HEATING UNIT CONTROLLER AT NSRC SOLARIS

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Abstract

Solaris is a third generation light source constructed at the Jagiellonian University in Krakow, Poland. The machine was designed by the MAX IV Laboratory team. Commissioning of the machine was accomplished at 2016 April and now synchrotron operates in decay mode. Two beamlines PEEM/XAS and UARPES were installed and now are being commissioned. Three more PHELIX, XMCD and diagnostic beamline have received funding and it will be installed and commissioned in range of next few years. The SOLARIS Heating Unit Controller (HUC) was designed to perform bake-out process of new installed vacuum systems. It will allow to perform activation process of undulator vacuum chamber inner coated with NEG layer and also activation process of NEG strips installed in dipole vacuum chambers. HUC is able to control independently up to six 2 kW temperature channels and two current channels. System was built based on Allen-Bradley PLC and Tango Controls. Easy access to the device is provided by the GUI design based on Taurus framework.

INTRODUCTION

The SOLARIS Heating Unit Controller (HUC) is used to bake-out the vacuum elements. It enables activation of the undulator vacuum chamber and activation of NEG strips, which are located in the dipole vacuum chambers. To bake-out the undulator vacuum chamber there are used up to six 2 kW temperature channels, while the activation of the NEG strips uses two DC power supplies. The HUC has been shown on the Fig. 1.

HUC SOFTWARE ARCHITECTURE

The HUC's software consists of three layers:

    1) Taurus based GUI,

    2) TANGO Controls devices,

    3) PLC program.

Figure 2 describes dependencies between the HUC elements. Thanks to the TANGO Controls the HUC is scalable and it is easy to fit it to the user's needs. In SOLARIS, three operating modes are used: a single temperature ramp, two synchronized temperature ramps and a current ramp. The HUC executes the segment by segment process and can be paused or turned off (***Cool Down*** procedure) at any time. If the process is turned off, the system will be slowly cooled down to the defined end temperature and according to the set slope.

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Figure 1: The SOLARIS Heating Unit Controller.

HUC application

Application is an entry point to the HUC. It allows to configure the heating process and then to monitor its progress. In order to configure the process, the user must enter the number of its segments, then define the following elements for each of them:

- **Start temperature**,

- **Stop temperature**,

- **Slope** (in °C per minute or °C per hour),

- **Segment time** (in minutes or hours) - it is automatically calculated after providing previous values or it can be set by the user if the slope is 0,

- **Output heating channels**,

- **Input analog channels** (pressure),

- **Channels temperature deviation** - if temperature between heating channels is higher than defined channels
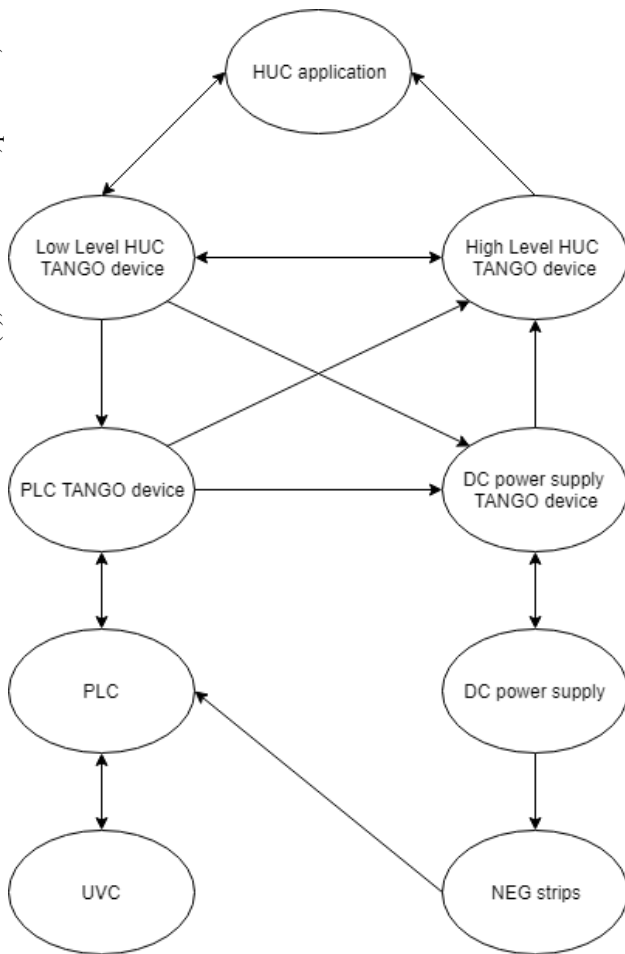
Figure 2: HUC architecture.

temperature deviation value and this state is present longer then Waiting Time the cold down process is automatically activated,

- **Setpoint temperature deviation** - if setpoint temperature is different from the average temperature on the heating section and this state is present longer than Waiting Time the cold down process is automatically activated ,

- **Maximum pressure** - if average pressure from the system is higher than defined maximum pressure value and this state is present longer then Waiting Time the cold down process is automatically activated,

- **Waiting Time** - time after which ***Cool Down*** process is activated in case of heating process interlock,

- **Execute** - it allows user to select one of the following action at the beginning of the segment:

  1. NULL - normal segment, no extraordinary actions,

  2. PAUSE - process is paused and awaits for user to resume it,

  3. DEGAS - interlocks from high pressure are bypassed, process is paused and awaits for user to resume it.

It is possible to save the configuration to a file and load it later. Application has been developed in Python using the Taurus library [1].

Low-Level HUC TANGO Device

Low Level HUC TANGO device is a central part of the HUC's software. It is responsible for the following activities:

1. realization of temperature/current ramp according to the configuration,

2. execution of actions at the beginning of segment,

3. heating process pause,

4. ***Cool Down*** process.

There is one such device for each type of process (a single temperature ramp, two synchronized temperature ramps and a current ramp in SOLARIS' case). Low Level HUC TANGO device has been developed in Python using the PyTango library [2].

High Level HUC TANGO Device

High Level HUC TANGO device is used to process data collected from the system. It calculates values such as average temperature and pressure. In addition, it is responsible for execution of interlocks defined in the configuration and cooling the system in case they do not disappear before Waiting Time. There is one such device for each ramp. This part of the HUC has been developed in Python using the facadedevice library [3].

PLC Layer

PLC is the lowest layer of the HUC control system. PLC's programs ares written in STL, FBD and LD programming languages. PLC is responsible among others for:

- PID control of the 6 temperature channels,

- PWM control of digital outputs, based on PID controllers CV outputs,

- bypasses and alarms,

- pressure and temperature monitoring.

To make the system work properly, the thermocouple connected to channel 1 must measure the temperature of the element heated by the heater working also on channel 1, a thermocouple connected to channel 2 must measure the temperature of the object heated by the heater working on channel 2, etc.

EXAMPLES OF HEATING PROCESSES

Both operating modes (temperature and current ramps) have been tested in the production environment.

Undulator Vacuum Chamber

To bake-out the undulator vacuum chamber, a work mode with two synchronized temperature ramps has been chosen. Theoretically, the process should take 114 hours 45 minutes, but in reality it took 128 hours 48 minutes. This is due to pauses during periods of too high pressure and the fact that the segment with the DEGAS action started at 23:55 and the work was resumed only the next morning. The highest setpoint temperature during this process was 200 °C and the segment with this temperature lasted 24 hours. During it only three readings (199.6, 200.3 and 200.4 °C) exceeded the range of 199.8 - 200.2 °C. The chamber heating was successful. Configuration of this process is presented in Fig. 3. Figures 4 and 5 show the evolution of the process.
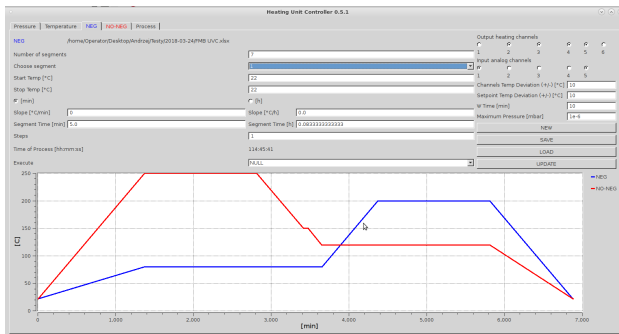

Figure 3: Configuration for undulator vacuum chamber activation process.
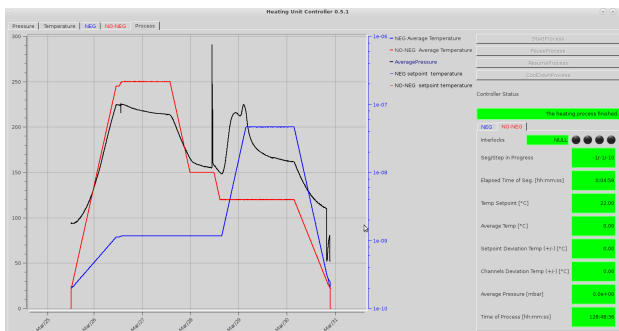

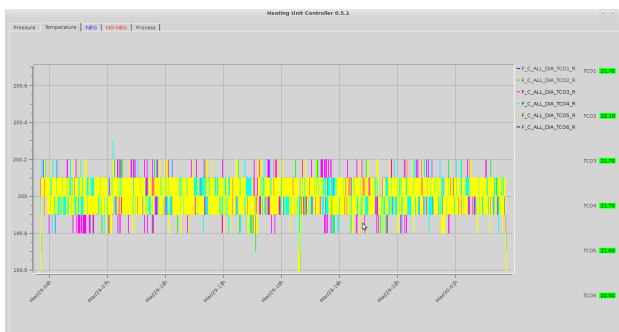Figure 4: Undulator vacuum chamber activation process.

Figure 5: Temperatures during segment with 200 °C setpoint.

NEG Strips

To activate NEG strips work mode with single current ramp has been chosen. As expected, the process took 7 hours 32 minutes. The maximum temperature measured by thermocouples is 35 degrees. Figures 6 and 7 illustrate the parameter levels over the course of the process.
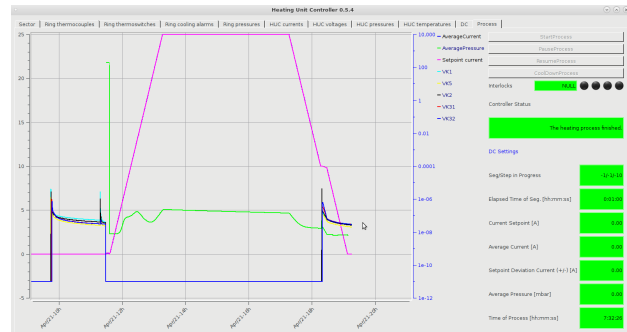

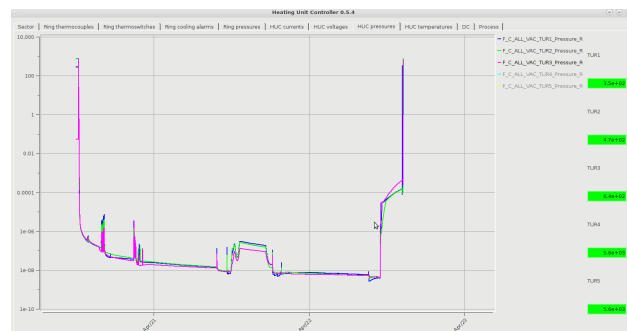Figure 6: NEG strips activation process.

Figure 7: Pressures during NEG strips activation process.

CONCLUSION

The HUC works according to the assumptions and without any problems. All software elements work stably and without crashes. Currently, it has three modes of operation, but thanks to software based on TANGO Controls it is possible to quickly and easily develop new functions. After successfully completed prototype tests, work on another copy has already started. The greatest advantage of the HUC is the optimization of the work of the vacuum section during the bake-out process of new installed vacuum systems.

REFERENCES

[1] Taurus,
    http://taurus-scada.org

[2] PyTango,
    http://pytango.readthedocs.io

[3] Facadedevice,
    http://tango-facadedevice.readthedocs.io