Developing a Graphical User Interface for Simulating NBSR Reactivity Controls

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Introduction

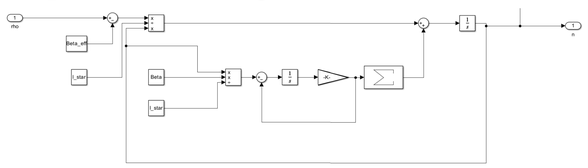
With the National Bureau of Standards Reactor (NBSR) predicted to open later this year, it is imperative to quickly train operators. A digital Graphical User Interface (GUI) could help expedite the training process, allowing for enhanced and increased training opportunities for operators. The GUI retains aspects of the control room panel relevant to shim arm and regulating rod manipulation as well as power measurements as displayed in the real panel. The back-end of the GUI is also developed, allowing for a reactor point kinetics model to be controlled by user inputs from GUI shim arm movements. The work is done in MATLAB, and leverages Simulink software capabilities.

Point Kinetics Model

$$\frac{dn}{dt} = \frac{\rho - \beta}{\Lambda} n + \sum_{i}^{14} \lambda_i C_i$$

$$\frac{dC_i}{dt} = \frac{\beta_i}{\Lambda} n - \lambda_i C_i$$

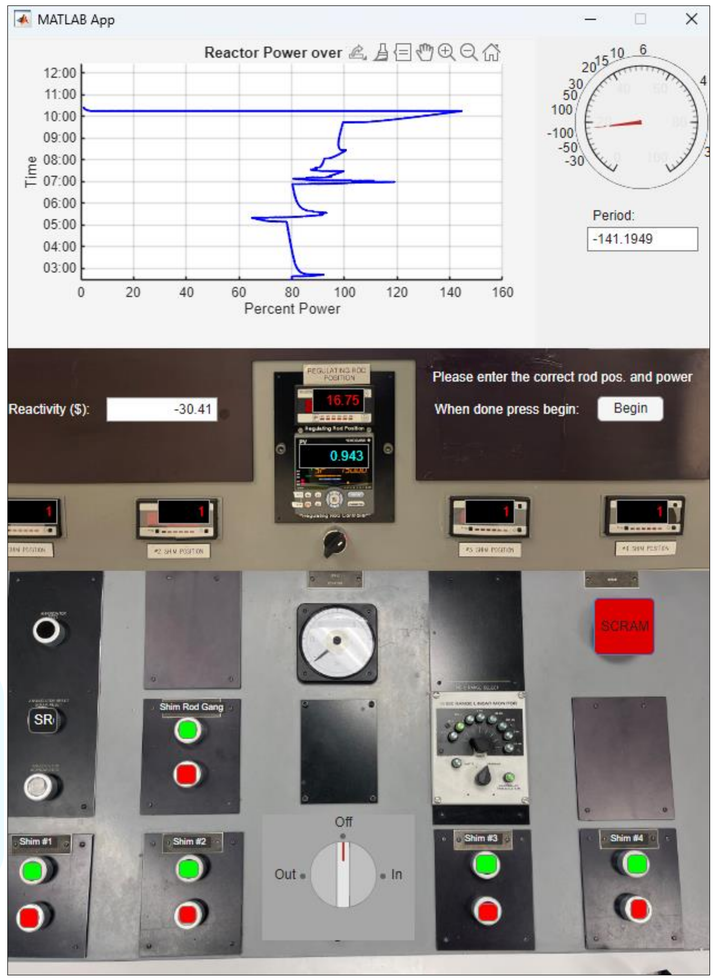
- We implemented these point kinetics equations in MATLAB's Simulink using a stiff differential equation solver, ODE15s, to ensure a small, accurate time step.
- We determined the input to these equations, change in Rho (circled), via the app designer graphical user interface (GUI) pictured to the right.



Results

The following image is of the GUI in action. The components are either pictures of the control room or replicas made with MATLAB app designer.

A scrolling time axis allows the simulation to run as long as the user wants.



The period is the amount of time it takes for the reactor's power to increase by a factor of 2.71 (e).

These displays show the operator the position of the shim arms

The GUI allows the operator to control the starting power and control rod position.

Much of the time, the operator moves the shim arms in "gang," or all together.

The SCRAM button quickly inserts the control rods, bringing power to zero.

Each of the four shim arms can individually be moved in or out, which is the cause of the smaller divots seen on the graph.

The regulating rod (Reg rod) similarly affects power, but to a much lesser degree. Operators use it to fine tune the power level.

= Out

= In

Methodology

- First, we convert change in shim arm position to worth by applying worth regressions. Then:

$$\$ = \frac{\rho}{\beta_{eff}}$$

$$\Delta\rho = \beta_{eff}(\$_1 - \$_2)$$

- We run Simulink by executing the model for one second, extract old and insert new data, then run the next second from the saved operating point.
- Shim arm worth charts:

Future Development

- Staying up to date with shim arm movement speeds and worth conversions. This model is based on 2019 data from before the reactor was closed.
- Automated control rod like in the actual reactor to keep reactivity at zero.
- More efficient code so the operator can input every quarter of a second instead of every full second

References

- *Point Kinetics Equations | Definition & Derivation | nuclear-power.com.* (n.d.). Nuclear Power. https://www.nuclear-power.com/nuclear-power/reactor-physics/reactor-dynamics/point-kinetics-equations/

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