MAW20CP001) will reduce slowly to 0 mbar.
    (c) SELECT furnace air flow controller (AirFlow (AUTO)) to manual. Note: this will cause ID and FD fans to decrease in load until boiler airflow is 0%.
    (d) STOP forced draught fan (1HLB10AN001 OFF).
    (e) STOP induced draught fan (1HNC10AN001 OFF).
    (f) STOP plant fuel oil supply system (0EGC10AP001 OFF).
    (g) STOP turbine control oil pump (1MAX10AP001 OFF).
    (h) STOP condenser cooling water pump (1PAB10AP001 OFF).
    (i) SELECT steam drum filing to manual (LAC (FWP-AUTO)).
    (j) STOP feedwater pump (1LAC10AP001 OFF).
    (k) SELECT deaerator filling to manual (LCB (CEP-AUTO)).
    (l) STOP condensate extraction pump (1LCB10AP001 OFF).
15. If however you plan to restart the turbine immediately or after a short time period please go directly to the Warm or Hot start procedure.
16. If turbine rotor metal temperature (1MAB50CT005) is <120 deg C;
    (a) STOP turbine turning gear (1MAK10AE001 OFF).

(b) STOP turbine jacking oil pump (1MAV20AP001 OFF). Note: turbine speed must be <2 rpm.

(c) STOP turbine lube oil pump (1MAV10AP001 OFF).

17. If Boiler back pass temperature (1HNA50CT001)) is <120 deg C;

    (a) STOP rotary airheater (1HLD10AC001).

4.5 Warm Start

A warm start is defined as one in which the turbine rotor metal temperature (1MAB10CT005) is >250deg C and <450 deg C.

The main differences compared to a cold start are;

- Auxiliary plant is already running.
- Need a higher steam temperature, pressure and flow from the boiler to match the steam turbine requirements.

A step by step procedure so as to accomplish a warm start is below and this should be followed as closely as possible to achieve the best possible score.

1. CHECK circuit breaker 1ADA10GS001 to backfeed power to 11kV electrical board 1BBA10 (0AEA10GH001 ON).
2. CHECK plant fuel oil supply system (0EGC10AP001 ON).
3. CHECK gland steam supply is available. If not then START the auxiliary boiler (0QHA10GH001 ON).
4. CHECK turbine lube oil pump (1MAV10AP001 ON).
5. CHECK turbine jacking oil pump (1MAV20AP001 ON).
6. CHECK turbine turning gear (1MAK10AE001 ON).
7. CHECK condensate extraction pump (1LCB10AP001 ON).
8. CHECK condensate extraction pump controller in AUTO (LCB (CEP-AUTO)).
9. CHECK feedwater pump (1LAC10AP001 ON).
10. CHECK feedwater pump controller in AUTO (LAC (FWP-AUTO)).
11. CHECK condenser cooling water pump (1PAB10AP001 ON).
12. CHECK gland steam system (1MAW10GH001 ON).
13. CHECK condenser vacuum pump (1MAJ10AP001 ON).
14. START furnace fans;
    (a) CHECK air heater (1HLD10AC001 ON). Air heater speed should be around 3 rpm.
    (b) START induced draught fan (1HNC10AN001 ON).
    (c) START forced draught fan (1HLB10AN001 ON).
    (d) SELECT furnace air flow controller (AirFlow (AUTO)) to automatic.
15. PURGE the furnace (PURGE button).
16. START fuel oil burner (1HHA10AV001 ON).
17. INCREASE fuel oil burner controller (1HHA10CQ001) to 100%.
18. ADJUST furnace burner tilt angle (1HFD10GF001a) to ensure superheater outlet temperature (1LBA30CT001) is 430 deg C $\pm$20.
19. CHECK turbine bypass valve (1MAN20AA251) will OPEN after a short period.
20. When the following turbine steam inlet condition are met the turbine can be started;
    (a) main steam temperature (1LBA60CT001) 430$\pm$20 deg C.
    (b) main steam pressure (1LBA60CP001) 110$\pm$10 bar.
    (c) main steam flow rate (1LBA50CF001) $\approx$25 kg/s.
21. CHECK turbine control oil pump (1MAX10AP001 ON).
22. RESET turbine trip.

23. CHECK generator synchronising circuit breaker (1MKA10GS001) has closed.
24. CHECK turbine load increases to minimum continuous load of approx. 15 MW (gross).
25. SELECT Turbine CTRL mode to "Turbine MW AUTO".
26. START primary air fan (1HFE10AN001 ON).
27. START coal pulveriser B (1HFC20AV001 ON).
28. START electrostatic precipitator (1HDE10AT001 ON).
29. INCREASE pulveriser B coal flow controller (1HFB20CQ001) to 20 t/hr.
30. START coal pulveriser A (1HFC10AV001 ON).
31. STOP fuel oil burner (1HHA10AV001 OFF).
32. INCREASE pulveriser A and pulveriser B coal flow controller (1HFB10CQ001 and 1HFB20CQ001) to 40 t/hr each. This should be done slowly whilst being mindful of boiler limits on rate of increase for pressure and temperature.
33. ADJUST furnace burner tilt angle (1HFD10GF001a) to ensure superheater outlet temperature (1LBA30CT001) does not exceed design values (design = 540 deg C; alarm = 545 deg C; trip = 555 deg C).
34. STOP plant fuel oil supply system (0EGC10AP001 OFF).
35. Increase boiler fuel firing until unit full load (approx. 150 MW gross) is reached.

4.6 Hot Start

A hot start is defined as one in which the turbine rotor metal temperature (1MAB10CT005) is >450deg C.

The main differences compared to a warm start are;

- Need evener higher steam temperature, pressure and flow from the boiler to match the steam turbine requirements.
- You may require to start a coal pulveriser before running up the steam turbine to achieve these temperature requirements.

A step by step procedure so as to accomplish a hot start is below and this should be followed as closely as possible to achieve the best possible score.

1. CHECK circuit breaker 1ADA10GS001 to backfeed power to 11kV electrical board 1BBA10 (0AEA10GH001 ON).
2. CHECK plant fuel oil supply system (0EGC10AP001 ON).
3. CHECK gland steam supply is available. If not then START the auxiliary boiler (0QHA10GH001 ON).
4. CHECK turbine lube oil pump (1MAV10AP001 ON).
5. CHECK turbine jacking oil pump (1MAV20AP001 ON).
6. CHECK turbine turning gear (1MAK10AE001 ON).
7. CHECK condensate extraction pump (1LCB10AP001 ON).
8. CHECK condensate extraction pump controller in AUTO (LCB (CEP-AUTO)).
9. CHECK feedwater pump (1LAC10AP001 ON).
10. CHECK feedwater pump controller in AUTO (LAC (FWP-AUTO)).
11. CHECK condenser cooling water pump (1PAB10AP001 ON).
12. CHECK gland steam system (1MAW10GH001 ON).
13. CHECK condenser vacuum pump (1MAJ10AP001 ON).
14. START furnace fans;
    (a) CHECK air heater (1HLD10AC001 ON). Air heater speed should be around 3 rpm.
    (b) START induced draught fan (1HNC10AN001 ON).
    (c) START forced draught fan (1HLB10AN001 ON).
    (d) SELECT furnace air flow controller (AirFlow (AUTO)) to automatic.
15. PURGE the furnace (PURGE button).
16. START fuel oil burner (1HHA10AV001 ON).
17. START primary air fan (1HFE10AN001 ON).
18. START coal pulveriser B (1HFC20AV001 ON).
19. START electrostatic precipitator (1HDE10AT001 ON).
20. ADJUST furnace burner tilt angle (1HFD10GF001a) to ensure superheater outlet temperature (1LBA30CT001) is 460 deg C $\pm$20.
21. CHECK turbine bypass valve (1MAN20AA251) will OPEN after a short period.
22. When the following turbine steam inlet condition are met the turbine can be started;
    (a) main steam temperature (1LBA60CT001) 460$\pm$20 deg C.
    (b) main steam pressure (1LBA60CP001) 120$\pm$10 bar.
    (c) main steam flow rate (1LBA50CF001) $\approx$25 kg/s.

23. CHECK turbine control oil pump (1MAX10AP001 ON).
24. RESET turbine trip.
25. CHECK generator synchronising circuit breaker (1MKA10GS001) has closed.
26. CHECK turbine load increases to minimum continuous load of approx. 15 MW (gross).
27. SELECT Turbine CTRL mode to "Turbine MW AUTO".
28. INCREASE pulveriser B coal flow controller (1HFB20CQ001) to 20 t/hr.
29. START coal pulveriser A (1HFC10AV001 ON).
30. STOP fuel oil burner (1HHA10AV001 OFF).
31. INCREASE pulveriser A and pulveriser B coal flow controller (1HFB10CQ001 and 1HFB20CQ001) to 40 t/hr each. This should be done slowly whilst being mindful of boiler limits on rate of increase for pressure and temperature.
32. ADJUST furnace burner tilt angle (1HFD10GF001a) to ensure superheater outlet temperature (1LBA30CT001) does not exceed design values (design = 540 deg C; alarm = 545 deg C; trip = 555 deg C).
33. STOP plant fuel oil supply system (0EGC10AP001 OFF).
34. Increase boiler fuel firing until unit full load (approx. 150 MW gross) is reached.

5 Alarms and Trips

The following list all the alarms that will result in either a trip of the turbine, the boiler or both.

5.1 Boiler

- 20001 - Boiler Pressure HIGH and Main Stop CLOSED
- 20002 - Steam Flow through Sky Vent HIGH HIGH
- 20003 - Boiler Outlet Temperature HIGH HIGH
- 20004 - Boiler Temperature rate of rise HIGH HIGH
- 20005 - Boiler Pressure rate of rise HIGH HIGH
- 20006 - Boiler PA Duct Pressure LOW LOW
- 20007 - Boiler Air Flow low <20%
- 20008 - Boiler Air Flow HIGH >102%
- 20009 - Unsupported Coal Pulveriser In Service <40% Feeder Speed
- 20010 - Boiler Loss of Fuel TRIP
- 20011 - Steam Drum level LOW LOW
- 20012 - Steam Drum level HIGH HIGH
- 20013 - Condenser Pressure HIGH HIGH HIGH
- 20014 - Boiler pressure HIGH HIGH
- 20015 - Coal Pulveriser In Service <30% Feeder Speed
- 20021 - Boiler emergency trip push button pressed

5.2 Turbine

- 10001 - Turbine NDE Vert vibration HIGH HIGH
- 10002 - Turbine DE Vert vibration HIGH HIGH
- 10003 - Gen NDE Vert vibration HIGH HIGH
- 10004 - Gen DE Vert vibration HIGH HIGH
- 10005 - Turbine NDE Horz vibration HIGH HIGH
- 10006 - Turbine DE Horz vibration HIGH HIGH
- 10007 - Gen NDE Horz vibration HIGH HIGH
- 10008 - Gen DE Horz vibration HIGH HIGH
- 10009 - Turbine NDE bearing temperature HIGH HIGH
- 10010 - Turbine DE bearing temperature HIGH HIGH
- 10011 - Gen NDE bearing temperature HIGH HIGH
- 10012 - Gen DE bearing temperature HIGH HIGH
- 10013 - Condenser Pressure HIGH HIGH
- 10014 - Turbine Steam Flow LOW LOW
- 10015 - Turbine at FSNL for X time
- 10016 - Control oil pressure LOW LOW

- 10017 - Reverse power
- 10018 - Turbine trip as below minimum load for X time
- 10019 - Bypass valve opening HIGH HIGH
- 10020 - not used
- 10021 - Turbine emergency trip push button
- 10022 - Generator warm air temperature HIGH HIGH
- 10023 - Generator liquid in casing HIGH HIGH
- 10024 - Generator CCW flow LOW LOW

5.3 Auxiliaries

- 30001 - IA Pressure LOW LOW
- 30002 - FO Supply Pressure LOW LOW
- 30003 - 11kV board Voltage low

6 Instructor/Trainer Window Usage

6.1 Sim RUN/PAUSE

This checkbox allows the Trainer/Instructor to RUN or PAUSE the simulator.

6.2 Scenarios

Load Easy Upload the plant initial condition for a COLD START in EASY mode. This means Boiler temperature and pressure rates of change is not limited (no alarms and no boiler trip). Note in easy mode 20% will be deducted from the cold start score, so it will not be possible to achieve a perfect score.

Load Hard Upload the plant initial condition for a COLD START in HARD mode. This means;

- Boiler temperature rate of change is limited. For firing on fuel oil only limits are; alarm=2 deg C/min, trip=2.5 deg C/min. For coal firing these limits increase to; alarm=6 deg C/min, trip=8 deg C/min.
- Boiler pressure rate of change is limited. For firing on fuel oil only limits are; alarm=0.25 bar/min, trip=0.3 bar/min. For coal firing these limits increase to; alarm=0.8 bar/min, trip=0.9 bar/min.

Show Summary This instructs the SUMMARY page to be displayed on the main simulator window. This is only useful once full load from a cold start has been achieved and will provide a breakdown of area for improvement

Figure 23: Not a great score!

6.3 Faults

The following faults or symptoms can be initiated by the Trainer / Instructor to allow various learning points by the operator.

Learning points should be productive and teach proper responses to each and every alarm. Some items to be covered, are;

- Each alarm should be understood. Proper descriptions of alarm meaning by operator and at least the understanding that more complete information can be found in the plant OEM manuals.
- Recording of operations actions and any significant faults within a log book for later review.
- Handover procedure to incoming shift and explanation of faults, etc in a clear and complete way.
- Standard items to check whenever a particular plant event occurs. i.e. Steam turbine trips - do the following (as an example);

  1. CHECK generator circuit breaker is OPEN.
  2. CHECK turbine speed is decreasing.
  3. CHECK turbine bypass valve is OPEN.
  4. CHECK boiler operation continues.
  5. CHECK fuel - has 1 pulveriser tripped. Maybe think about fuel oil support.
  6. CHECK Jacking oil pump starts.
  7. CHECK Turning gear motor starts.
  8. CHECK Turning gear engaged and rotor speed increases to 30rpm.
  9. CHECK all screens for correct operation of plant in bypass operation.
  10. CHECK First out and Alarm/Event page - investigate cause of turbine trip.

  Do not rush in to find the cause of trip without first ensuring the plant is in a safe and stable condition.

  Similar quick Checksheets should be developed for all similar plant occurrences to ensure a standard and safe response by all operational staff.

- CHECK multitasking ability of operation staff and that they do not become overloaded by introducing faults/alarms such as generator closed cooling water leak (to which they must drain the generator casing on a regular schedule), fouling of boiler furnace area (to which they must sootblow the furnace regularly), various random alarms, requested load changes, shut downs, re-starts, fuel runbacks (Pulveriser trips), and ensuring coal bunker levels are always sufficient.
- CHECK understanding of operational staff of plant equipment interlocking. i.e. the reason we need a condenser vacuum before turbine bypass valve can be operated, or why cooling water pump must be in service before operating gland steam, etc.

Ideally a training matrix should be created for each operational staff member, followed by a gap analysis to determine what they each already know and what then needs to be covered in more indepth training.

The following is the current list of faults or symptoms that can be initiated;

IDF UVolt Will initiate a trip of the Induced Draught Fan by electrical undervoltage.

FDF UVolt Will initiate a trip of the Forced Draught Fan by electrical undervoltage.

PAF UVolt Will initiate a trip of the Primary Air Fan by electrical undervoltage.

CEP UVolt Will initiate a trip of the Condensate Extraction Pump by electrical undervoltage.

CEP OverC Will initiate a trip of the Condensate Extraction Pump by electrical overcurrent.

FWP UVolt Will initiate a trip of the Feedwater Pump by electrical undervoltage.

FWP OverC Will initiate a trip of the Feedwater Pump by electrical overcurrent.

CW UVolt Will initiate a trip of the Cooling Water Pump by electrical undervoltage.

PulvA UVolt Will initiate a trip of Pulveriser A by electrical undervoltage.

PulvB Uvolt Will initiate a trip of Pulveriser B by electrical undervoltage.

PulvB windingT Will initiate a trip of Pulveriser B by motor winding temperature HIGH.

ESP off

Foul ON Turn Boiler furnace surface fouling ON. When coal firing fouling of the furnace heat transfer surfaces by the products of combustion takes place. This will cause a reduction in heat transfer within the furnace and an increase of the IDF inlet temperature.

Foul OFF Turn Boiler furnace surface fouling OFF.

Gen casing Simulate a leak of the CCW system within the generator coolers[4].

CTRL O clog ON Turn CTRL oil filter clogging to ON. As filter gets clogged, CTRL oil supply pressure will drop[5].

CTRL O clog OFF Turn CTRL oil filter clogging to OFF.

TG lock Will prevent turbine turning gear to start when turbine speed runs down. Good fault for insuring that this is checked as part of the operators shutdown routine (e.g. CB open, turbine speed reducing, jacking oil on, turning gear on, turning gear engaged, etc)

TG unblock Will unblock operation of the turbine turning gear and allow it to be start.

Unlock AH If boiler trips, including rotary airheater and it is not started again within sufficient time, it will lock in place preventing operation until cool. This command will allow the AH to be unlocked.

Rand HIGH Introduce a high number of random alarms/faults.

Rand MED Introduce a medium number of random alarms/faults.

Rand LOW Introduce a low number of random alarms/faults.

Rand OFF Turn off random alarms/faults.

[4] Generator CCW coolers can leak on occasions, so therefore the casing drain valve (1MKA10AA501) must be used to drain any water before level is high enough to cause a turbine/generator trip.

[5] Control oil filters (1MAX30AT001 and 1MAX31AT001) will become blocked over time and will require cleaning. If the in service filter is dirty (control oil pressure after filter is in alarm) then change to the standby filter.

A List of equipment

Electrical screen;

0ADA00CE003 220kV incomer 1

0ADA00CE005 220kV incomer 2

0ADA00CE001 220kV bus voltage

1BAA10CE001 Generator running Hz

1MKA10CE001 Generator incoming Hz

1BBA10CE001 11kV bus voltage

1BBA10GS001 CEP pump supply

1BBA10GS002 FWP pump supply

1BBA10GS003 ID fan supply

1BBA10GS004 FD fan supply

1BBA10GS005 PA fan supply

1BBA10GS006 Pulv A supply

1BBA10GS007 Pulv B supply

1BBA10GS008 CW pump supply

1MKA10GS001 Generator synchronising CB

1ADA10GS001 11kV board supply CB

1BBT10GT001 220/11kV Unit supply transformer

1BAT10GT001 220/11kV generator transformer

1BFB10GH001 415V unit supply switchboard

1BFT10GT001 11lV/415V unit supply transformer

0BFB10CE001 415V unit supply switchboard voltage.

1BFB10GS023 Water Treatment Plant supply.

Water Treatment Plant screen;

0GCF10BB001 Demin tank

0GCF10LT001 Demin tank level

0GCF10AP001 Demin forwarding pump

0GCF20CP001 Demin pump discharge pressure

Closed Cooling Water screen;

1PGA10AP001 CCW pump

1PGB20CP001 CCW pump discharge pressure

1PGB30LS001 CCW head tank level low

1GHC10AA201 CCW head tank filling valve

1PGB30BB001 CCW head tank

1PGA10AN001 CCW cooling fan

1PGA10AN002 CCW cooling fan

1PGA10AN003 CCW cooling fan

1PGA10AN004 CCW cooling fan

1PGA10AN005 CCW cooling fan

1PGA10AN006 CCW cooling fan

1PGA20AN001 CCW cooling fan

1PGA20AN002 CCW cooling fan

1PGA20AN003 CCW cooling fan

1PGA20AN004 CCW cooling fan

1PGA20AN005 CCW cooling fan

1PGA20AN006 CCW cooling fan

1PGA30AN001 CCW cooling fan

1PGA30AN002 CCW cooling fan

1PGA30AN003 CCW cooling fan

1PGA30AN004 CCW cooling fan

1PGA30AN005 CCW cooling fan

1PGA30AN006 CCW cooling fan

1PGA40AN001 CCW cooling fan

1PGA40AN002 CCW cooling fan

1PGA40AN003 CCW cooling fan

1PGA40AN004 CCW cooling fan

1PGA40AN005 CCW cooling fan

1PGA40AN006 CCW cooling fan

1PGB80AA001 Generator CCW supply valve.

Instrument Air compressor screen;

0SCA10AN001 Air compressor

0SCA30CP001 Compressed air supply pressure

0SCA20BB001 Instrument air receiver

Plant Fuel Oil Supply screen;

0EGB30BB001 FO tank

0EGD30LT001 FO tank level

0EGC10AP001 FO delivery pump

0EGD10CP001 FO delivery pump discharge pressure

0EGD65AA101 FO supply to auxiliary boiler

1EGD20AA101 FO supply to Unit 1

2EGD20AA101 FO supply to Unit 2

3EGD20AA101 FO supply to Unit 3

4EGD20AA101 FO supply to Unit 4

0EGC10AA251 FO pressure control valve

Auxiliary Boiler screen;

0HAE10GH001 Boiler

0HAE10AN001 Boiler forced air fan

0EGD65AA251 FO supply control valve

0LBG10AA001 Auxiliary boiler steam main stop valve

1LBH10AA001 Auxiliary Steam supply to Unit 1

2LBH10AA001 Auxiliary Steam supply to Unit 2

3LBH10AA001 Auxiliary Steam supply to Unit 3

4LBH10AA001 Auxiliary Steam supply to Unit 4

Main Cooling Water screen;

1PAB10AP001 CW pump

1PAC10CT001 CW inlet temperature

1PAC40CT001 CW outlet temperature

1PAC40CT901 CW delta temperature

1MAG10AA401 Vacuum breaker valve

1MAJ10AP001 Vacuum pump

1MAG10CP001 Condenser pressure indication

Condensate Extraction pump screen;

1LCA10BB001 Condenser hotwell

1LCA10LT001 Condenser hotwell level

1GHC10AA301 Condenser filling valve

1LCB10AP001 Condensate Extraction pump

1LCA10CP001 Condensate Extraction pump discharge pressure

1LCB12AA001 Condensate Extraction pump minimum flow valve

1LCA10AA251 DA level control valve

1LCA20CF001 Condensate flow

1LAA10BB001 DA feedwater tank

1LAA10LT001 DA feedwater tank level

TRIP (CEP) TRIP (CEP) button

Boiler Air Flow screen;

1HNA50CT001 Boiler backpass temperature

1HNA10AC001 Air Heater rotation speed

1HNC10AN001 ID fan load

1HLB10AN001 FD fan load

1HFE10AN001 PA fan load

1HFE20CP001 PA duct pressure

1HDE10AT001 ESP ON indication

1HNE10CQ001 Stack opacity measurement

Boiler Fuel Control screen;

1EGD20AA101 FO supply block valve

1HHA10AA251 FO supply control valve

1HHA10CQ001 FO flow control

1HFA10LT001 Bunker A level

1HFA20LT001 Bunker B level

1HFA10BB001 Bunker A

1HFA20BB001 Bunker B

1HFE10AN001 PA fan

1HFC10AV001 Pulv A

1HFC20AV001 Pulv B

1HFB10CQ001 Pulv A speed control

1HFB20CQ001 Pulv B speed control

1HFD10FG001A Burner Tilt control

1HFD10FG001B Burner tilt position

FILL (REQUEST) Request to fill button

Wait Filling (F WAIT) Wait filling indication

TRIP (B) Boiler TRIP button

Turbine system screen;

1LBA60CT001 Turbine inlet steam temperature

1LBA60CP001 Turbine inlet steam pressure

1LBA50CF001 Turbine inlet steam flow

1MAB10AA001 Turbine ESV valve

1MAB10AA002 Turbine CV valve

1MAN20AA251 Turbine bypass valve

1MAB50CS901 Turbine speed

1MAB50CE001 Generator gross power

Turbine Supervisory screen;

1MAD10 Turbine NDE bearing

1MAD20 Turbine DE bearing

1MAD30 Generator DE bearing

1MAD40 Generator NDE bearing

1MAB10CT005 Turbine rotor temperature

1MAD10CY001 Turbine NDE bearing vibrations vertical

1MAD10CY002 Turbine NDE bearing vibrations horizontal

1MAD10CT001 Turbine NDE bearing temperature

1MAD20CY001 Turbine DE bearing vibrations vertical

1MAD20CY002 Turbine DE bearing vibrations horizontal

1MAD20CT001 Turbine DE bearing temperature

1MAD30CY001 Generator DE bearing vibrations vertical

1MAD30CY002 Generator DE bearing vibrations horizontal

1MAD30CT001 Generator DE bearing temperature

1MAD40CY001 Generator NDE bearing vibrations vertical

1MAD40CY002 Generator NDE bearing vibrations horizontal

1MAD40CT001 Generator NDE bearing temperature

1MAD50FY001 Turbine overall expansion

1MAD50FY002 Turbine differential expansion

1MAD50FT003 Turbine shaft position

1MAB50CS001 Turbine speed 1

1MAB50CS002 Turbine speed 2

1MAB50CS003 Turbine speed 3

1MAB50CS901 Turbine speed combined

Turbine Lube Oil systems screen;

1MAV12AP001 DC Lube Oil control

1MAV10BB001 Lube oil tank

1MAV10AP001 Lube oil AC pump

1MAV12AP001 Lube oil DC pump

1MAV15CP001 Lube oil supply pressure

1MAV20AP001 Jacking oil pump

1MAV25CP001 Jacking oil supply pressure

1MAB10HA001 Turbine

1MKA10GS001 Generator

1MAB10CT005 Turbine rotor metal temperature

1MAB50CS901 turbine speed

Turbine Gland Steam screen;

1LBA50AA001 Steam from main steam isolation valve

0LBH10AA001 Steam from Auxiliary boiler isolation valve

GS supply AVAIL Steam available indication

1MAW10AA251 Gland steam pressure control valve

1MAW20CP001 Gland steam pressure

1MAB10CT005 Turbine rotor metal temperature

1MAB10HA001 Turbine

1MAW10AN001 Gland steam exhauster fan

Turbine Control Oil screen;

1MAX10BB001 Control oil tank

1MAX10AP001 Control oil pump

RESET (Turbine) Reset Turbine button

TRIP (T) Turbine TRIP button

1MAX30AT001 Control oil filter A

1MAX31AT001 Control oil filter B

1MAB10AA001 Turbine ESV valve

1MAB10AA002 Turbine CV valve

1MAX50AA001 Trip valve 1

1MAX50AA002 Trip valve 2

1MAX50AA003 Trip valve 3

Boiler Electrostatic Precipitator (ESP) screen;

1HDE10AT001 ESP

1HDE10AT001A Emitting rapping gear

1HDE10AT001B Collecting rapping gear

1HNC10AN001 ID fan

1HNE10CQ001 Stack Opacity indication

Feedwater Pump system screen;

TRIP (FWP) TRIP (FWP) button

1LAA10BB001 Feedwater storage tank

1LAA10LT001 Feedwater storage tank level

1LAC10AP001 Feedwater pump

1LAB10CP001 Feedwater pump discharge pressure

1LAC12AA001 Feedwater pump minimum flow valve

1LAB10AA251 Steam drum level control valve

1LAB20CF001 Feedwater flow

1HAE10BB001 Steam drum

1LAB10LT001 Steam drum level

Boiler Main Steam screen;

1LAB10LT001 Steam drum level

1HAE10CT001 Steam drum water temperature

1HAE15AA001 Steam drum vent valve

1LBH10AA401 Steam drum safety valve

1LBA30CT001 superheater outlet temperature

1LBA30CP001 superheater outlet pressure

1LBH20AA101 boiler main stop valve

1LBH10AA151 boiler startup vent valve (skyvent)

1HCB10AA001 Sootblowing supply isolation valve

1LBA50AA001 Gland steam supply isolation valve

1LBA50CT001 steam leg temperature

1LBA50CP001 steam leg pressure

1LBA50AA501 steam leg drain valve

1LBA60CT001 Turbine inlet steam temperature

1LBA60CP001 Turbine inlet steam pressure

1LBA50CF001 Turbine inlet steam flow

1MAG10CP001 condenser pressure

1MAB10AA001 Turbine emergency stop valve (ESV)

1MAN20AA251 Turbine bypass valve

Generator systems screen;

1MKA10AA501 Casing drain ON control

1PGB80AA001 CCW isolation valve

1PGB80CP001 CCW pressure

1MKY10CT001 Generator cold gas temperature

1MKY10CT002 Generator hot gas temperature

1MKA10AA501 Generator casing drain

1MAB50CS901 Turbine speed

1BAA10CE001 Generator running Hz

1MKA10CE001 Generator incoming Hz

1MKA10GS001 Generator synchronising CB

Furance Sootblowing screen;

1HCB10AA001 Sootblowing steam isolation valve

1HCB10AA101 Sootblowing steam control valve

1HCB10AT001 Sootblower 1

1HCB10AT002 Sootblower 2

1HCB10AT003 Sootblower 3

1HCB20AT001 Sootblower 4

1HCB20AT002 Sootblower 5

1HCB20AT003 Sootblower 6

1HCB30AT001 Sootblower 7

1HCB30AT002 Sootblower 8

1HCB40AT001 Sootblower 9 (Airheater)

1HNA50CT001 Backpass temperature

1HNA80CT001 ID fan inlet temperature

1HNC10AN001 ID fan

B Screenshots

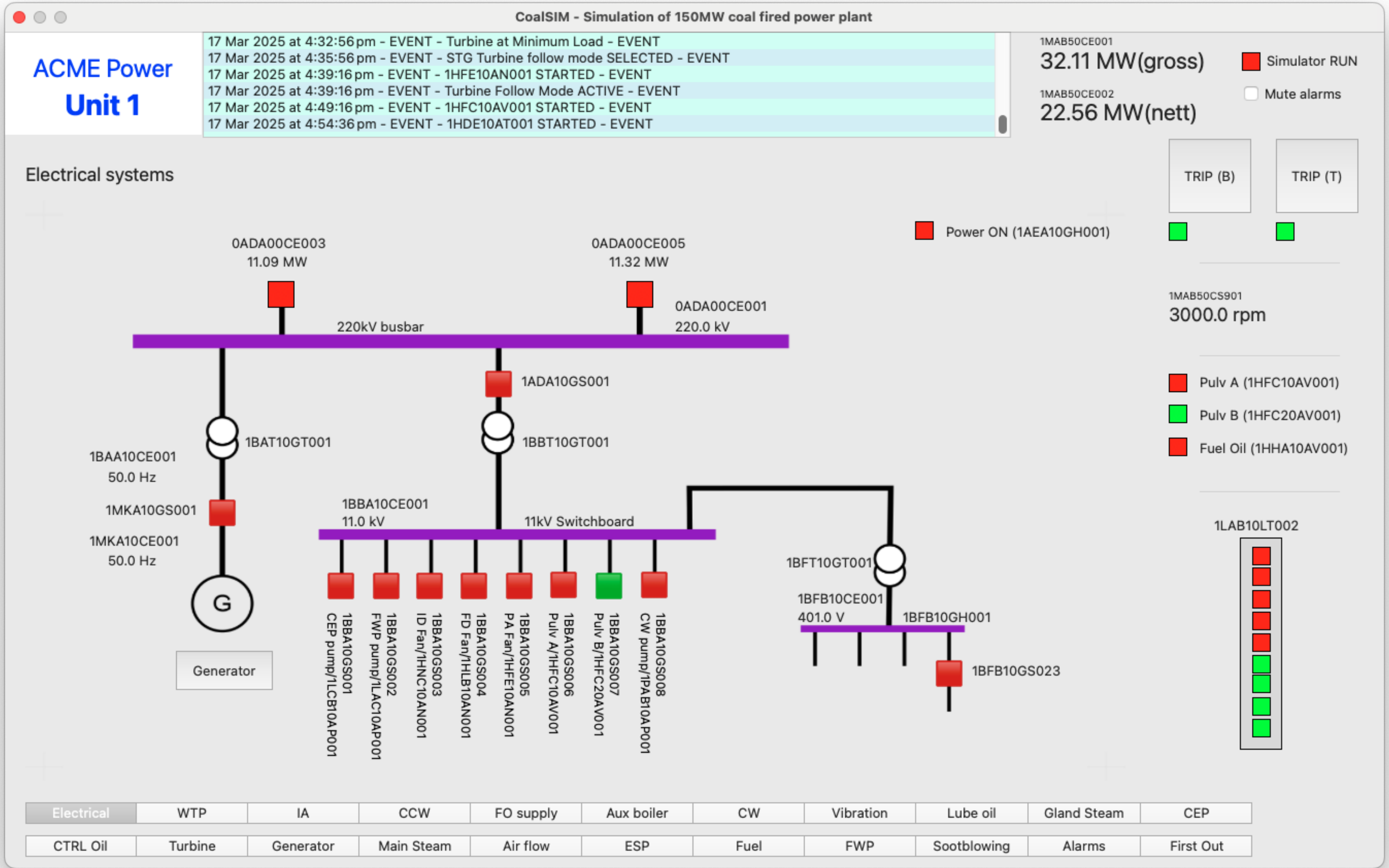


Figure 24: Electrical systems screenshot

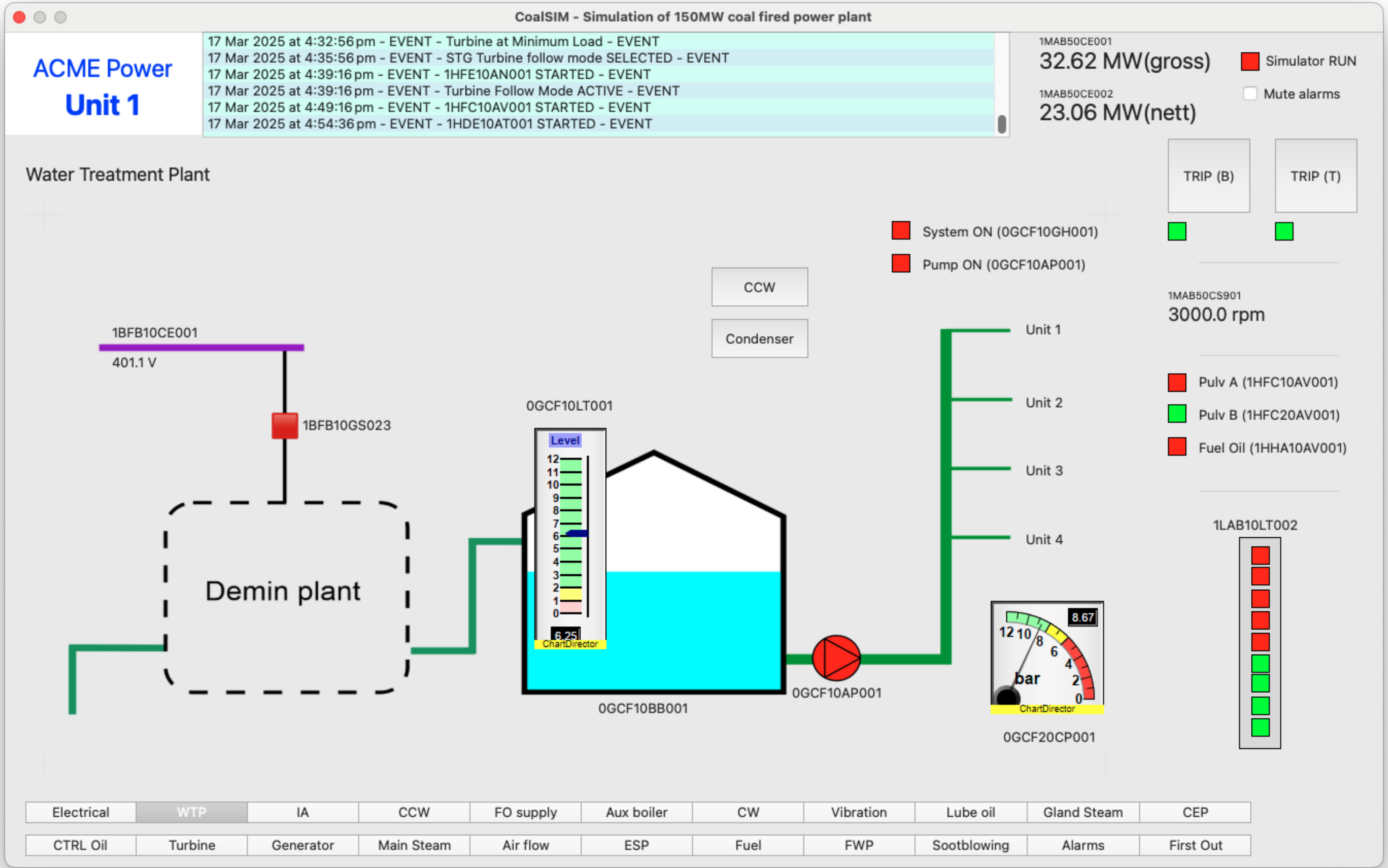


Figure 25: Water treatment plant screenshot

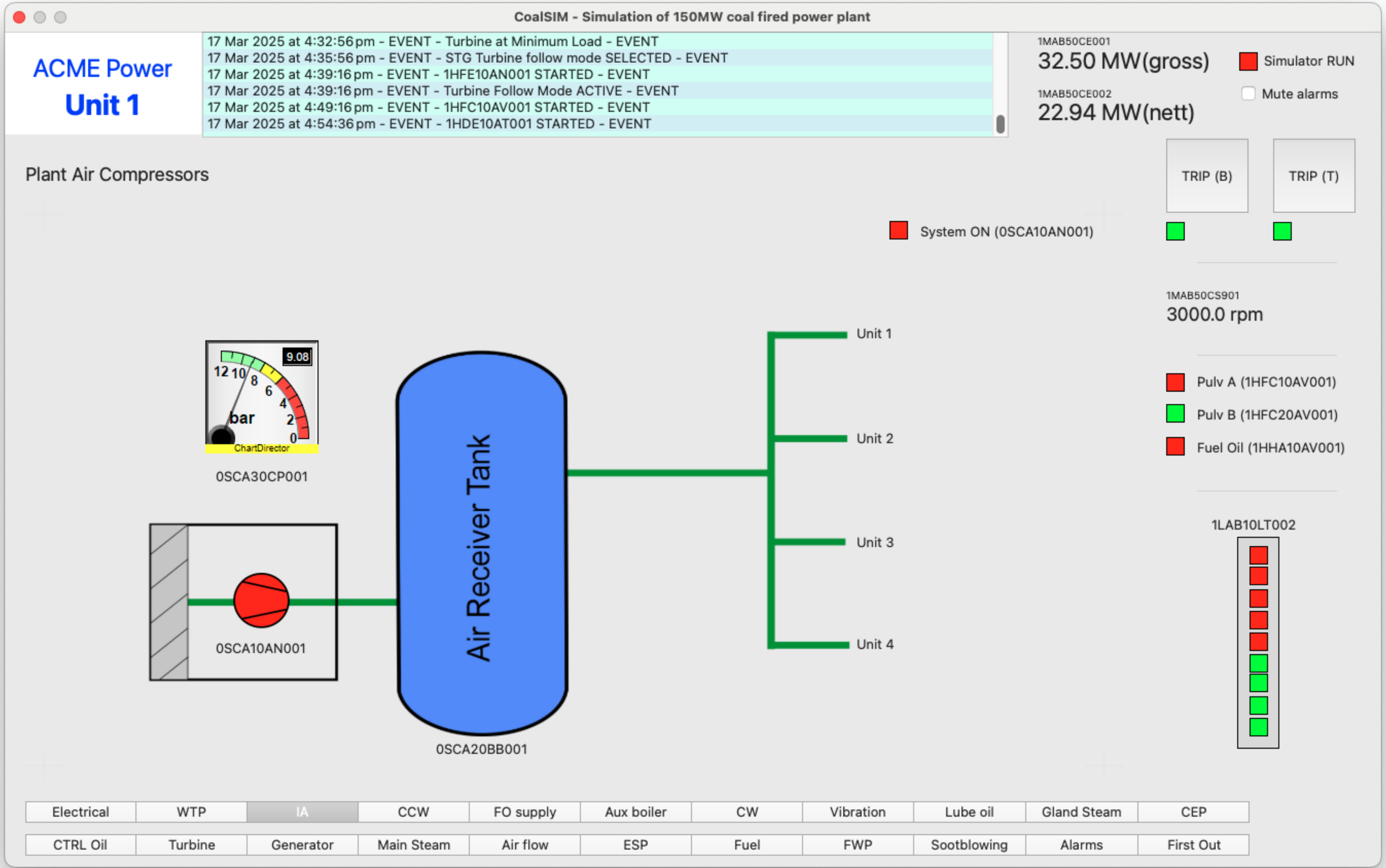


Figure 26: Instrument Air (IA) compressor screenshot

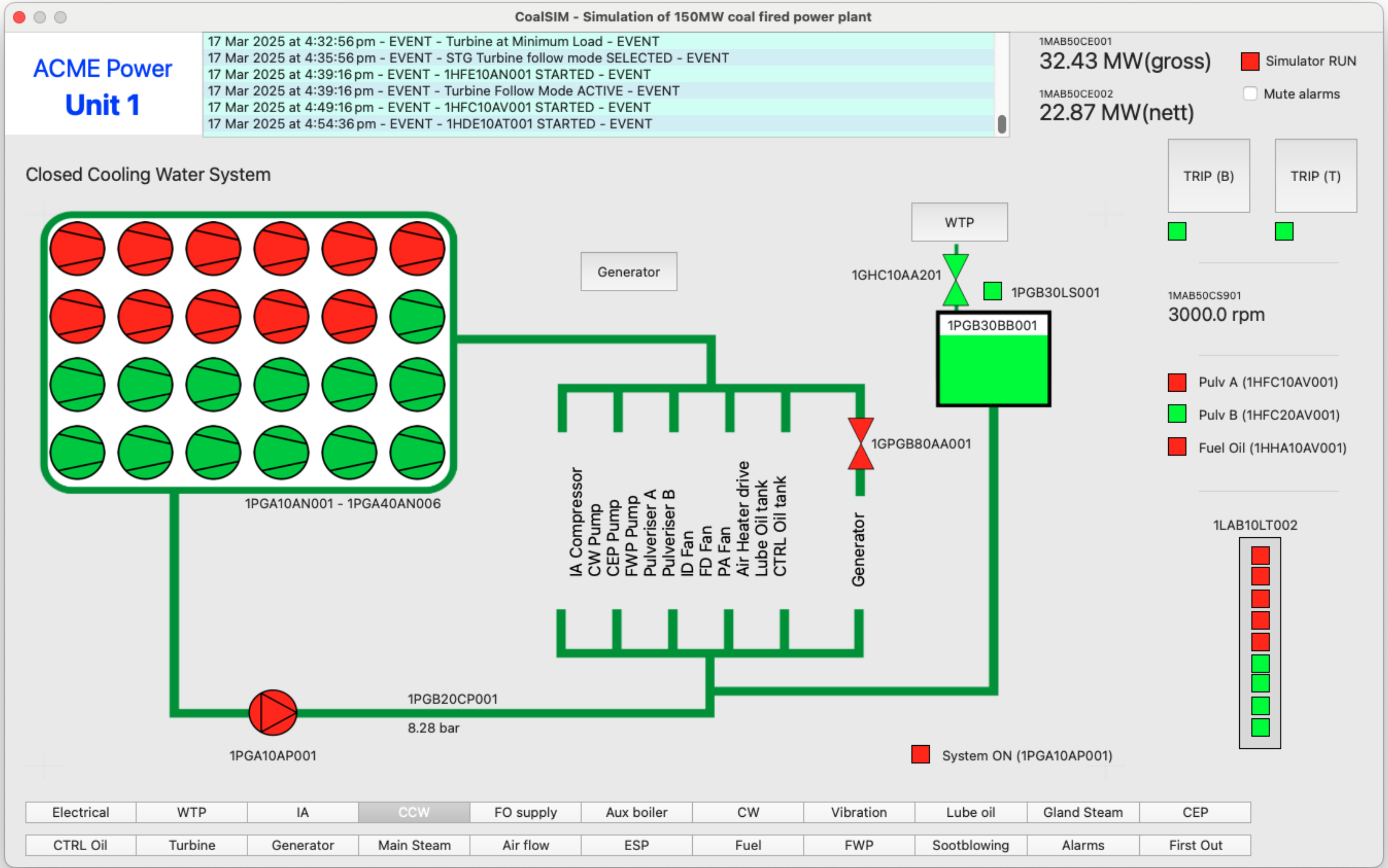


Figure 27: Closed Cooling Water (CCW) screenshot

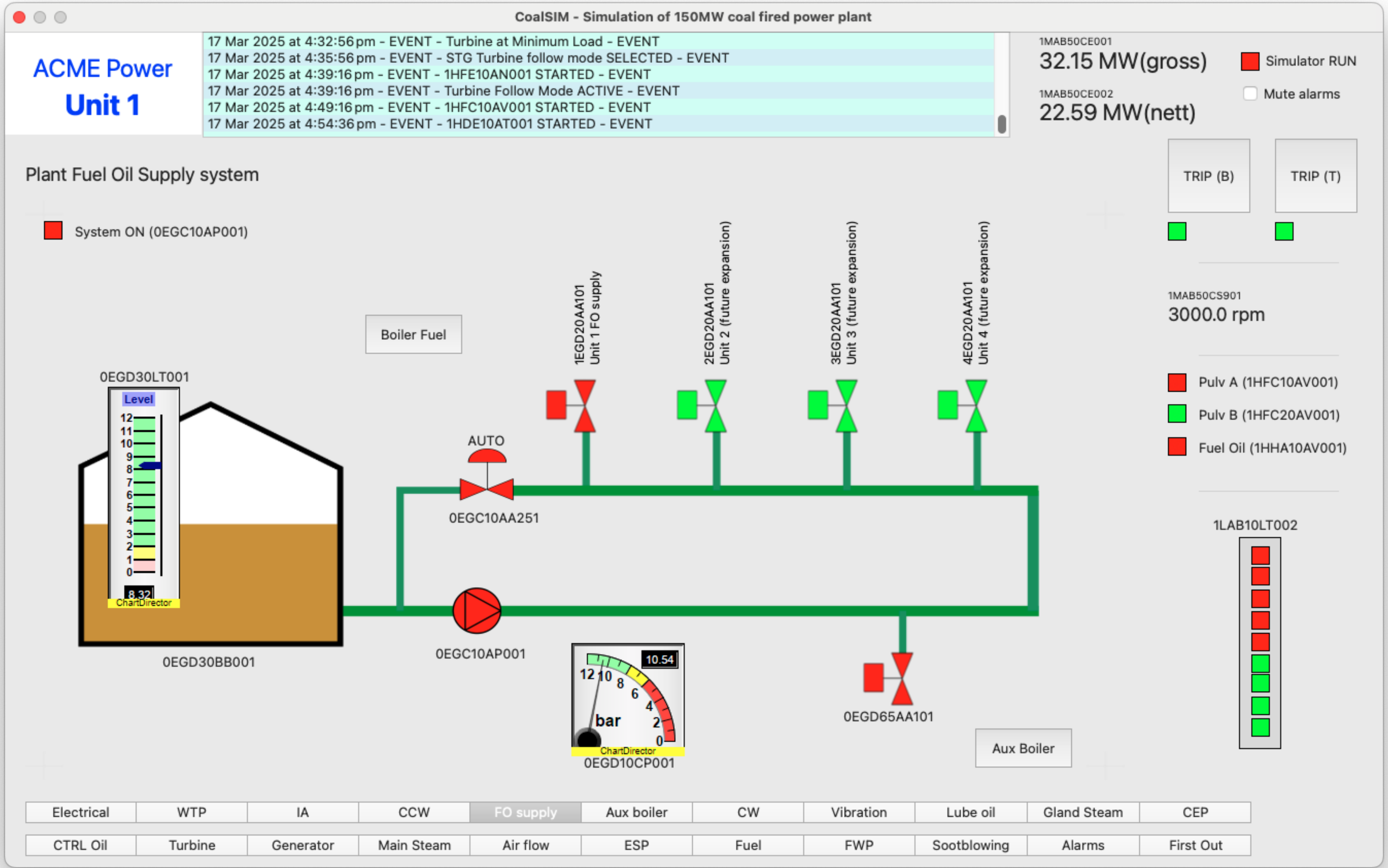


Figure 28: Fuel Oil supply system screenshot

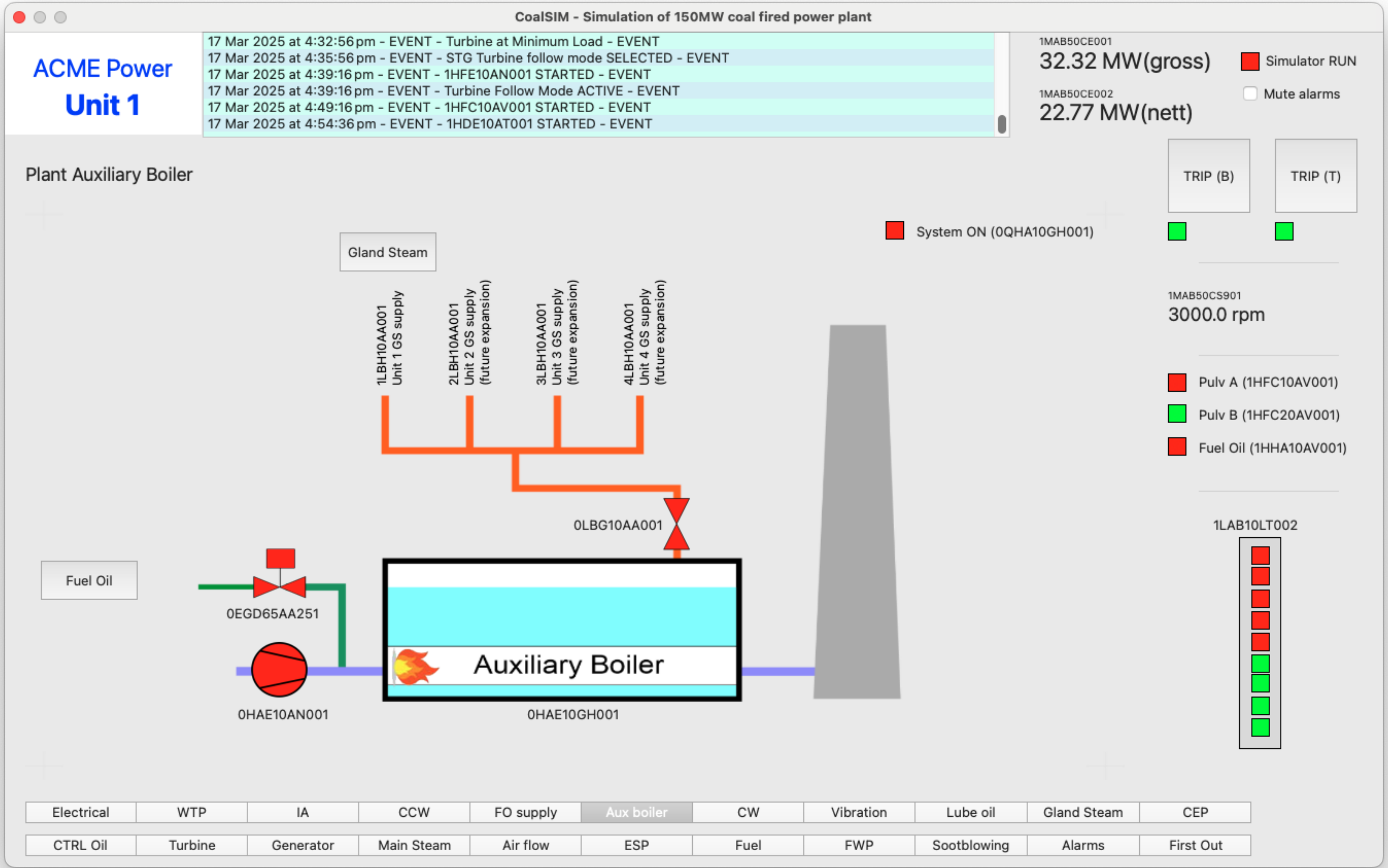


Figure 29: Plant Auxiliary Boiler screenshot

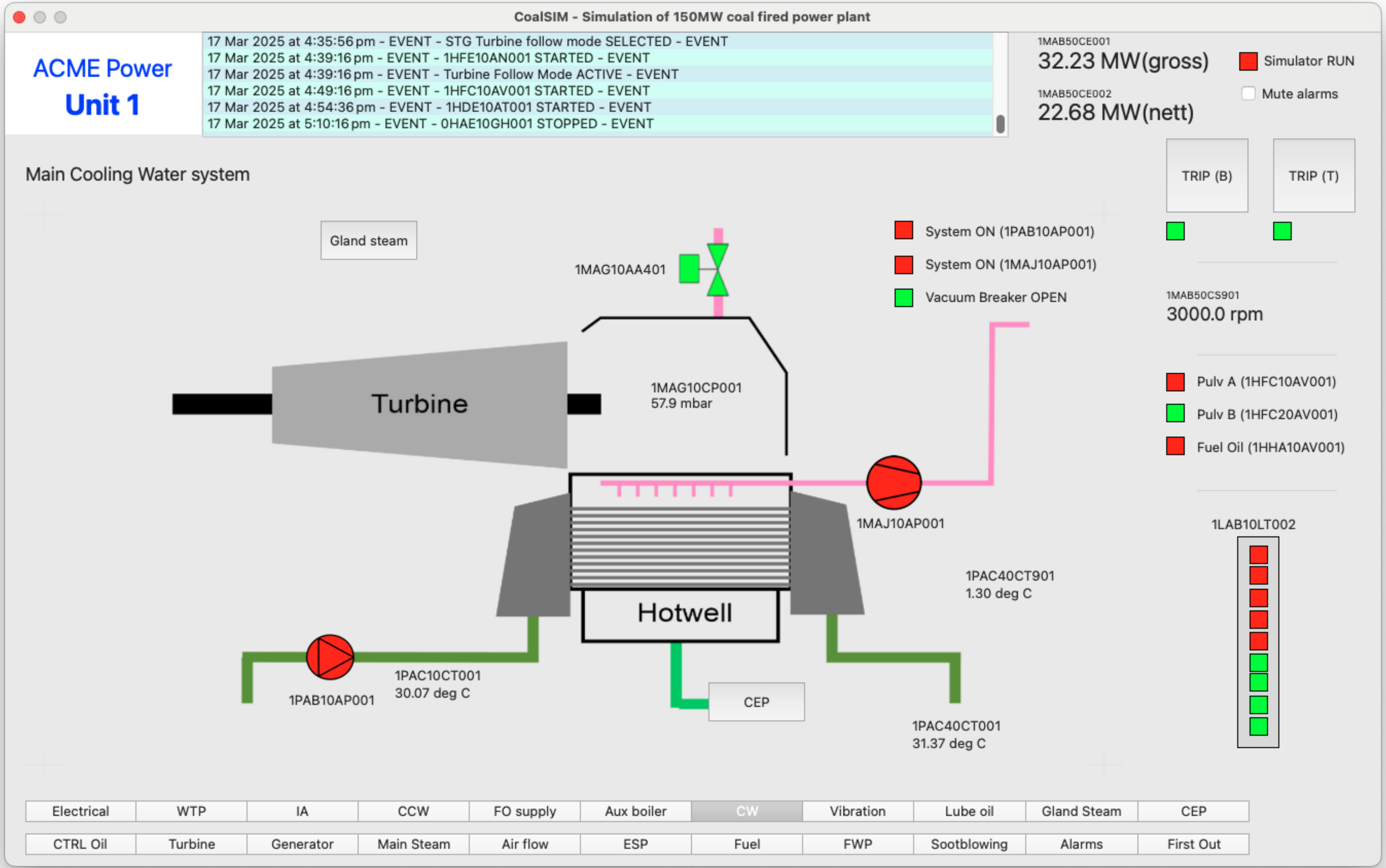


Figure 30: Main Cooling Water system screenshot

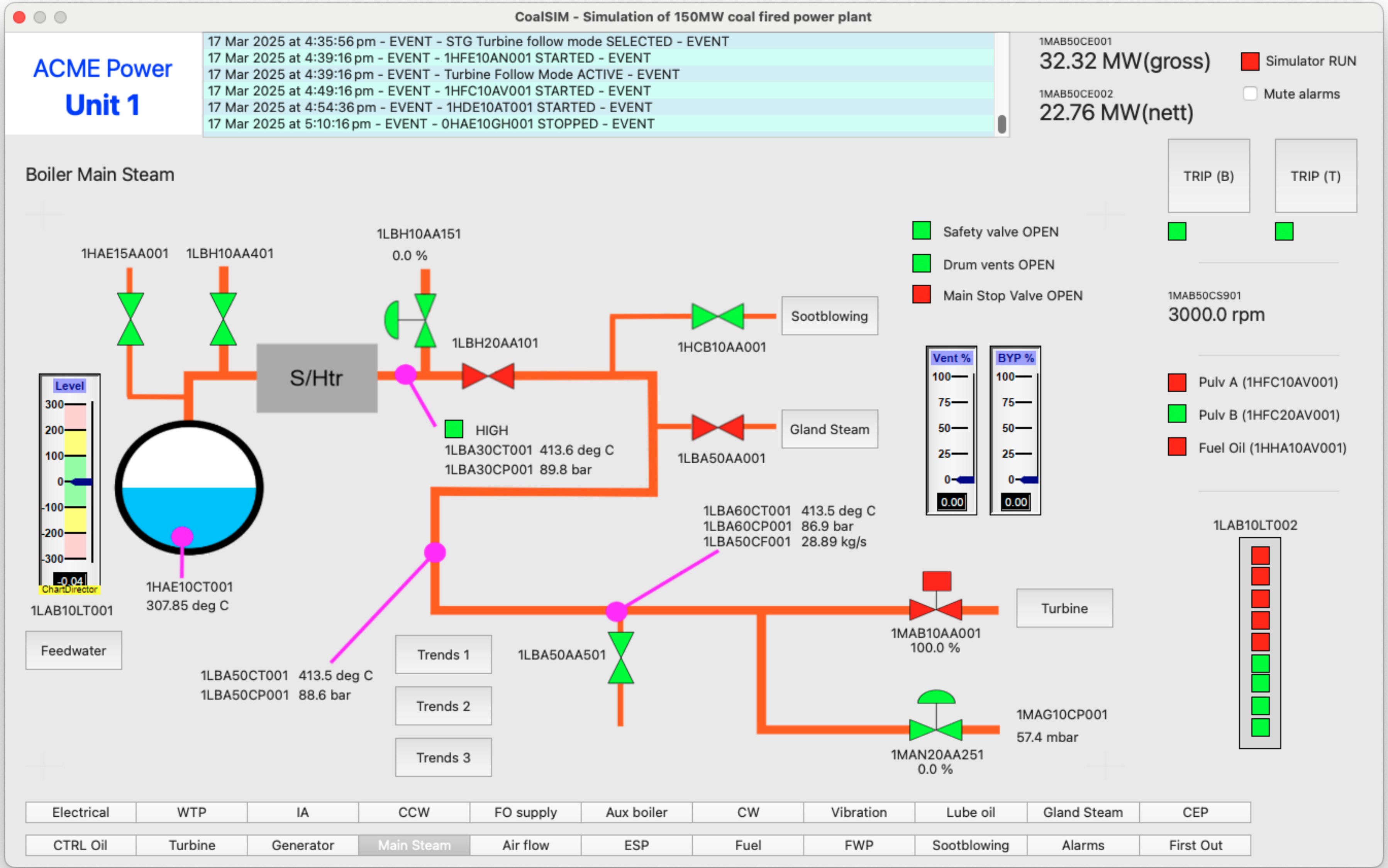


Figure 31: Boiler Main Steam screenshot

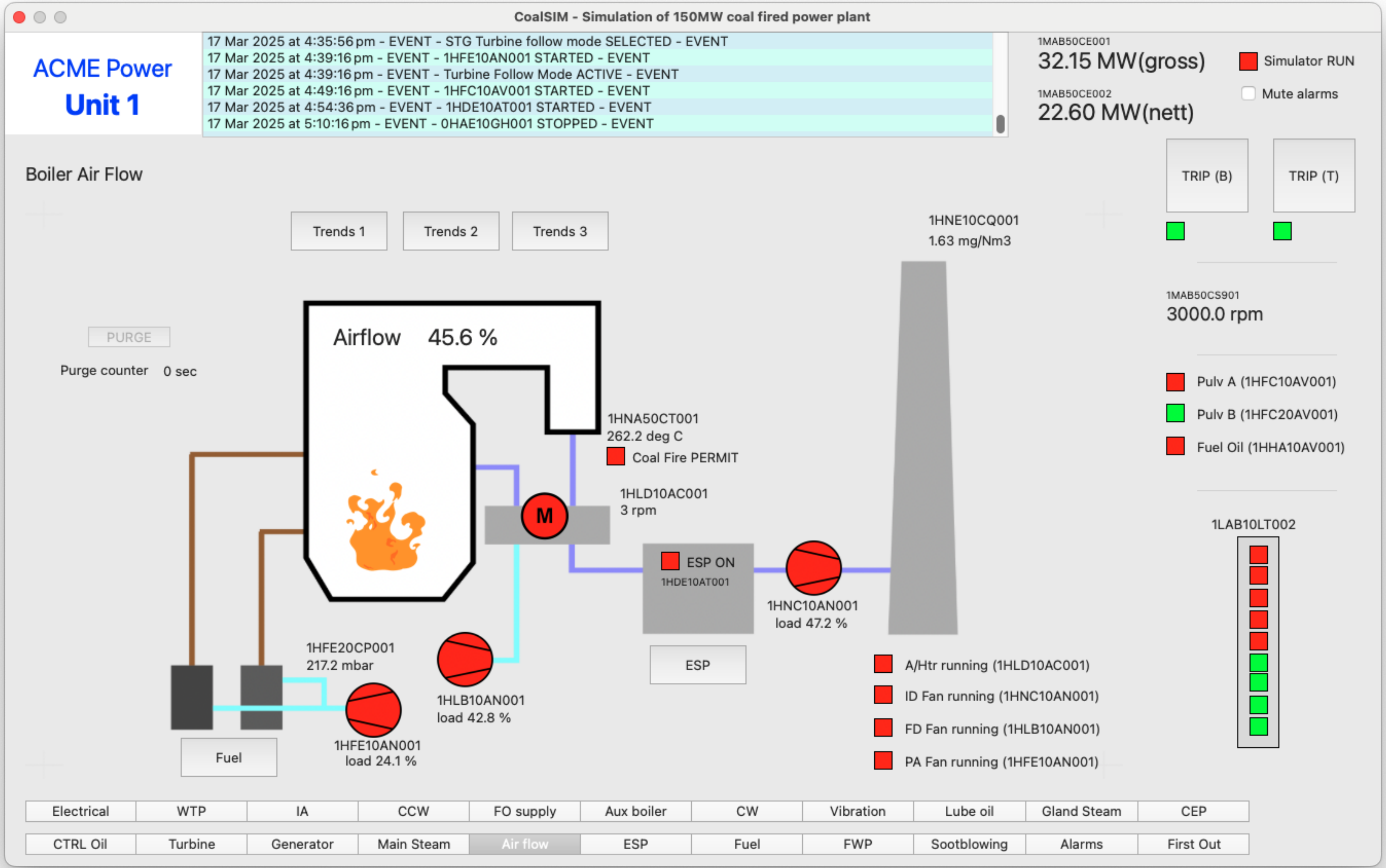


Figure 32: Boiler Air Flow screenshot

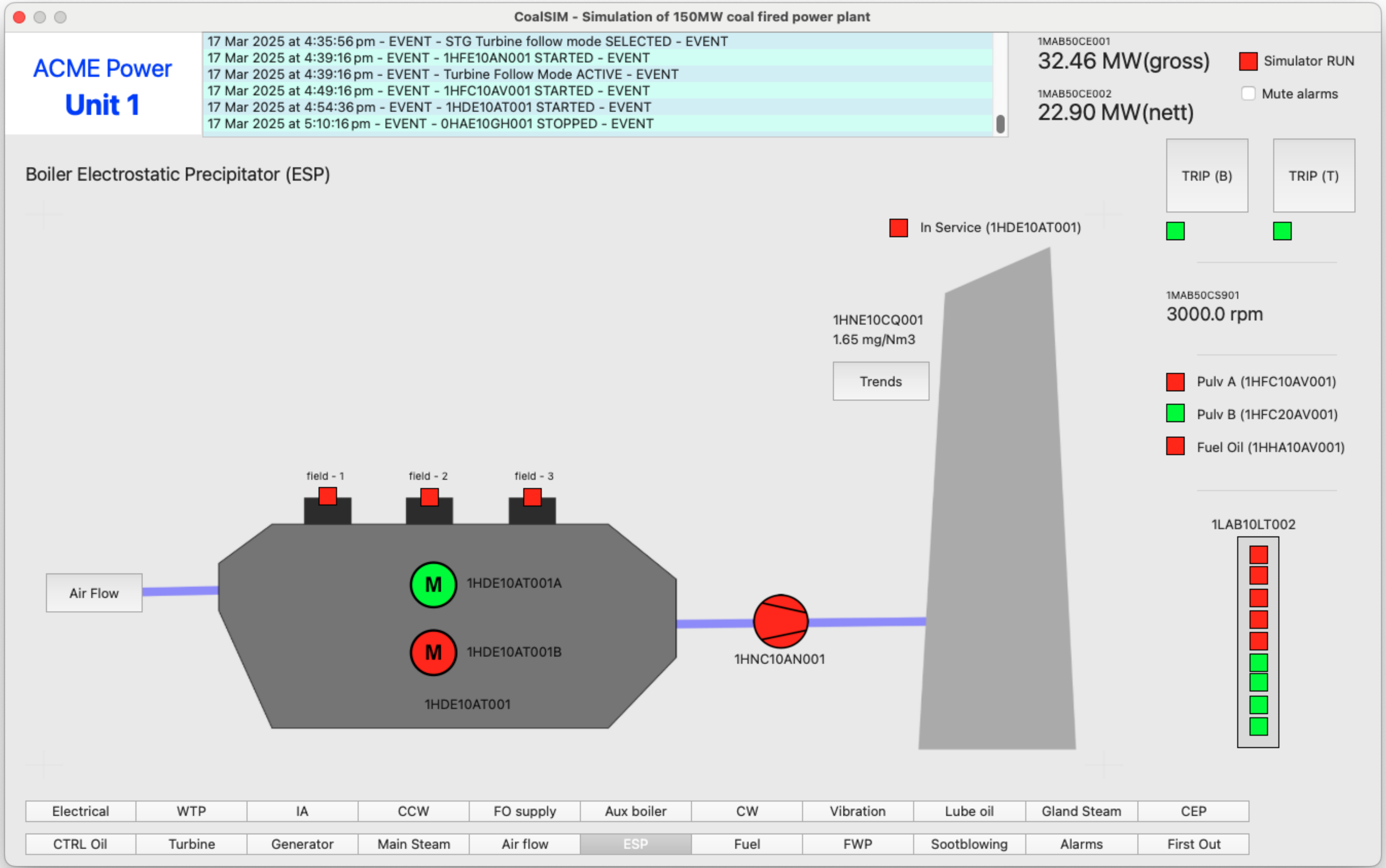


Figure 33: Electrostatic Precipitator (ESP) screenshot

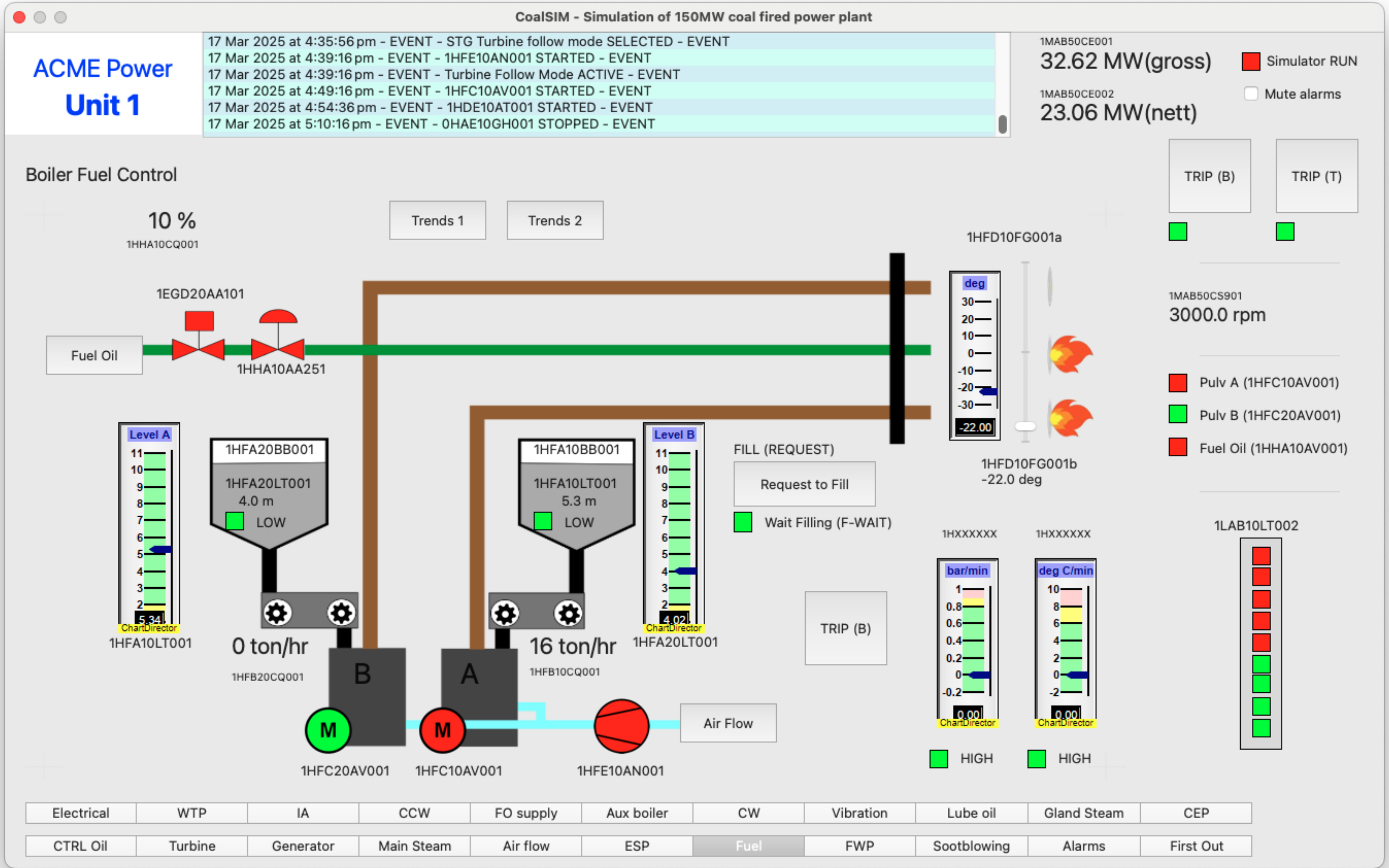


Figure 34: Boiler Fuel Control screenshot

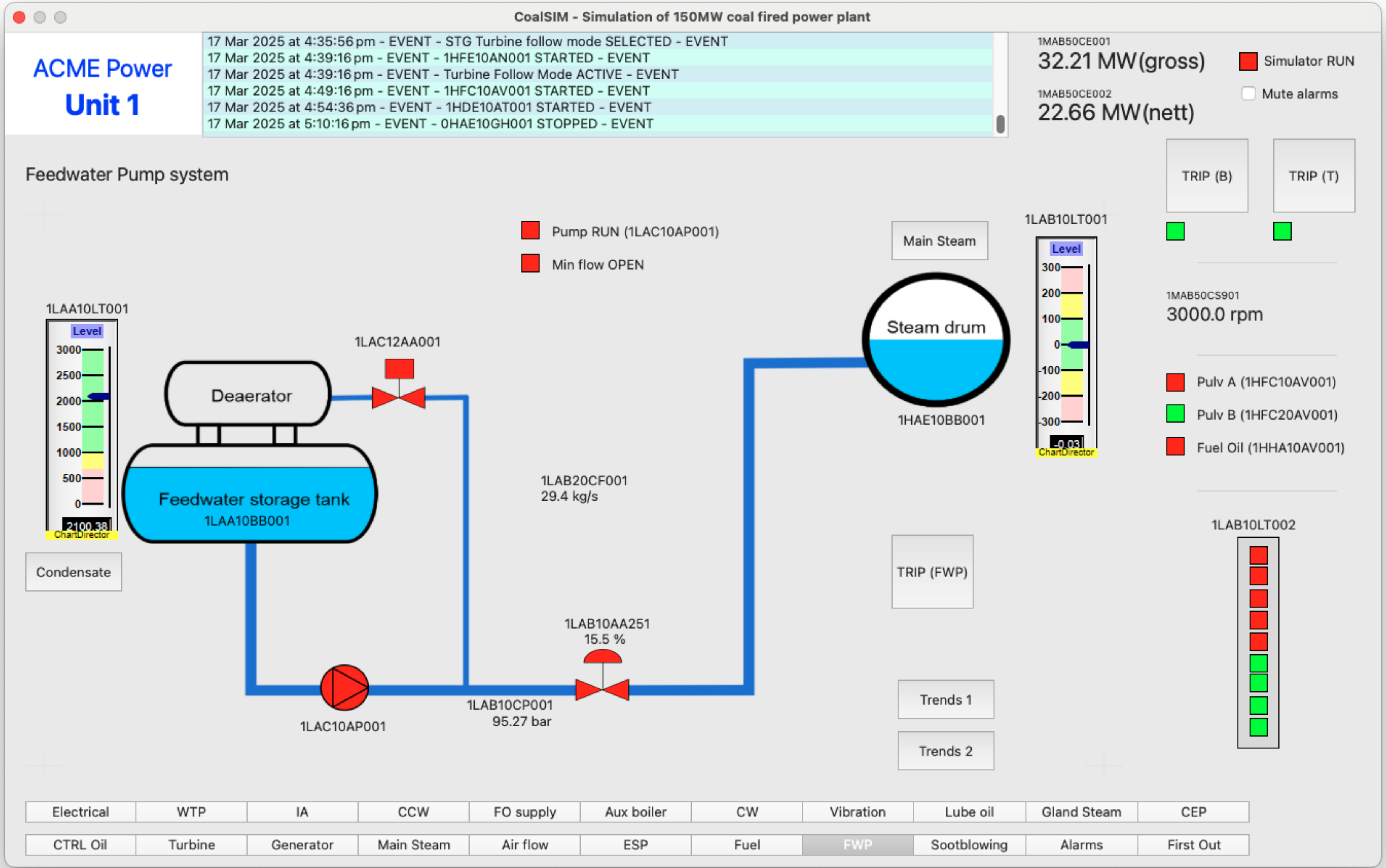


Figure 35: Feedwater Pump system screenshot

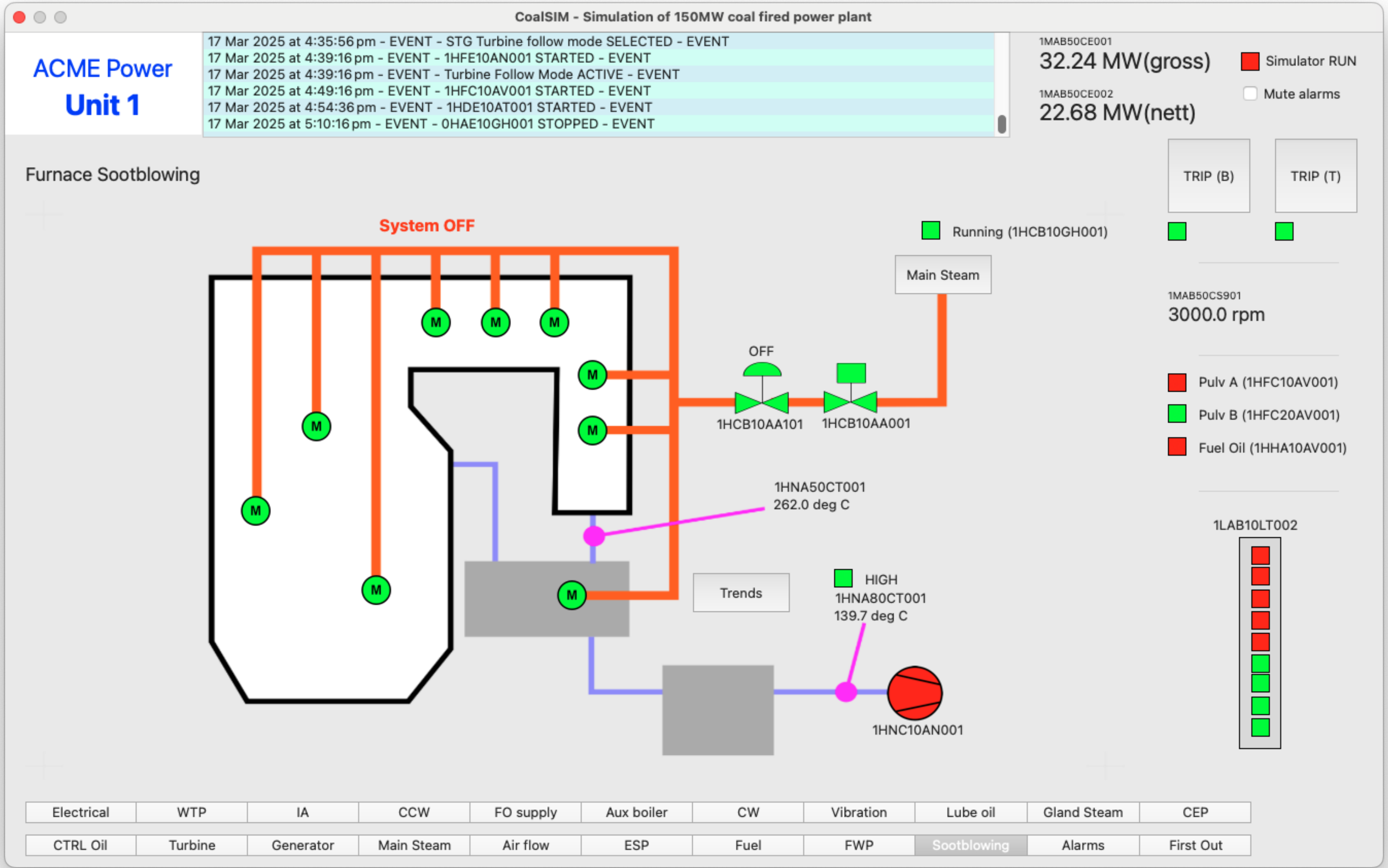


Figure 36: Furnace Sootblowing screenshot

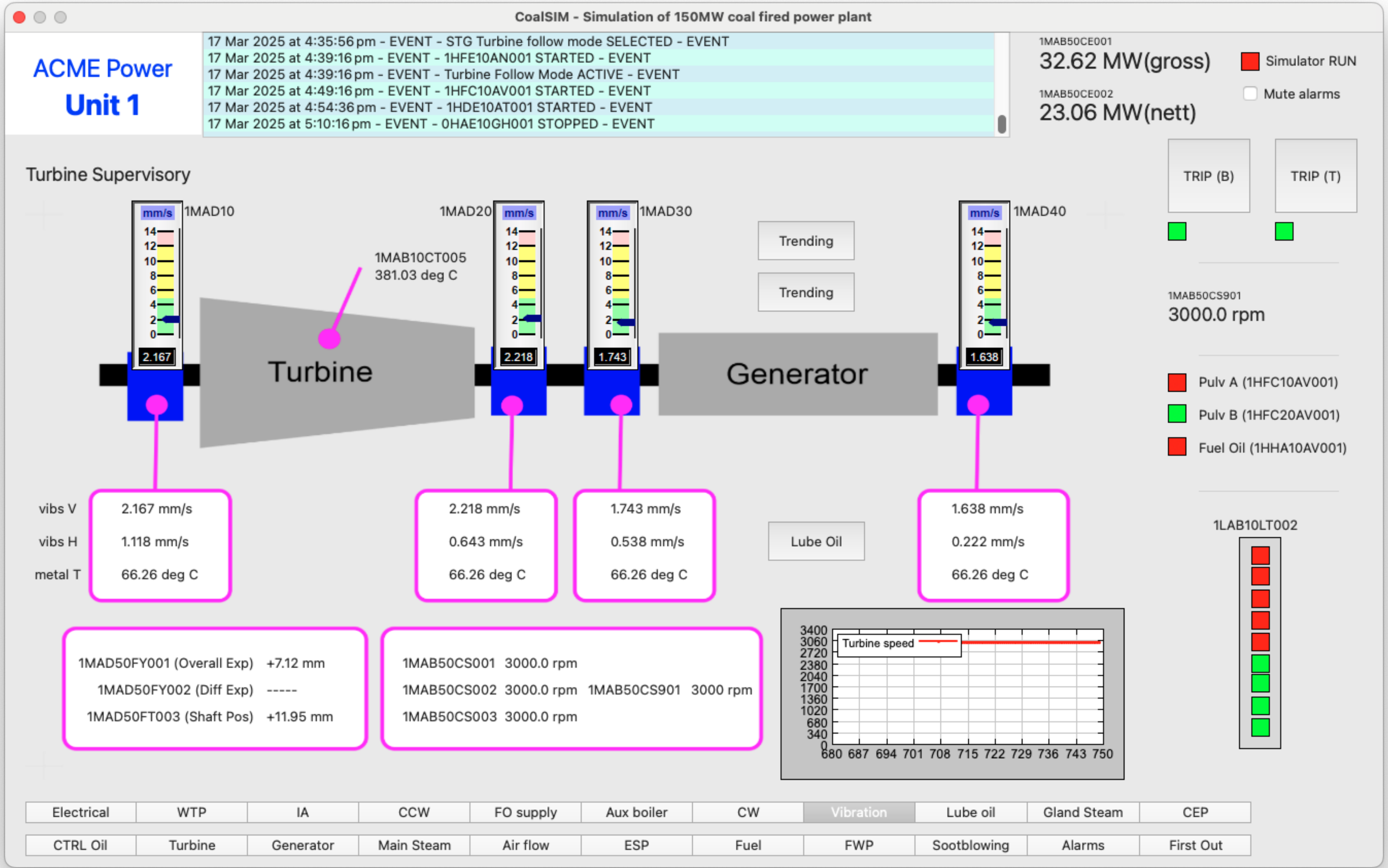


Figure 37: Turbine Vibration and speed monitoring screenshot

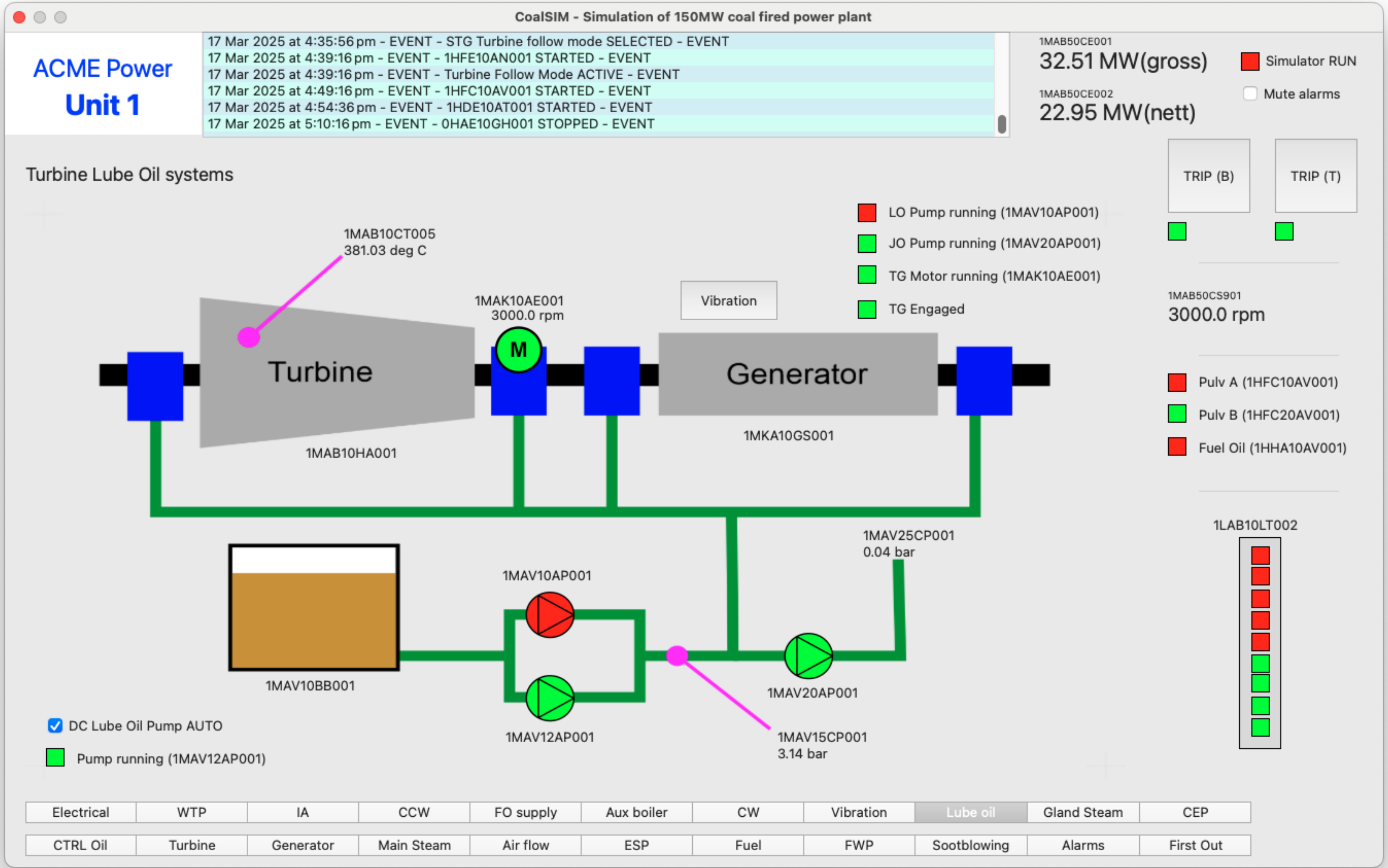


Figure 38: Turbine Lube Oil systems screenshot

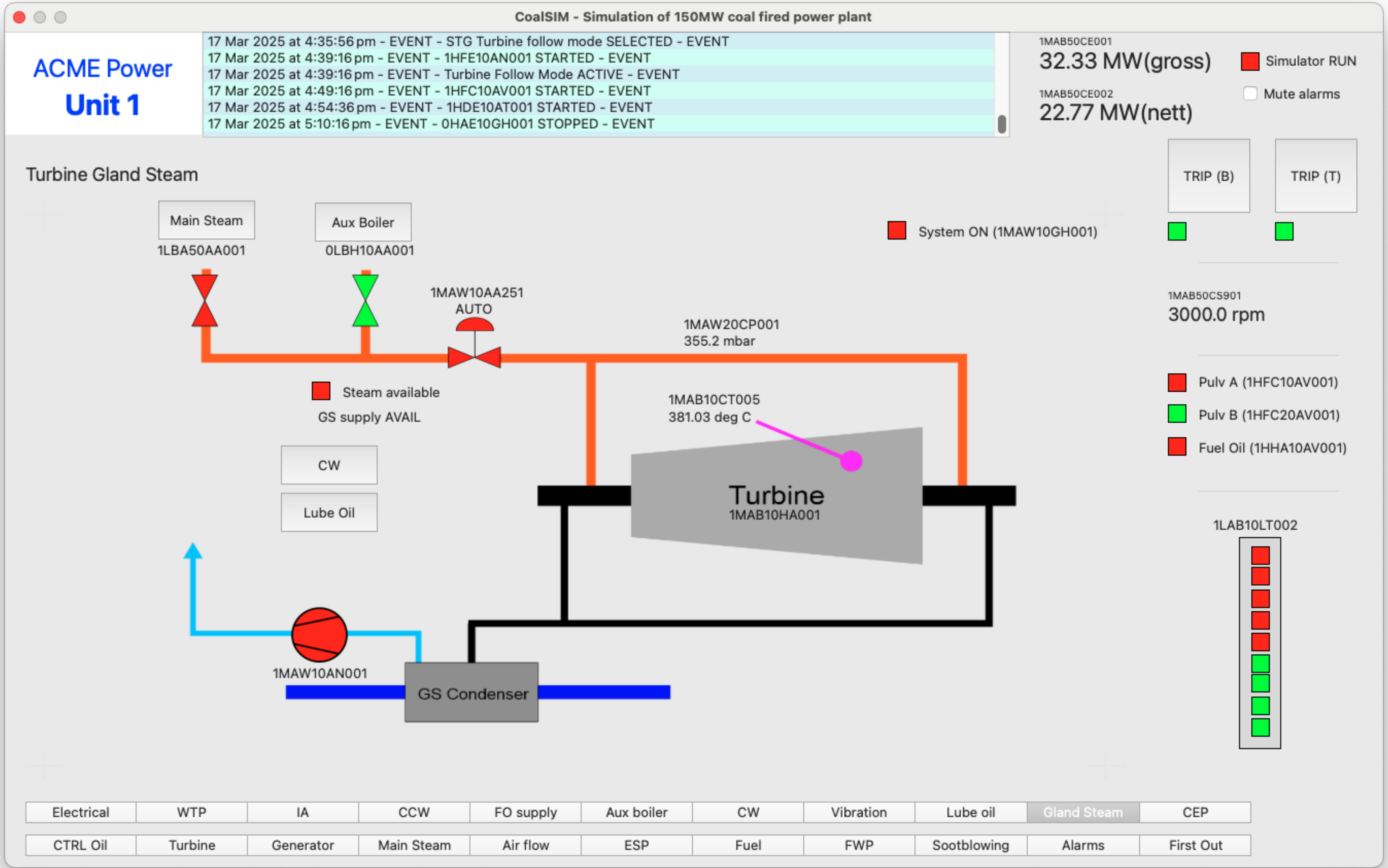


Figure 39: Turbine Gland Steam screenshot

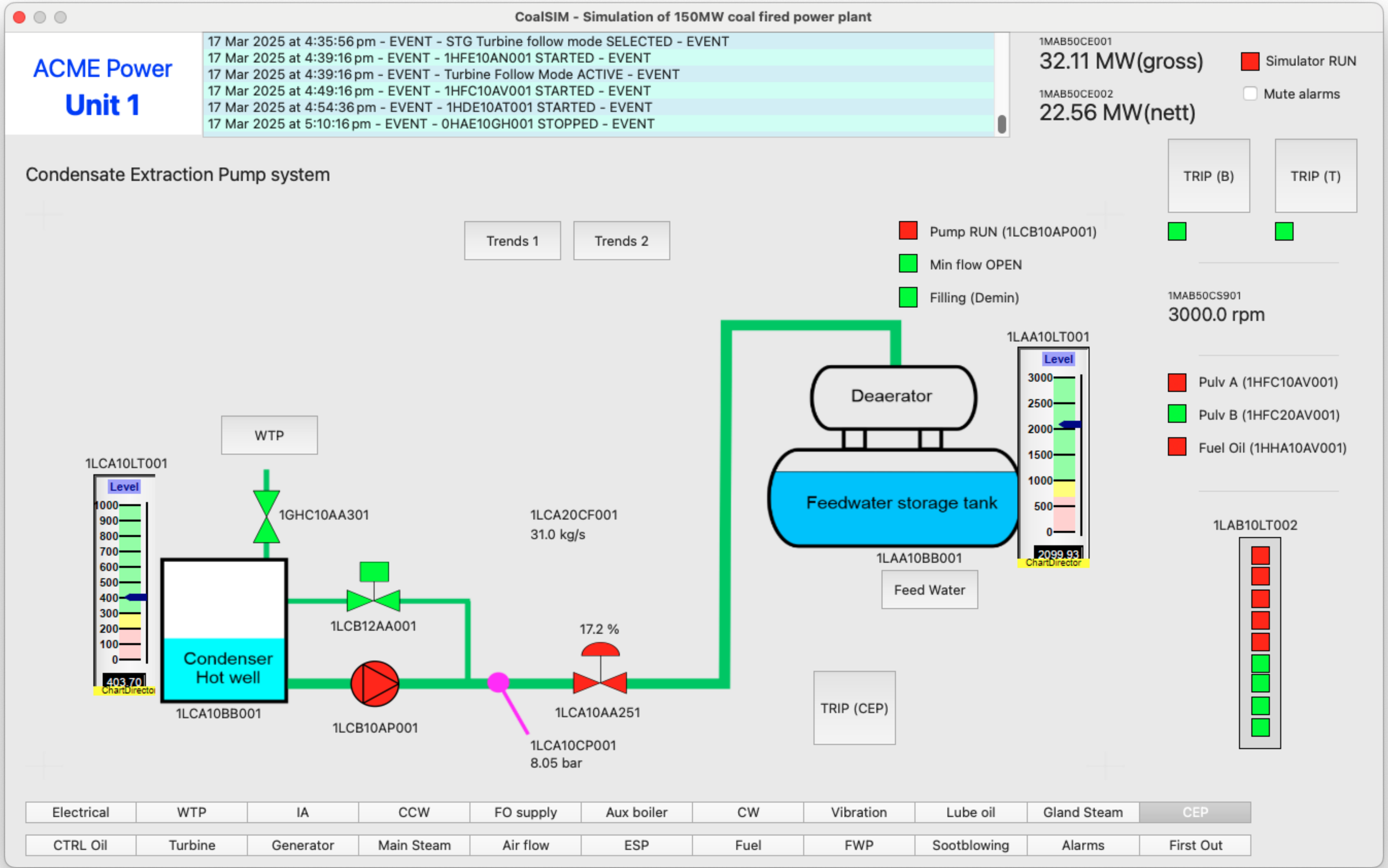


Figure 40: Condensate Extraction Pump (CEP) system screenshot

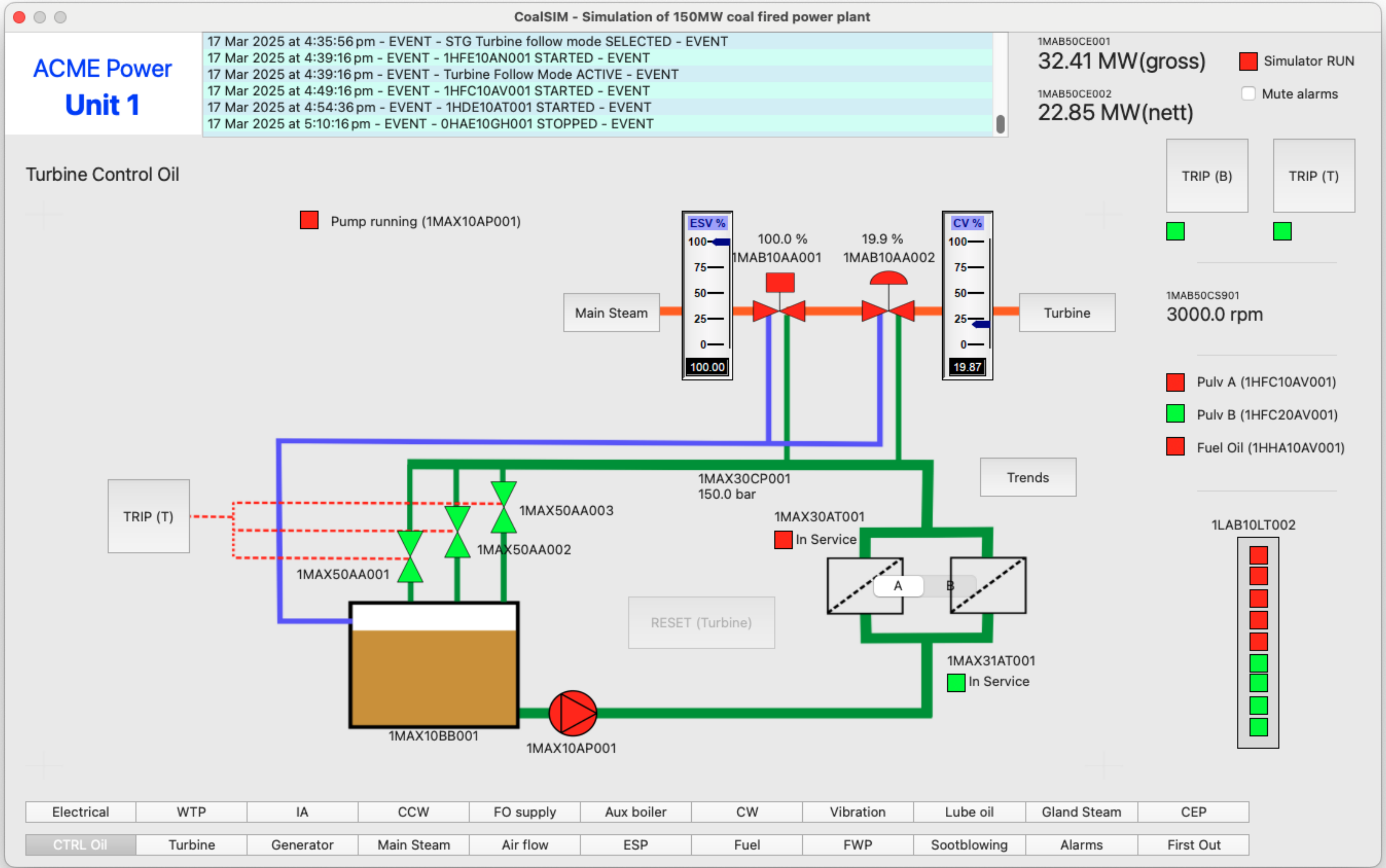


Figure 41: Turbine Control Oil screenshot

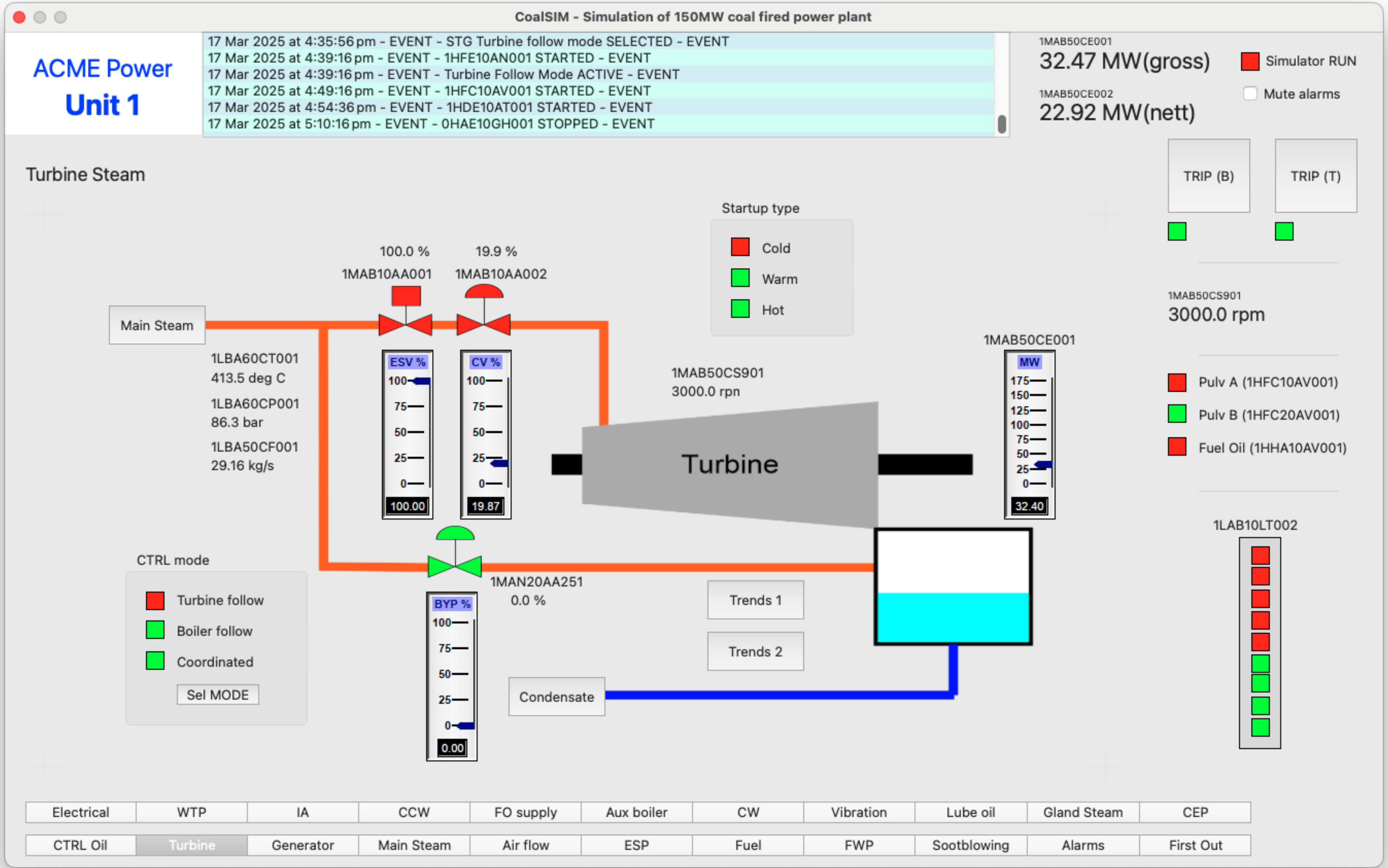


Figure 42: Turbine Steam screenshot

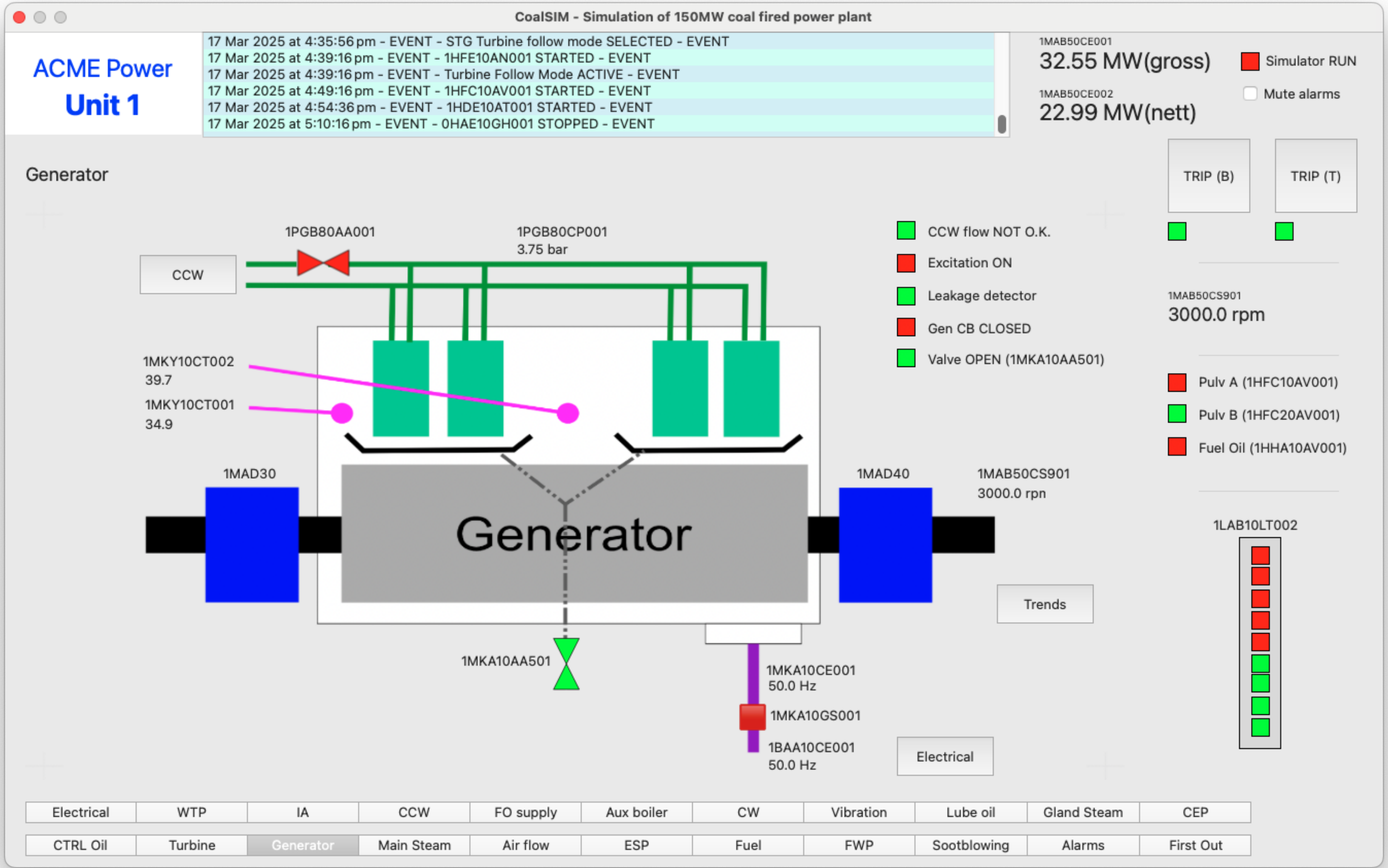


Figure 43: Generator system screenshot

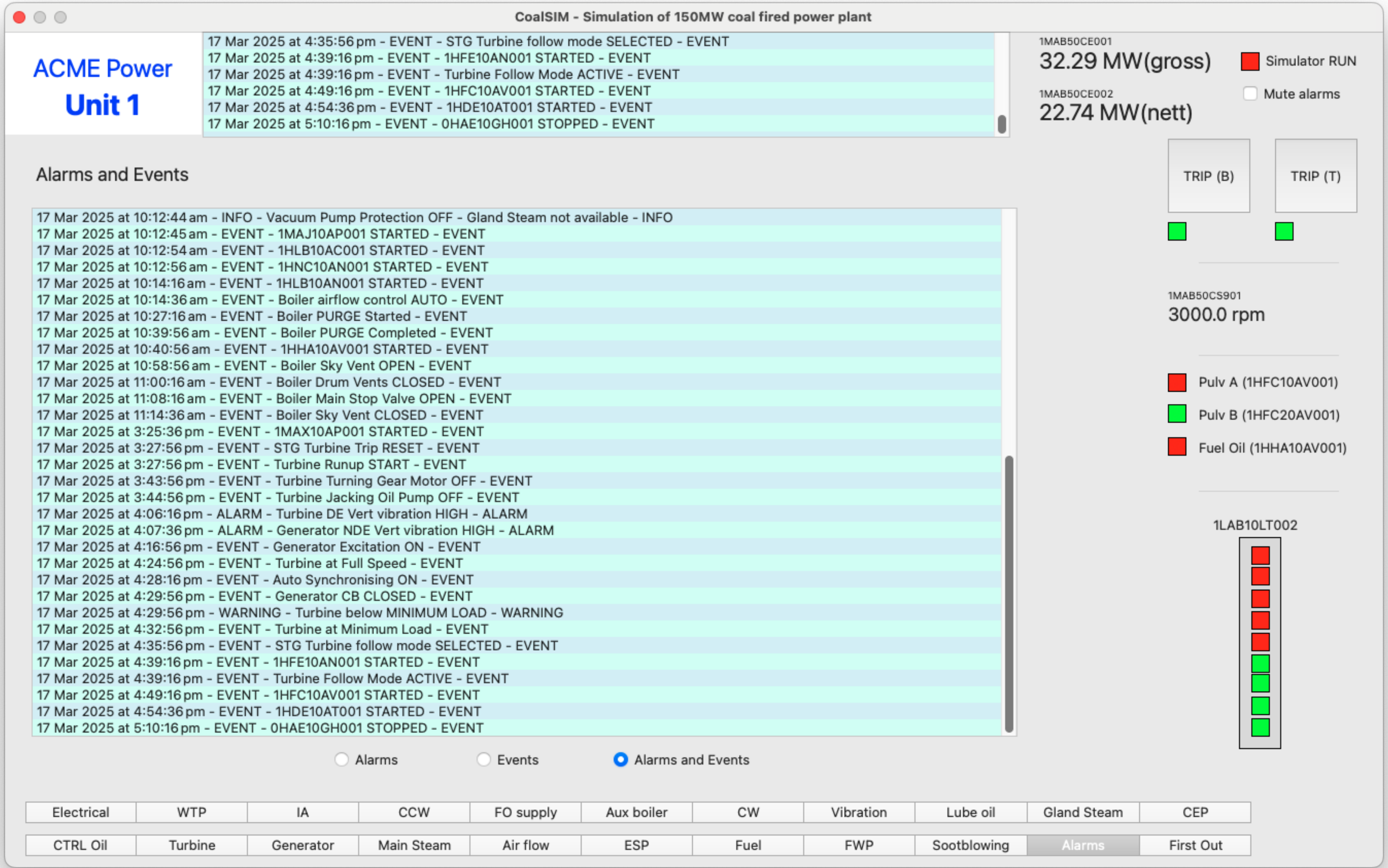


Figure 44: Alarm and Event page screenshot

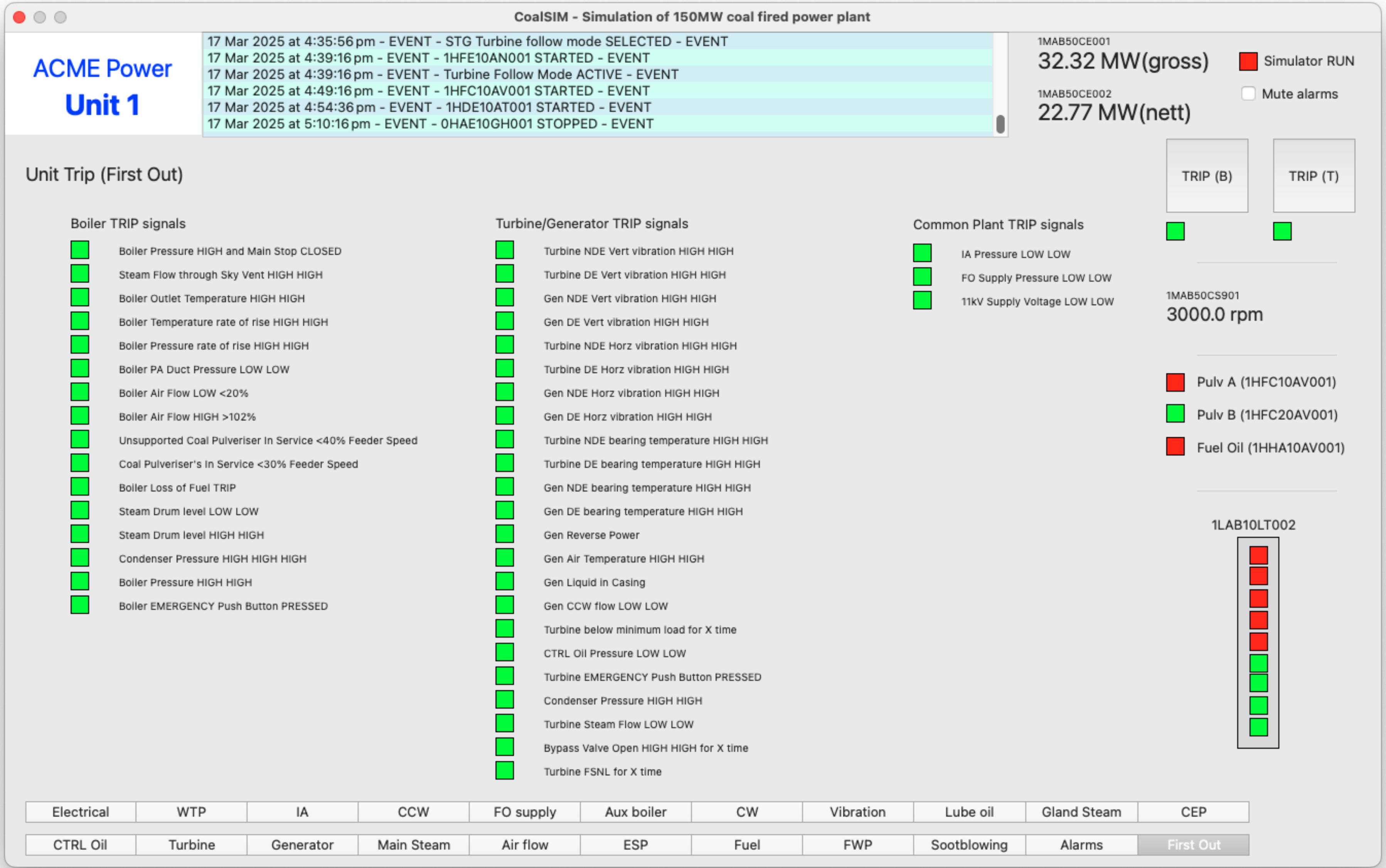


Figure 45: Unit Trip (First Out) page screenshot

C Thermodynamics

The thermodynamic cycle modelled in this simulation is shown below. It consists of a Rankine superheat cycle with one open feed heater (the Deaerator).

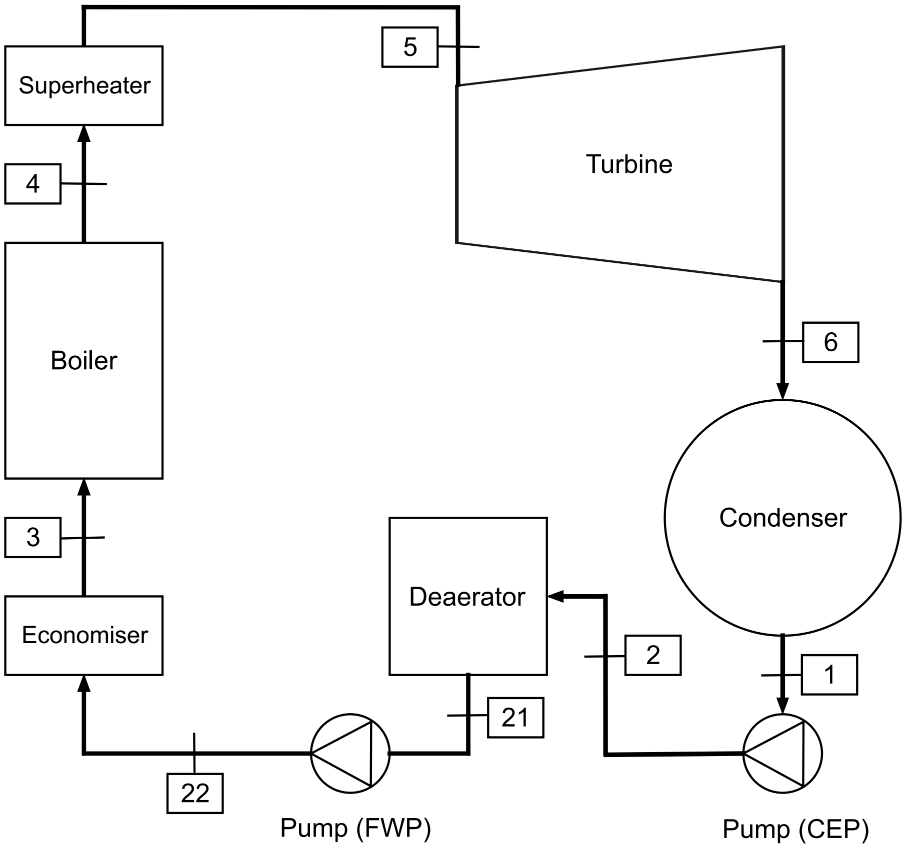


Figure 46: Rankine cycle diagram of ACME unit 1 plant.

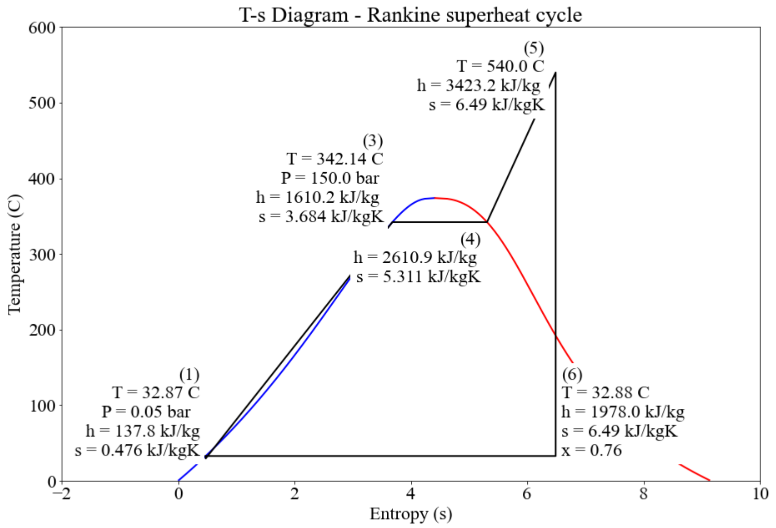


Figure 47: Ts (Temperature-Entropy) diagram of ACME unit 1 plant.

D Plant systems not covered

This simulation is a vastly simplified model of a real coal fired power generation unit. So as to concentrate on the important areas and make the programming slightly easier for myself, the following area have either been omitted or simplified;

- bled steam from turbine to deaerator for heating.
- feedwater heaters (other than the Deaerator).
- boiler blowdown vessel.
- condensate/feedwater chemical dosing system.
- boiler chemical dosing system.
- ash removal (bottom and fly ash).
- boiler water/steam sampling (pH, Na, SiO2, O2, etc).
- flue gas sampling (O2, CO, NoX, SO2, Hg, CO2) Note: Particulates (i.e. dust) is measured in this model.
- Backpass O2 measurement.
- steam air heater.
- Oil burner scavenging system.
- drains (boiler, steam legs, etc) Note: A single leg drain is modelled.
- excitation and VAR control.
- Fuel handling including delivery (Stacking/reclaiming).

You can see on the 2 screenshots below a comparison of the amount of information presented on the simulated plant (48) compared to a real plant (49) of the generator page.

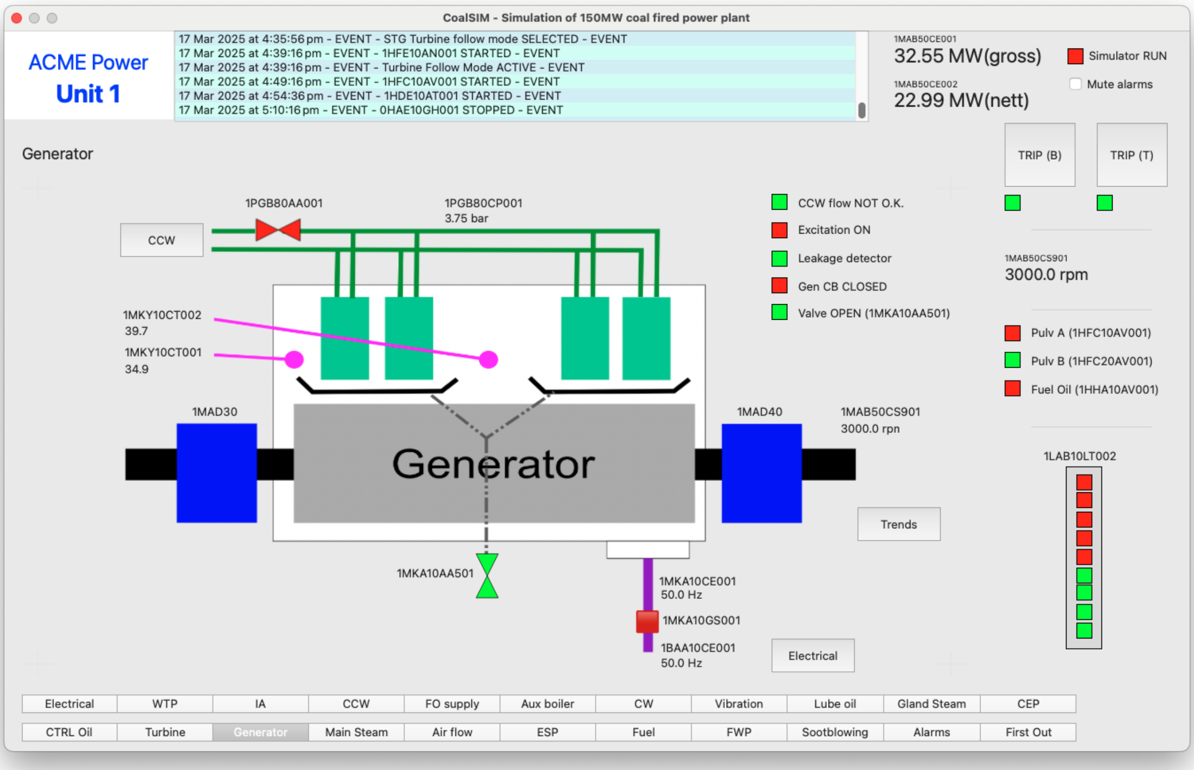


Figure 48: Screenshot from CoalSIM application

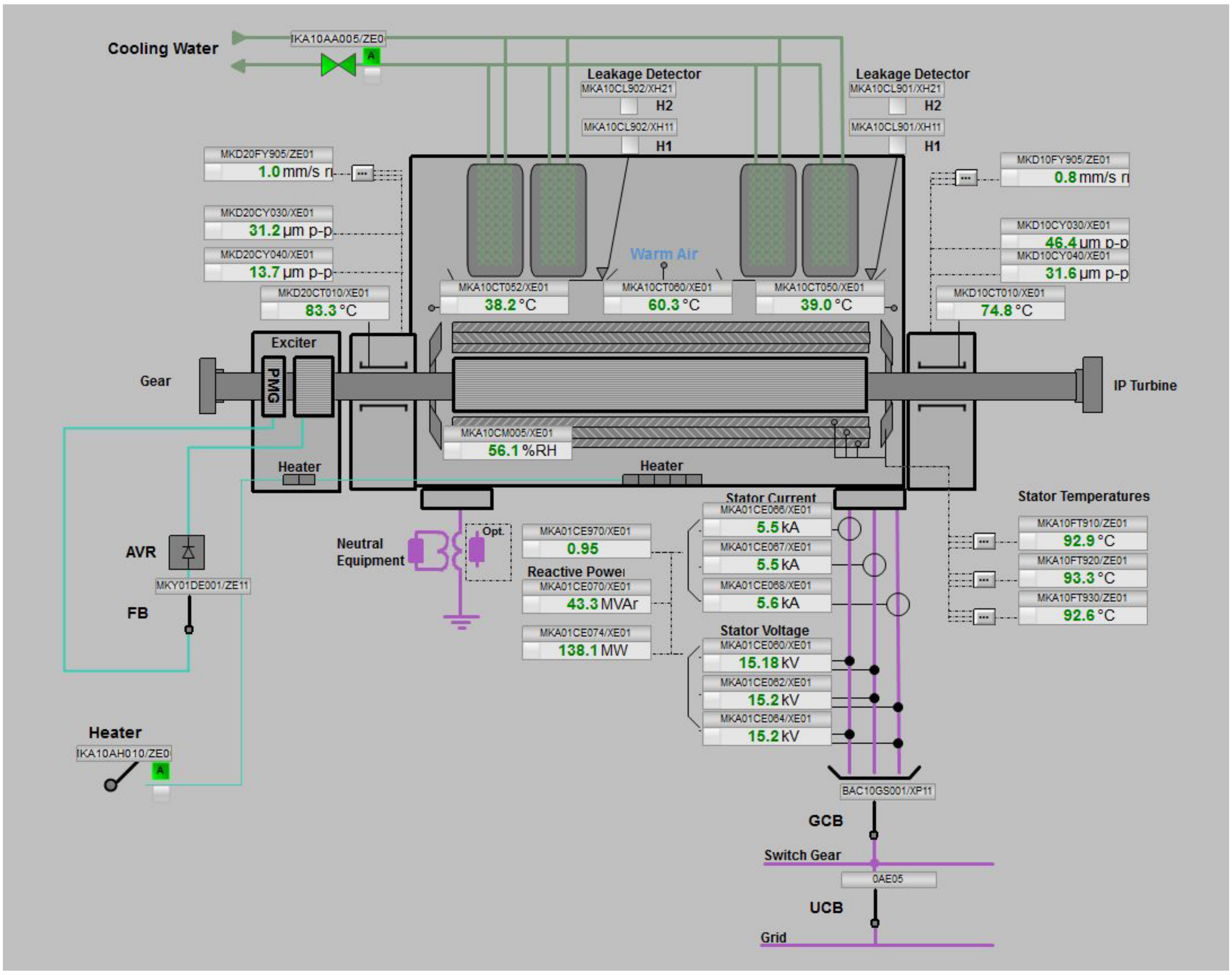


Figure 49: Screenshot from real world DCS

E Revision History

3 May 2022 Simulation at initial release stage.

7 May 2022 Documentation ready as 1^{st} draft.

20 Jan 2023 Update normal shutdown procedure to reflect MFT after shutdown of fuel oil burner causes only a soft boiler trip.

22 Mar 2025 Complete update of documentation to accommodate new version of CoalSIM sofware (version 2 / 2025).

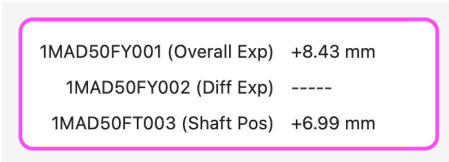
F Known issues

A number of plant system either do not work correctly or work not as well as I would like. They are listed below;

1. level control of the Deaerator can sometimes get a little confused. I'm working on a fix.

2. Trending is another area that I would like to improve. Whilst currently it does work, its implementation could be much better. For some reason (probably a lack of skill on my part) I am unable to get the X axis to display a time and/or date.

3. Turbine Differential expansion non-functional. On the to-do list.



G Figures

List of Figures

1 Power plant icons created by Freepik - Flaticon . . . 4
2 Application opening screen . . . 9
3 Top bar of application window . . . 10
4 Right side panel of application window . . . 10
5 Bottom bar of application window . . . 11
6 Buttons to redirect to a screen displaying system parameter trends . . . 11
7 Typical trend screen display . . . 12
8 Rankine cycle diagram of ACME unit 1 plant. . . . 13
9 Feedwater Pump ON/OFF and Steam drum level control AUTO selection. . . . 33
10 Turbine Control faceplate. . . . 38
11 Condenate Extraction Pump ON/OFF and Deaerator level control AUTO selection. . . . 44
12 Electrical systems screen - 11kV board de-energised . . . 50
13 Electrical systems screen - 11kV board LIVE . . . 51
14 Furnace purge in progress with 6 seconds remaining. . . . 53
15 Fuel Oil burner isolation/trip valve (1EGD20AA101) after Purge completed. . . . 53
16 Ready to RESET turbine trip and run-up the turbine. . . . 54
17 Turbine in the process of run up to 3000 rpm. . . . 54
18 First Out screen showing a Turbine TRIP. . . . 55
19 First Out screen showing a Boiler TRIP. . . . 59
20 Alarms and Events shown together. . . . 61
21 Events only shown. . . . 61
22 Alarms only shown. . . . 62
23 Not a great score! . . . 74
24 Electrical systems screenshot . . . 85
25 Water treatment plant screenshot . . . 86
26 Instrument Air (IA) compressor screenshot . . . 87
27 Closed Cooling Water (CCW) screenshot . . . 88
28 Fuel Oil supply system screenshot . . . 89
29 Plant Auxiliary Boiler screenshot . . . 90
30 Main Cooling Water system screenshot . . . 91
31 Boiler Main Steam screenshot . . . 92
32 Boiler Air Flow screenshot . . . 93
33 Electrostatic Precipitator (ESP) screenshot . . . 94
34 Boiler Fuel Control screenshot . . . 95
35 Feedwater Pump system screenshot . . . 96
36 Furnace Sootblowing screenshot . . . 97
37 Turbine Vibration and speed monitoring screenshot . . . 98
38 Turbine Lube Oil systems screenshot . . . 99
39 Turbine Gland Steam screenshot . . . 100
40 Condensate Extraction Pump (CEP) system screenshot . . . 101
41 Turbine Control Oil screenshot . . . 102
42 Turbine Steam screenshot . . . 103
43 Generator system screenshot . . . 104
44 Alarm and Event page screenshot . . . 105
45 Unit Trip (First Out) page screenshot . . . 106
46 Rankine cycle diagram of ACME unit 1 plant. . . . 107
47 Ts (Temperature-Entropy) diagram of ACME unit 1 plant. . . . 107
48 Screenshot from CoalSIM application . . . 108
49 Screenshot from real world DCS . . . 109