Massachusetts Institute of Technology
Department of Nuclear Science and Engineering

22.06 Engineering of Nuclear Systems

Dynamic Behavior of PWR

PRISM Simulator Quick Reference Guide

On the Desktop open (double click) 'My Computer'

Open (double click) the c:\ drive

Open (double click) the PRISM folder

You will see a number of files, the following of which are the most important:

> PRISM.EXE - PRISM executable file needed to run the code
> PRISM.DAT - File of input data of initial conditions based on a four loop Westinghouse PWR
> PRISM.OUT - Output file of data of last run of PRISM.EXE
> PGRAPH.EXE - Graphing program which reads PRISM.OUT

Initiate (double click) the PRISM.EXE file to run PRISM.

Initial PRISM Input

When entering PRISM you are presented with eight questions. For the first three questions, the default values are sufficient. For the number of loops, enter

> <4>

for the reactor power enter

> 100%

Choose the units with which you are most familiar. Finally, use the plant default data. As you become more familiar with the program you may want to alter these inputs later.

Definitions and Acronyms

The PRISM code is littered with shortened terminology and reactor specific nomenclature. To eliminate confusion, the following list is supplied from the Manual, with some additions:

The NSSS View Screen

NSSS stands for "Nuclear Steam Supply System". The **NSSS View** screen will appear first after the **TITLE** screen (See Figure #2 in Appendix A).

This screen provides a dynamic graphic mimic of the NSSS including the Reactor Coolant System (RCS) and steam generators. In addition, the following parameters are displayed:

- FW   Feedwater flow rate in kg/s or lbm/s

- FL   RCS loop flow rate in % of rated flow
- HTR   Pressurizer Control (P) and Backup Heaters (B)
- L   Pressurizer level in %
- MWTH   RCS thermal power in MW
- NL   Steam generator narrow-range level in %
- P   Steam generator or pressurizer pressure in MPa or psig
- RXPWR   Reactor power (fission power plus decay heat) in % of full power
- SI Flow Safety Injection flow in kg/s or lbm/s
- SPRY   Pressurizer spray flow rate in kg/s or lbm/s
- ST   Steamline flow rate in kg/s or lbm/s
- SUBCL   RCS subcooling margin in degrees C or F
- SURG   Pressurizer in-surge flow rate in kg/s or lbm/s
- TAVG   RCS average temperature in degrees C or F
- TC   RCS cold leg temperature in degrees C or F
- TFW   Feedwater temperature in degrees C or F
- TH   RCS hot leg temperature in degrees C or F
- TL   Pressurizer liquid temperature in degrees C or F
- TS   Pressurizer saturation temperature in degrees C or F
- TV   Pressurizer vapor temperature in degrees C or F
- VL   Reactor vessel level in %
- WL   Steam generator wide-range level in %

In the upper right-hand corner of the title menu bar, the current simulation time is displayed in "hours:minutes:seconds". To the left of the simulation time, one of the following simulation statuses is displayed:

- REAL   This indicates that the simulation is running in real time
- FAST   This indicates that the simulation is in fast time: the simulation will progress as fast as the microprocessor can calculate
- FREEZE This indicates that the simulation is frozen

To the left of the simulation status the word *ALARM* will appear when an alarm condition exists. The alarms can be viewed on the **ALARM PANEL** screen discussed later in this chapter.

OPERATIONAL TRANSIENTS

Exercise 1: Approach to Criticality

<u>Objective</u>

Use PRISM simulator to verify the principles of subcritical reactor response and criticality approach:

- Steady state subcritical multiplication count rate / Reactivity relationship (count rate doubling)
- Identification of criticality

<u>Theory review</u>

Show N (neutron population) vs. t for the following 5 cases:

1) Critical reactor, no neutron sources
2) Supercritical reactor, no neutron sources
3) Subcritical reactor, no neutron sources
4) Subcritical reactor with neutron sources
5) Critical reactor with neutron sources

Subcritical multiplication at steady-state (asymptotic values):

$$N \propto S/(1-K_{eff})$$

$$N_1/N_2 \equiv (1-K_2)/(1-K_1) \approx (-\rho_2)/(-\rho_1)$$

S is the intensity of the neutron sources (e.g., Pu-Be, Pu-Ra). Why do we need neutron sources to start up?

This equation also shows that if the distance to criticality is halved, the count rate is doubled.

Show plot for K vs. t and N vs. t for approach to criticality.

Set up PRISM as follows:

1.	Start the program and enter initial and control parameters as follows:

    Total simulation time = 150 min. Accept (Y=return / N=No)? <ENTER>
    Time interval for hardcopy data = 60 sec. Accept (Y=return / N=No)? <ENTER>
    Time interval for screen data display = 1 sec. Accept (Y=return / N=No)?
    <ENTER>
    Enter number of RCS loops simulated (1 to 4): <1>
    Enter reactor power (HFP=100;HZP=0): <0>
    Select display units (0=SI;1=British): <0>
    Use default plant data. Accept (Y=return / N=No)? <ENTER>
    Are all input correct. Accept (Y=return / N=No)? <ENTER>

2.	Silence PRISM alarms for exercise <d>

3.	Select primary indications screen <F3>
We will focus on the following four indicators on this page: "Source Range (SR)
Power", "Step" (in the Control Rod Drive panel), "Startup Rate", "Net Reactivity".

4.	Record initial count rate from Source Range instrument_____

    Record initial control rod height (bank and steps)   ———   ———

    ———   ———

    Record reactivity value   ———

5.	Shift to fast time <F9>

6.	Pull control rods <UP cursor arrow> until negative reactivity is half of the value
    recorded in item 4. Record reactivity   ———

7.	Wait until steady-state is achieved, then record count rate from Source Range
instrument   ———

    Record change in count rate (Item 7 – Item 4)   ———

    Record control rod height (bank and steps)   ———   ———

    ———   ———

    Compare count rates in Items 4 and 7. You should note that the count rate has

    doubled, in accordance with the theory.

8   Switch to Fast Time. Again pull control rods <UP cursor arrow> until negative reactivity is half of the value recorded in item 6. Record reactivity
_____

9. Wait until steady-state is achieved, then switch to real time, then record count rate from Source Range instrument   _____

Record change in count rate (Item 9 – Item 7)   _____

Record control rod height (bank and steps)   _____   _____

_____   _____

Compare count rates in Items 7 and 9. You should note that the count rate has again doubled.

10. Final pull to, and recognition of, criticality.

a. Place a small piece of opaque tape (or a Post-it note) over the reactivity indicator so it cannot be seen. This is done to prevent you from using the reactivity indicator to identify criticality.

b. Pull control rods until 120 steps on CR Bank D. Is the reactor critical? Criticality can be identified using start-up rate remaining positive and a continuing increase in count rate.

c. The reactor should still be subcritical here. Wait until you reach steady-state (i.e., zero start-up rate).

d. Pull Bank D another 20 steps, and then observe parameters to see if criticality has been achieved. If not critical, continue to pull Bank D, 20 steps at a time. Call the reactor critical when you observe the proper indications (increasing count and steady positive Startup Rate). A pull-and-wait methodology, moving rods about 20 steps should be used to ensure that criticality is not significantly overshoot.

e. Quickly record the following information:

Control rod height (bank and steps)   _____   _____

_____   _____

Count rate at criticality   _____

f. Remove the tape from the reactivity indicator and record its value _____

g.   The actual rod height at which the reactor went critical was 160 steps on Bank D. Also, the value of reactivity should be near 0. How close were you?

Optional Exercise (do it on your own at home)

11. Start over with the same initial conditions:

reset PRISM   <r>

Select primary indication screen   <F3>

Shift to fast time   <F9>

We want to demonstrate now that criticality does not depend on the time it takes to pull the control rods out, but just on the control rods final position. That is, the control rod position at which criticality is achieved is independent on how fast or slow one has reached that position.

Pull directly to 160 steps on Bank D without stopping.

1. Pull rods to 160 steps on control bank D. When the rod pull begins, do not stop pulling until 160 steps on control rod bank D is reached.

2. At 160 steps on control rod bank D, verify reactivity is 0 and record the count rate _____

3. Compare the critical count rate to count rate logged in Item 10. Since a pull and wait approach was used above, there was increased time for subcritical multiplication to occur. Therefore the count rate should have been much bigger than in this case where rods were rapidly pulled to the critical position.

Exercise 3: Change of Grid Power Demand

This exercise illustrates the "load following" capability of a PWR.
This transient is characterized by the following sequence of events:

1. The grid demands more power
2. Higher steam flow rate is supplied to the turbine
3. As the outgoing steam rate is greater than the incoming feedwater rate, the pressure and temperature in the secondary side of the steam generator (SG) decrease
4. Primary coolant cold leg temperature (T_c) decreases
5. Colder and denser water enters the core
    - ⇨ more efficient neutron moderation
    - ⇨ reactivity increases
    - ⇨ core power increases
6. Fuel temperature increases
    - ⇨ neutron capture (parasitic absorption) increases (due to the Doppler effect)
    - ⇨ reactivity decreases
7. New steady-state condition at a higher power is reached

Start PRISM with:
- – default values, where possible
- – 4 loop
- – 90% power
- – SI units

Go to the Primary Plant Control Panel (F3)

Set Control Rod Drive mode to "manual", this will prevent an automatic insertion or removal of reactivity during the transient and will enable a "cleaner" observation of the natural load following capability of the reactor.

Record the values of:
- o Reactor Power (%) _____
- o Net Reactivity (pcm) _____
- o Cold Leg Temperature (°C) _____
- o Hot Let Temperature (°C) _____
- o ΔT rise in the core (°C) _____
- o Pressurizer (PRZ) Level (%) _____

Go to the Secondary System Control Panel (F4)

Record the Secondary Pressure (MPa) _____

Freeze time (F10)

Following the instructions at the bottom of the screen, set the Turbine Load to 1065 MWe and the rate of change to 10% of full power per minute.

Restore real time (F8)

Observe the increasing Steam Flow Rate supplied to the turbine and the slightly decreasing pressure in the secondary side of the SG.

Go to the Primary Plant Control Panel (F3)

Observe:
- the decreasing Cold Leg Temperature
- the positive Net Reactivity
- the increasing Reactor Power

Switch to Fast Time (F9) and run until the transient is over, a couple of minutes after the Net Reactivity returns to 0 will do.

Record the value of:
- o Reactor Power (%) _____
- o Net Reactivity (pcm) _____
- o Cold Leg Temperature (°C) _____
- o Hot Let Temperature (°C) _____
- o ΔT rise in the core (°C) _____
- o Pressurizer (PRZ) Level (%) _____
- o Secondary Pressure (MPa) _____

Note that:
- the Reactor Power has increased
- Cold Leg and Hot Leg Temperatures have decreased
- However, the ΔT rise in the core (which is proportional to Reactor Power) has increased
- Pressurizer Level is lower because the average temperature in the RCS is lower; normally, the automatic Control Rod System and CVCS operate such that the average temperature of the primary coolant does not deviate too much and the PRZ Level is kept at a more or less constant value. If desired, this exercise could be run without setting the Control Rod System to "manual" for comparison

ACCIDENTS

Exercise 4: Reactivity Excursion

Set reactor at 100% power in PRISM

Freeze time

In the "Malfunction" menu select "Reactivity Accident" with +100 pcm reactivity step change and 5 s delay

Do you expect the reactor to trip? If so, upon what signal?

Run the simulation and observe what happens. Go to the ALARM panel and identify the first trip signal (high neutron flux)

Repeat the simulation at 30% power. Does the reactor trip?

Repeat the simulation at 30% power and +300 pcm. Does the reactor trip now?

Exercise 5: Loss of Feedwater

Set reactor at 100% power in PRISM and freeze time

In the "Malfunction" menu select "Main FW isolation" with 5 s delay

Predict the reactor behavior upon isolation of the main FW lines.

Run the simulation and watch T and P increase in the primary system until reactor trip on high-P signal.

How did power change prior to scram?

After reactor trip how is FW supplied to the SGs?

Exercise 6: Steam Line Break

Set reactor at 100% power in PRISM and freeze time

In the "Malfunction" menu select "SteamLine Break bf. MSIV" in Loop 3 with break fraction 20% and 5 s delay

Run the simulation and watch reactor power increase until reactor trip.

Why did the power increase following the steam line break?

What happened in the PRZ following the steam line break?

Important takeaway
    Exceeding specified set points for reactor pressure, neutron flux and neutron flux rate, pressurizer level, SG level, main coolant flow, etc., will cause the reactor to trip.

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