PWR Steady-State Topics and Exercises

Information Systems Laboratories, Inc.

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Objectives

The objective of our discussion and exercises is to provide insights in obtaining steady-state conditions using the PWR power plant model. At the end of this session, the PWR model will be ready to run a cold leg small-break LOCA.

Topics

- **Managing Multiple Simulations in a Single Model**
- Achieving Steady-State Target Conditions
- Debugging TRACE Input Errors
- Break Modeling & Validation
- Reflood Configuration and Steady-State Calculation

One Model – Multiple Simulations

Multiple accident simulations for a nuclear plant, such as an LBLOCA and an SBLOCA, may be performed using a TRACE model. Accidents may assume different initial and boundary conditions (e.g., power level, ECCS flow assumptions, etc.)

Maintaining multiple models is inefficient when model updates are required, and can lead to inconsistencies.

One Model – Multiple Simulations

How do you conveniently maintain multiple accident configurations within a single model?

- Control Systems*
- Restart Input File*
- SNAP Numerics

* Discussed only briefly

One Model – Multiple Simulations

Control Systems can be included in a model to manage differences between simulations:

Advantages:

- Single Base TRACE Input File
- Minimal model reconfiguration via restart file (if well organized)

Disadvantages:

- Limited Scope - Some properties are not controllable
- Less Maintainable – Can lead to complex control systems. SNAP layout/annotation can help significantly.

One Model – Multiple Simulations

Restart files can be used to manage differences between simulations:

Advantages:

- Flexibility - Most components can be updated via restart files
- Simple Reconfiguration – When combined appropriately with control systems
- Model changes are documented (They are explicit in the restart file)

Disadvantages:

- Complexity – Restart files can become large and complex if components are modified
- Less Maintainable – Corrections in base model may be unintentionally overwritten in restart deck
- Fragile – Changes in base deck can cause restart to be incompatible
- Simulation differences are not incorporated in the base model
- Restart overwrites initial conditions for components in restart file

One Model – Multiple Simulations

SNAP Numerics is a more recent option that can be used to manage accident simulation differences:

Advantages:

- Flexibility – Most model parameters are configurable via Numerics (but not all)
- Maintainability – Differences are included in the base SNAP model
- Robustness – Changes to model do not typically impact Numerics
- Simplicity – Can simplify implementation for some configuration changes
- Differences are included in base SNAP model

Disadvantages:

- One SNAP Model, but multiple TRACE input files
- There is not a way from within SNAP to see where Numerics is used in the model. (However, you can export an input file with Numerics preserved, which shows where Numerics variables are used in the model.)
- The SNAP UI is not very good for managing a large number of parameters

Storing Multiple Steady-States

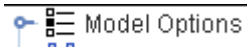
SNAP allows multiple sets of steady-state conditions to be stored in the SNAP model. This is useful when separate accident simulations begin from different steady-state conditions.

The following exercise demonstrates the process of saving initial conditions.

Open the ‘Day3/Afternoon/PWR/1_Numerics' folder and double click on 'PWR1-SS-N.med' to open the example PWR model.

Saving SS Conditions Exercise

The initial conditions in the model are currently best estimate conditions. Save the best estimate initial conditions by doing the following:

1. In the model click on 

2. In the properties window click  on 

3. In the 'Manage Initial Conditions' dialog click 

4. On the item that appears in the initial conditions list, double click on 'unnamed'. Replace 'unnamed' with 'Best Estimate' and click 

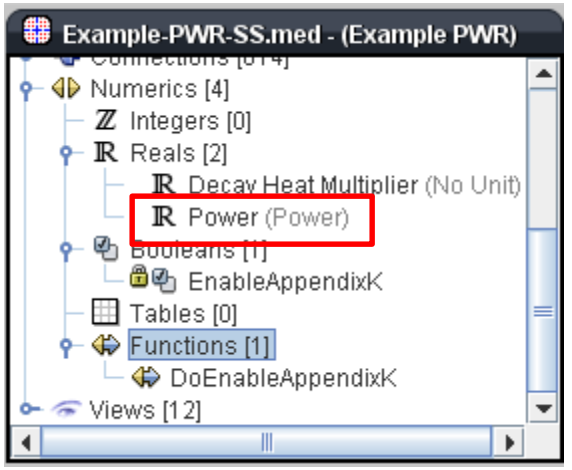
This makes it possible to restore best estimate conditions even after other initial conditions have been imported into the model.

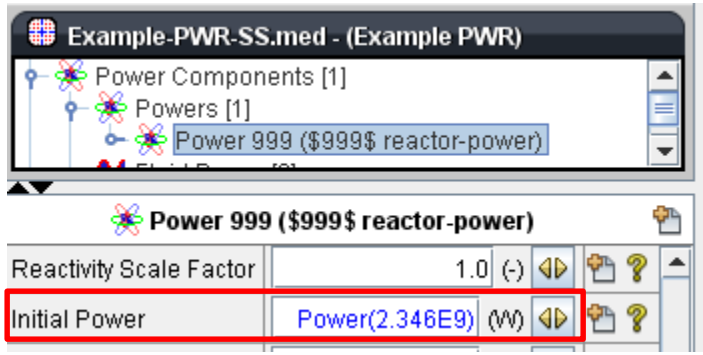
Do not close the PWR1-SS-N.med file

SNAP Numerics

What is SNAP Numerics?

- SNAP Variables – Used to configure model parameters
- Programming tools used to configure these variables:
  - Python (Built in)
  - Matlab
  - Mathcad





Python

- Python is a popular scripting language
- You don't need to know much Python to be effective in SNAP!
- There are many simple tutorials available on the web.

Brief Python Basics

- # is used before comments
- Indentation is used to delineate code blocks (such as for 'if')

```
# Get variable that tells whether Appendix K
# Options are used.
isAppendixK = GetVariable("EnableAppendixK")

decay_heat_multiplier = 1.0
power = 2.3E9

if isAppendixK == True:
    decay_heat_multiplier = 1.2
    power = power*1.02

SetVariable("Decay Heat Multiplier", decay_heat_multiplier)
SetVariable("Power", power)
```

Numerics Exercise

The PWR model contains fictional best estimate conditions. Configure the model via Numerics to use power that is 102% of best estimate conditions (an Appendix K assumption).

Refer to the Day3 Afternoon Exercise: **PWR Model – Numerics Exercise** located at

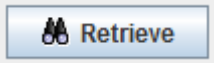
Day3\Afternoon\PWR\1_Numerics\NumericsExercise.pdf

The PWR model used to demonstrate saving initial conditions (PWR1-SS-N.med) will be used for the Numerics exercise.

Retrieving SS Conditions Exercise

In the Numerics exercise just completed, a steady state calculation was made with the power and decay heat multiplier set to Appendix K values. The initial conditions generated in that run will be saved by doing the following steps:

1. In the model right click on the 

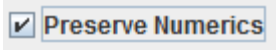
tab and click on “Manage Initial Conditions”
2. In the popup window click on the 

button.
3. In the “Initial Conditions” dialog click on the button that will retrieve data from “A Submitted Run”.
4. Select the trcxtv file of the PWR1-SS-Numerics calculation

Instructions continue on next page

Retrieving SS Conditions Exercise

Retrieve SS Conditions Exercise (continued):

5. Click on the Preserve Numerics box 

6. Click on the Load Timesteps box 

7. Highlight the last row of timestep data that appears and click 

8. In the 'Manage Initial Conditions' dialog click on 

9. On the item that appears in the initial conditions list, double click on 'unnamed'. Replace 'unnamed' with 'Appendix K' and click 

This makes it possible to restore Appendix K conditions even after other initial conditions have been imported into the model.

Restoring SS Conditions Exercise

Initial conditions from “Best Estimate” can be restored by doing the following steps:

1. In the model right click on the 

tab and click on “Manage Initial Conditions”
2. In the popup window click on the index named “Best Estimate”

Index	Name
1	Best Estimate
2	Appendix K

3. Click on 

, then click OK

The initial conditions from “Best Estimate” are now loaded and can be used for simulations.

Topics

- Managing Multiple Simulations in a Single Model
- **Achieving Steady-State Target Conditions**
- Debugging TRACE Input Errors
- Break Modeling & Validation
- Reflood Configuration and Steady-State Calculation

Steady-State Challenge

In achieving steady-state conditions, there are multiple target conditions that need to be achieved simultaneously.
(e.g., Loop Flows, Primary Side Pressure, Tave, etc.)

Parameters changed to achieve one target condition often affect other target conditions.

Steady-State Challenge

How do you efficiently achieve all steady-state target conditions?

Manually adjusting parameters to achieve steady-state is a time consuming process that has to be repeated each time targets change. Typically this requires several iterations.

Control Systems can be used to adjust control parameters automatically in order to achieve steady-state target values. Targets can typically be achieved in a single steady-state run.

Steady-State Challenge

How do you efficiently achieve all steady-state target conditions?

- Manual Adjustment
  (Some parameters are not controllable)
- Constrained Steady-State (CSS)
  (Built in Control Systems)
- User Defined Control Systems

Manual Adjustment

Some parameters are not adjustable via control systems and must be adjusted manually.

It is recommended that manual adjustments be made after control systems have been implemented for other steady-state targets.

Note that K losses, which where not controllable in early versions of TRACE, are now controllable.

Constrained Steady-State (CSS)

TRACE has built-in steady-state control systems that can be enabled for a few common cases. These include:

- CSS Type 1 - Controls Pump speed to achieve a target mass flow or velocity
- CSS Type 2 - Controls Valve area to achieve a mass flow or upstream pressure

- Simple to add – 1.) Specify Component and 2.) Choose Target Value.
- Achieves steady-state fairly rapidly
- Limited to a few cases
- Not usable during transient

CSS Exercise

Add a constrained steady state controller to PUMP 315

- Set the target mass flow to 4259 kg/s
- Set the max pump speed to 200 rad/s

(See CSS_Exercise1.pdf)

Refer to the Day3 Aternoon Exercise: **Constrained Steady-State Exercise** located at Day3\Afternoon\PWR\2_Achieving_Steady-State\CSS_Exercise1.pdf

User Defined Control Systems

A typical control system is comprised of a Signal, an Error Signal, a Control System, and a Control Parameter. The control system adjusts the control parameter to minimize the error. For simple control systems, there should be a monotonic steady state relationship between the control parameter and the error signal over the range of control.

Signal

(Temperature)

Error Signal

(Δ from Target Temp.)

Control System

(Hand)

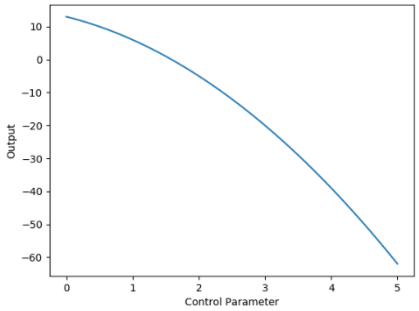
Control Parameter

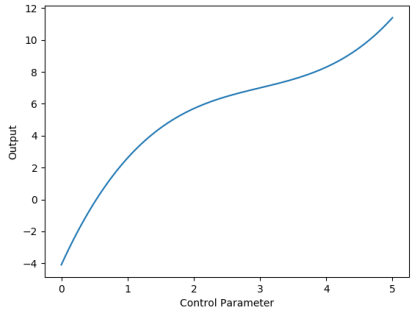
(Faucet Handles)

User Defined Control Systems

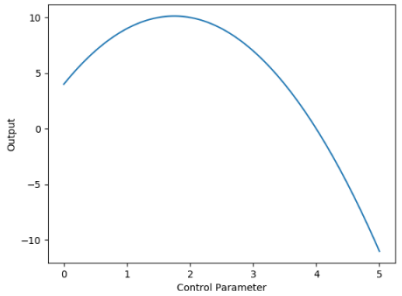
A monotonic steady state relationship between control and output requires that (1) for a fixed control parameter value the output to go to steady state and (2) as the control parameter is increased the steady state output value always increase or always decreases.

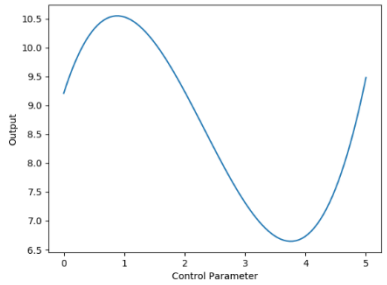
Monotonic





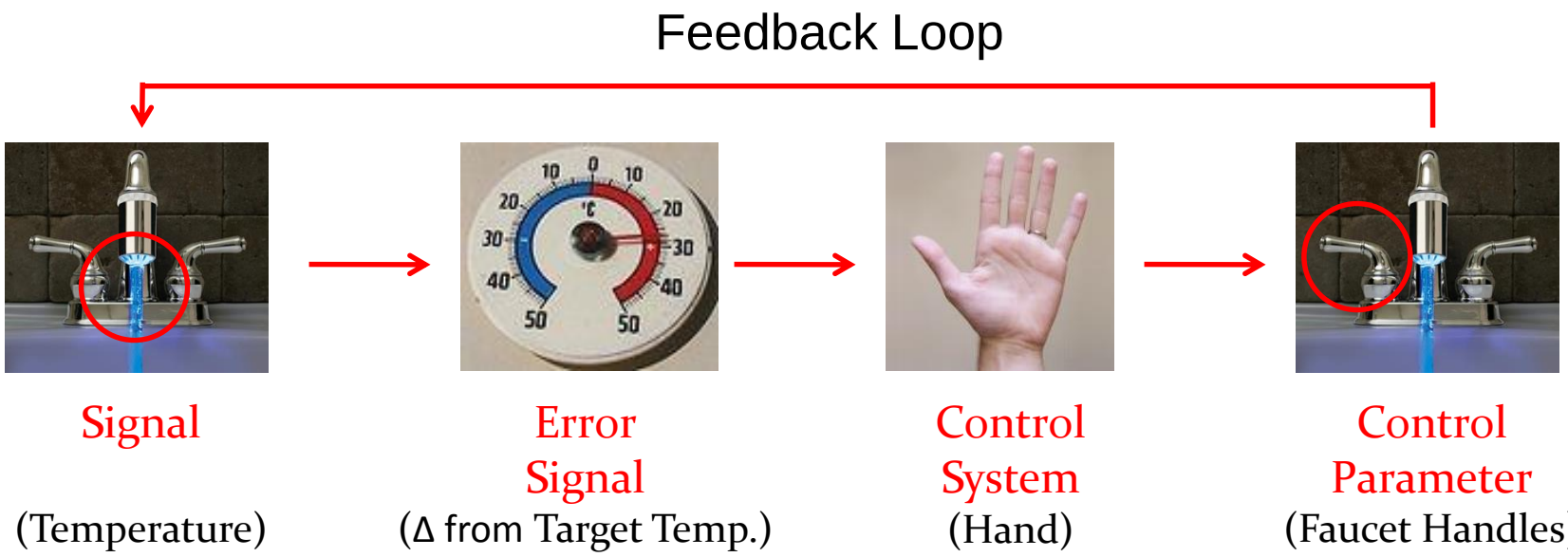
Not Monotonic





Control System Stability

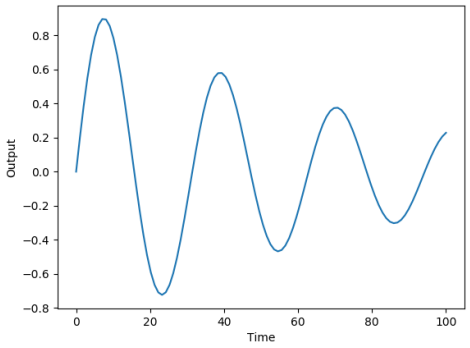
The control system acts on a feedback loop. When the control parameter changes, there is a **delay time** before the error signal measures the response (e.g., the time for the water to go from the valve to the faucet exit).



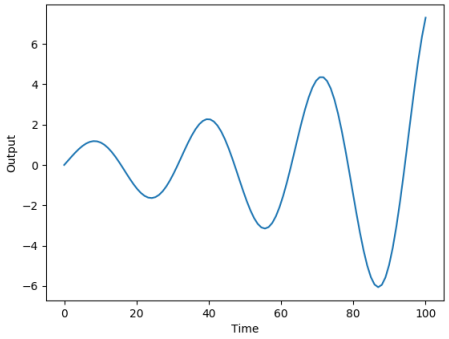
Control System Stability

- If the control parameter is adjusted too quickly (overcontrolled), it can overshoot the target and take several oscillations to settle.
- If it is overcontrolled too much, the error signal can amplify and become unstable (think feedback through a microphone).
- If the parameter is adjusted too slowly (undercontrolled), the time to reach steady state can be excessive. No oscillations are usually visible.

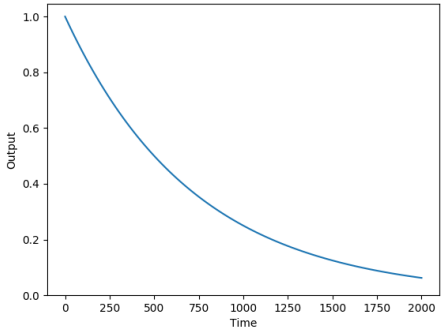
Overcontrolled



Excessive Overcontrol (Unstable)



Undercontrolled



Control System Theory

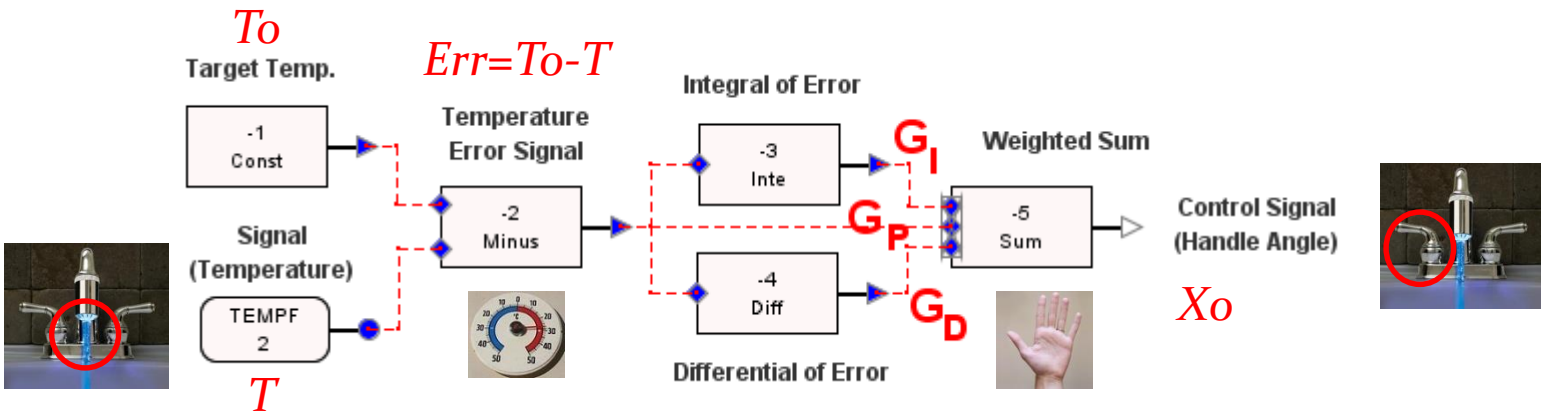
A common controller type is the PID controller. The control signal value is adjusted:

- (P)roportional to the Error, and proportional to the
- (I)ntegral of the Error, and the
- (D)ifferential of the Error

$$Xo = G_P Err + G_I \int Err \cdot dt + G_D \frac{d(Err)}{dt}$$

Control System Theory

One of the challenges is choosing the P, I, & D Gains to optimize the time to reach steady-state. If the Differential gain G_D is set to zero, this is called a PI controller. If Integral gain G_I is also set to zero, this is called a P controller.



$$Xo = G_P Err + G_I \int Err \cdot dt + G_D \frac{d(Err)}{dt}$$

Control System Theory

The control system needs to supply a Control Signal value (e.g., Faucet Handle Position), which defines the form of the control logic. However, we are interested in the responsiveness and effectiveness of the controller, so the derivative of the control system equation is more convenient to examine.

P Controller: $$\frac{d(Xo)}{dt} = G_P \frac{d(Err)}{dt}$$

PI Controller: $$\frac{d(Xo)}{dt} = G_P \frac{d(Err)}{dt} + G_I Err$$

PID Controller: $$\frac{d(Xo)}{dt} = G_P \frac{d(Err)}{dt} + G_I Err + G_D \frac{d^2(Err)}{dt^2}$$

Note that the Proportional (P) controller reaches equilibrium (i.e. $d(X_o)/dt = 0$) when the **Change in Error** , not the Error, goes to zero. Proportional controllers often settle at a constant error. Thus proportional controllers are often a poor choice. **The integral term is necessary to make the error go to zero.**

Gain Guidelines

The G_P, G_I, and G_D gains should all be positive or negative. The sign of the gains depends on whether there is a positive or a negative slope correlation between the control variable *Xo* and error signal *Err*.

- A positive slope correlation indicates negative gains are needed, and a negative slope correlation indicates positive gains are needed.
- If the sign of the gains is chosen incorrectly, then the error will typically diverge from zero without exhibiting persistent oscillations about the target value.
- If the error signal shows persistent oscillations about the target value, this suggests that the sign on the gains is correct, but the gain is too large causing overshoot (i.e. overcorrection).

Initial Estimates on Gp Gain

PI controllers work best for systems that have a nearly linear relationship between the control and output parameter (i.e. the slope does not vary by large magnitudes).

Since the control system can become unstable, or take a long time to reach the target value, if gains are not optimized, it is useful to have some sense of how to set and optimize gains to avoid instability and get reasonable performance.

In the slides that follow we will discuss how to estimate the stability limit. Later in todays exercises we will talk about the Zeigler-Nichols method for getting reasonable control performance.

Initial Estimates on Gp Gain

To simplify the problem, lets assume a simple linear relationship between the control parameter X_o and the output parameter T expressed in terms of $Err = T - T_o$ (where T_o is the target steady state value).

$$X_o = A \cdot Err$$

Initial Estimates on Gains

Now consider the proportional controller equation $X_o = G_p Err$. Let's add indexes to indicate time steps:

$$X_{o,i+1} = G_p Err_i$$

This states that the Err at time step i determines the control value at time step $i + 1$. Now assume that the control system acts almost instantly such that the steady state value $X_o = A \cdot Err$ is reached between each time step. Then can make the substitution:

$$A \cdot Err_{i+1} = G_p Err_i \qquad or \qquad Err_{i+1} = \frac{G_p}{A} Err_i$$

Note that if $|G_p/A| > 1$ then the **error grows each time step** and the control system is unstable (i.e., $|Err_{i+1}| > |Err_i|$).

Initial Estimates on Gains

Thus for a very fast controller with the approximate relationship $X_o = A \cdot Err$, the stability limit for G_p is near:

$$\left|\frac{G_p}{A}\right| < 1 \qquad or \qquad |G_p| < |A|$$

For controllers that take many time steps to reach equilibrium, the controller can remain stable for values of $|G_p|$ that are (possibly much) larger than $|A|$. However, the slope relationship between X_o and Err is a good starting point for determining the stability limit for $|G_p|$.

Note that according to our guideline for selecting G_p, the sign of G_p should be opposite of the sign of A.

Initial Estimates on Gains

For a nonlinear relationship between the control variable and the output, the smallest slope is the most limiting from a stability perspective. If the slope changes significantly, the controller will perform poorly over part of the control range.

A function control block can be used to linearize the relationship between control signal and the error and get better performance over a wider range of control values.

Initial Estimates on Gains

We don’t cover the method for calculating the nonlinear relationship between the control and output variable in the exercises, but the basic technique is to slowly vary the control variable upward, then downward. If the control is adjusted slowly enough, plotting the control variable value vs. the output value will trace out the relationship.

Initial Estimates on Gains

To estimate the relationship between X_o and Err, a control parameter step function is useful. To apply a step function:

1. Set the control parameter X_o to a constant value and run the simulation till the output Err is at steady state. The SS points will be called $X_{o,1}$ and Err_1.
2. Use a function block to implement a step change in the control parameter after steady state is reached. Then let the system run till the new steady state is reached. The SS points will be called $X_{o,2}$ and Err_2
3. Approximate A in $X_o = A \cdot Err$ as:

$$A = \frac{X_{o,2} - X_{o,1}}{Err_2 - Err_1} = -G_{p0}$$

Initial Estimates on Gains

Note that initial estimate of the stability limit for the gain is not necessarily a good estimate. The actual stability limit may be a few orders of magnitude larger. However, it does provide a lower bound to start with.

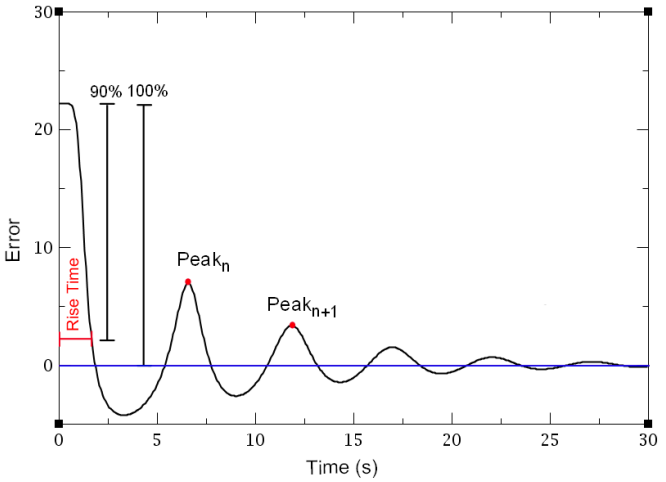
$$A = \frac{X_{o,2} - X_{o,1}}{Err_2 - Err_1} = -G_p$$

This is an initial estimate of G_p that can be used in Zeigler-Nichols tuning method discussed later.

Refer to the Day3 Afternoon Exercise: **Initial Gain Stability Estimate Exercise** located at Day3\Afternoon\PWR\2_Achieving_Steady-State\GainEstimate_Exercise2.pdf

PID Characterization

Four major parameters are used to characterize a PID controller:



1. Rise Time – The initial time it takes for the Error to be reduced by 90%.
2. Overshoot – |Error Peak (n+1)|/|Error Peak (n)|

   For oscillatory error

2. Settling Time – Time it takes for Error to stay within 99% of equilibrium.
3. Steady-State Error Offset

PID Tuning

Assuming the sign of the gains is correct, the typical effect of increasing $|G_P|$, $|G_I|$, and $|G_D|$ is summarized in the Table below:

	Rise Time	Overshoot	Settling Time	S-S Error
$\|G_P\|$	Reduce	Increase*	-	Increase
$\|G_I\|$	Reduce	Increase*	Reduce /(Inc.*)	Remove
$\|G_D\|$	-	Reduce*	Reduce	-

*When overcorrection occurs signaled by oscillations

General Tips:

- Use non-zero G_I to achieve the correct target.
- Increase G_P or G_I if convergence is slow and there is no overshoot
- Decrease G_P or G_I if oscillations are noticeable & damping is slow
- G_D is often not included, but if added it may improve the settling time (Warning - Differential term will amplify noise in the Error signal)

PID Configuration

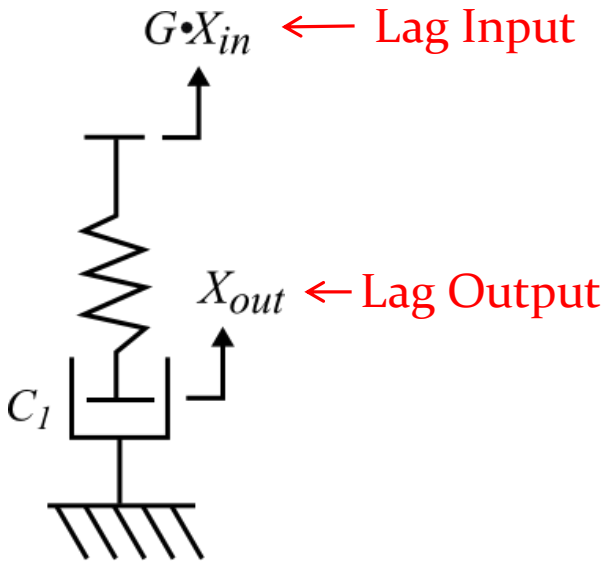
The Ziegler-Nichols method is a simple structured tuning technique for PID controllers. The Steps are:

1. Set the Integral and Differential gains (G_I and G_D) to zero
2. Tune the Proportional gain (G_P) till the Error oscillates with constant amplitude (Borderline unstable) – This is the stability limit G_{PMax}
3. From the Error response take the oscillation Period T_P (Peak to Peak time)
4. Depending on the type of controller desired, modify the gains based on the following Table:

	G_P	G_I	G_D
P Controller	$0.5\ G_{PMax}$		
PI Controller	$0.45\ G_{PMax}$	$1.2\ G_{PMax}/T_P$	
PID Controller	$0.6\ G_{PMax}$	$2\ G_{PMax}/T_P$	$T_P\ G_{PMax}/8$

Reducing Noise

When the input signal has a significant amount of noise it is often desirable to filter out the noise. A lag Control Block [26] can be added to the PID controller output to filter noise effects. The lag control acts like a spring-damper system. CBCON1 (C_1) is the lag (or damping) constant.

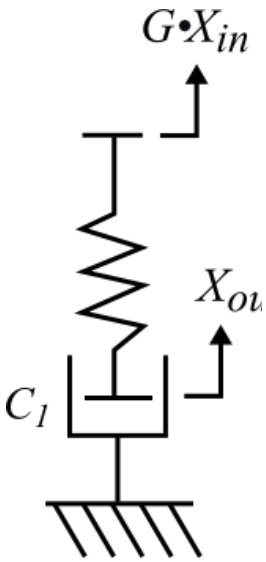


Lag Control Equation:

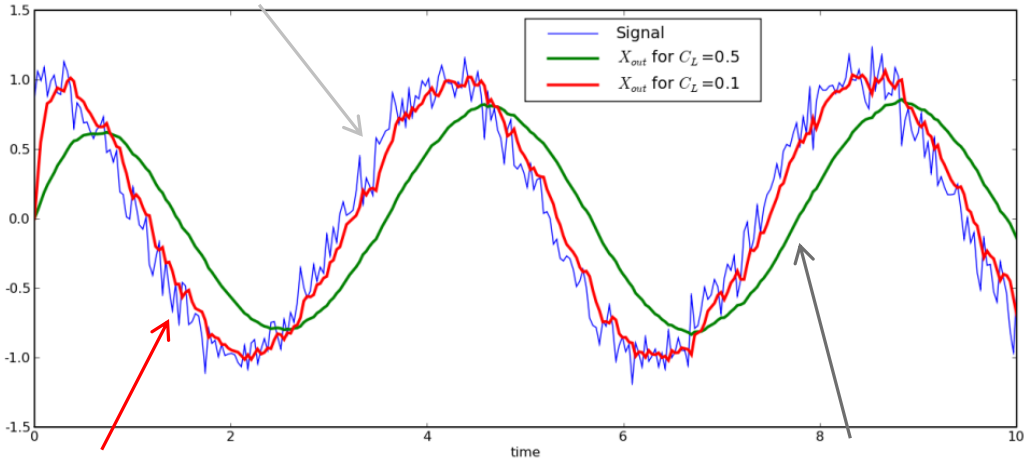
$$\underbrace{C_1 \cdot \frac{dX_{out}}{dt} + X_{out}}_{\text{Spring-Damper Terms}} = \underbrace{G \cdot X_{in}}_{\text{Forcing Term}}$$

Reducing Noise

Increasing the lag constant C_1 increases the filtering of the high frequency noise, but reduces the responsiveness of the control signal.



Sinusoidal Signal with Noise



Lagged Signal with Small Lag Constant (C_1=0.1)

- Small Response Delay
- Noticeable Noise

Lag Signal with Larger Lag Constant (C_1=0.5)

- Significant Response Delay
- Noise mostly filtered out

PID with Lag Tuning

Assuming the sign of the gains is correct, and that a lag control of Gain 1 and Lag constant C_L is added to the PID output, the typical effect of increasing $|G_P|$, $|G_I|$, $|G_D|$, and C_L is summarized in the Table below:

	Rise Time	Overshoot	Settling Time	S-S Error	Noise
$\|G_P\|$	Reduce	Increase*	-	Increase	-
$\|G_I\|$	Reduce	Increase*	Reduce or Increase*	Remove	-
$\|G_D\|$	-	Reduce*	Reduce	-	Increase
C_L	Increase	Reduce*	Increase or Reduce*	-	Reduce

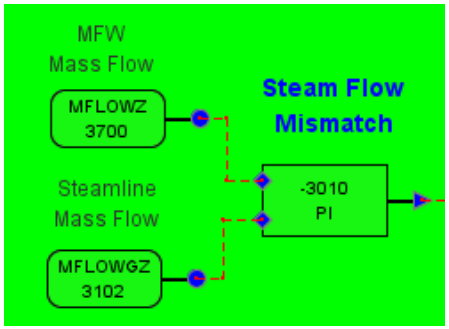
*When overcorrection occurs signaled by oscillations

TRACE PI and PID Controls

For convenience, TRACE includes PI and PID control blocks. The PI and PID controls include a lag block. The PI control is characterized below:

X_{in}

$X_{\otimes}$



	Type	[200] PI controller
	Description	<none>
G	Gain	1.0 (-)
	Minimum	-1.0 (-)
	Maximum	1.0 (-)
$X_{\otimes}$	Constant 1	0.0 (-)
X_o	Constant 2	0.049264191 (-)
T	Delta T	100.0 (s)
C_L	Time Constant	2.0 (s)

$$Target\ Value = X_{\otimes} \qquad Err = X_{\otimes} - X_{in}$$

$$C_L \cdot \frac{dX_{out}}{dt} + X_{out} = G\left(Err + \frac{1}{T}\int Err \cdot dt \right)$$

X_o is the initial value of X_{out}

* The target $X_{\otimes}$ can be specified via a control block (ICB2). Otherwise it is defined via PI control constant 1 (CBCON1)

Conversion from G_P & G_I to TRACE PI constants G & T

$$G = G_P \qquad T = \frac{G_P}{G_I}$$

Control Systems Exercise

In the PWR model, tune the Tave controller using the Ziegler-Nichols method.

Refer to the Day4 Afternoon Exercise: **PID Controller Exercise** located in the Day4 afternoon section of your workbook or PIDExercise2.pdf located in the Day3\Afternoon\PWR\2_Achieving_Steady-State folder.

Topics

- Managing Multiple Simulations in a Single Model
- Achieving Steady-State Target Conditions
- **Debugging TRACE Input Errors**
- Break Modeling & Validation
- Reflood Configuration and Steady-State Calculation

Debugging Input Errors

TRACE input is complex, which increases the potential for input errors.

The error messages printed by TRACE are not always informative.

How do you identify the location of an input error so that it can be fixed?

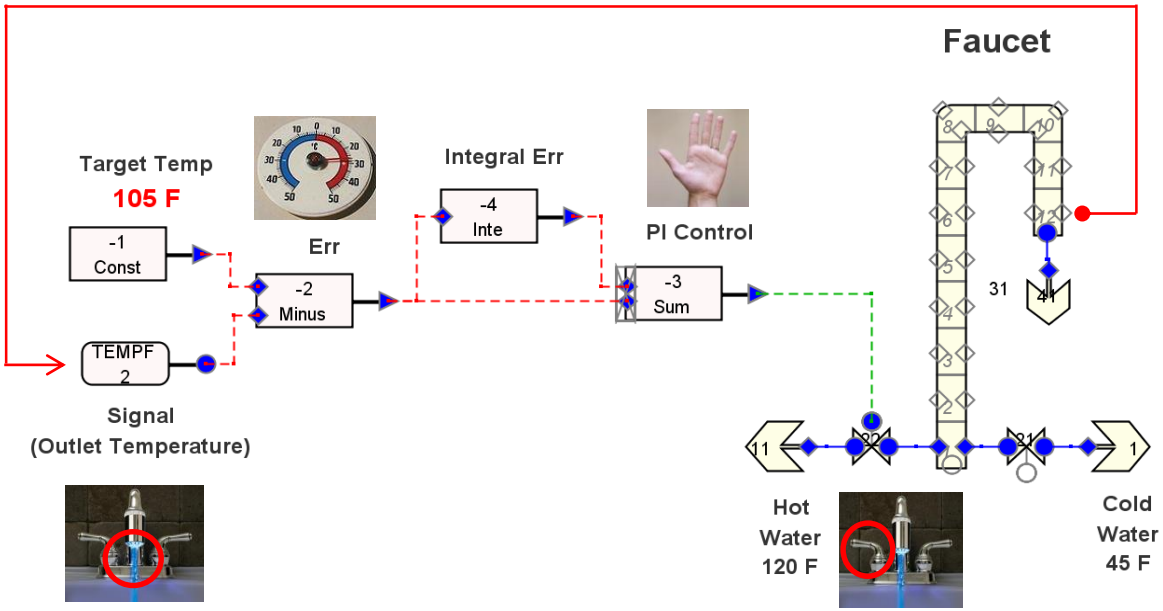
Debugging Input Errors

Suggested Steps:

1. Review ALL errors and warnings carefully
   (The relevant error is often reported before the ‘fatal error’ message)
2. Look for the string ‘error’ in the *.echo file
   (The error file may report the line where an error occurred)
3. Look at where the *.out file stopped
   (Sometimes stops at or near the error location – look at what component was being processed when *.out file stops)
4. Compare input file against recently working model
   (Use of a source control is recommended for evolving models)

Input Debugging Exercise - Water Faucet Model

A simple faucet model with some errors will be used as a debugging exercise. A PI controller is used for the hot water valve such that the temperature should reach 105 °F (313.7 K). Correct the input errors that cause the model to fail and verify that the controller causes the faucet to reach 105 °F. There are 3 errors.



Input Debugging Exercise

Refer to the Day4 afternoon Exercise: **Debugging TRACE Input Errors** located in the Day4 afternoon section of your workbook or TRACE_Input_Error_Debugging.pdf located in the Day3\Afternoon\PWR\3_Input_Debugging folder.

Topics

- Managing Multiple Simulations in a Single Model
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- Debugging TRACE Input Errors
- **Break Modeling & Validation**
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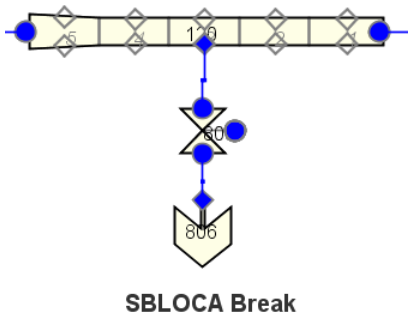
Modeling Breaks via Valves

For SBLOCA accidents, a valve components connected to a pipe side junction is a convenient way to model the. Some of the advantages are:



SBLOCA Break

- Valves are easily configured to open in response to trips.
  Break assumptions are explicitly included in the model when the break valve opens in response to the SBLOCA trip. This leads to better self-documentation for the model.
- Valves can be resized via control systems.
  Break size logic can be included in the control systems, so a single valve may be configured to handle multiple SBLOCA break sizes.

Valve Caveat

By default, valves include a built in form loss which impacts break flow. In the current version of TRACE, valves include an option to turn off this internal form loss and instead specify an explicit flow area fraction vs. K Loss table:

Valve Internal Loss Parameter

INTLOSSOFF	0 – Internal Loss Enabled
	1 – Internal Loss Disabled (Include 'kopen' Table)

Modeling Breaks via Valves

Side junction connections are NOT recommended for LBLOCA accidents. TRACE solves the side junction momentum equations using a pseudo 2-D flow method, which has some limitations (see the TRACE Theory Manual second on “Pseudo 2-D Flow”)

Instead the break components should be connected to the end of the pipe as shown below. This requires a restart from the steady state simulation to insert the breaks.

LBLOCA Break

Containment Break Modeling

For the break component, the effect of the length (DXIN) and volume (VOLIN) were covered on Day 3 in the afternoon. The conclusion was that for a large volume pressure sink VOLIN/DXIN should be large (i.e. the Area should be large), so that the pressure of the break represents a stagnant pressure.

Containment Break Modeling

Break pressure is of course important since this governs the break flow and the timing of choked flow events. Sometimes backflow from containment occurs, so break mixture conditions are also important. To avoid liquid entering via backflow through the break do the following:

- Set initial gas volume fraction (ALPIN) to 1.0

And do one of the following

- Set temperature table option (ISAT) to '[3] Set liquid and gas to Tsat' to cause saturated steam to enter during backflow.

OR

- Set the noncondensible partial pressure (PAIN) close to the initial pressure and set the initial mixture temperature (TIN) to containment conditions.

Break Modeling Exercise

Add a 3 inch cold leg break to the Loop 1 cold leg PWR model using the directions provided in the 'Break Modeling Exercise' document.

Refer to the Day3 Afternoon Exercise: **Break Modeling Exercise** located in the Day3 afternoon section of your workbook or BreakModelingExercise.pdf located in the Day3\Afternoon\PWR\4_Break_Model folder.

Topics

- Managing Multiple Simulations in a Single Model
- Achieving Steady-State Target Conditions
- Debugging TRACE Input Errors
- Break Modeling & Validation
- **Reflood Configuration and Steady-State Calculation**

Reflood Configuration

The example PWR model has been set up to perform a small break loss-of-coolant-accident. It is expected that during this transient, core uncovery will occur and the fuel rods will heat up. Emergency core cooling systems are expected to activate, injecting coolant into the primary system. Core reflood is expected to occur, stop the fuel rod heatup process and subsequently quench the fuel rods.

Reflood Configuration Exercise

To predict a more accurate representation of the fuel rod behavior during the transient, the reflood and fine-mesh renodalization options should be activated in the model.

Check the PWR model for reflood and fine-mesh capabilities. Make the appropriate modifications to activate the reflood and fine-mesh capabilities if needed.

Refer to the Day4 Morning Exercise: **Reflood Activation Exercise** located in the Day4 morning section of your workbook or Reflood_Activation_Exercise.pdf located in the Day4\Morning\PWR_Steady-State folder.

PWR Steady-State Calculation Exercise

The model is now ready to run a steady-state calculation. The small break LOCA transient calculation will restart from the end of the steady-state run.

Run a 1000 s steady-state calculation.

Refer to the Day4 Morning Exercise: **PWR Steady-State Calculation Exercise** located in the Day4 morning section of your workbook or Steady-StateRunExercise.pdf located in the Day4\Morning\PWR_Steady-State folder.