TRACE Control System Components

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Objective

Provide information about the TRACE control system components and their functions.

Outline

- Introduction to control system models
- Signal Variables
- Control Blocks
- Trips

TRACE Control System Models

In reactors, electronic and mechanical systems are put into place which give the operating staff either manual or automatic control over system behavior.

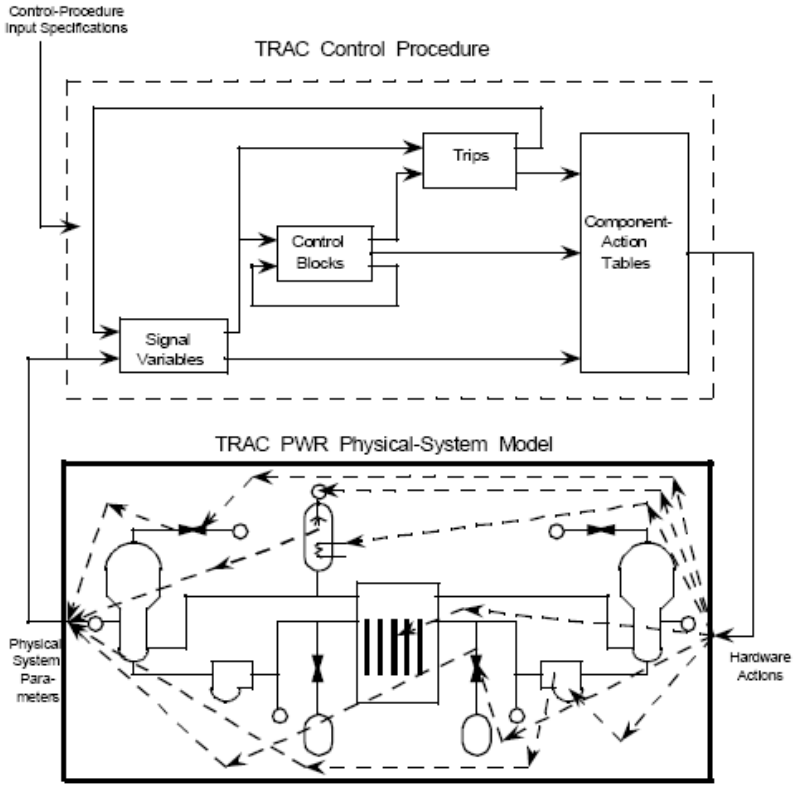
The TRACE control procedure is the means by which the code user is given the same level of control over his or her computer model as a reactor operator has over his or her real reactor system. It also allows the user to model automatic control of regulating hardware as well as abnormal hardware behavior.

Abnormal hardware behavior might consist of opening a valve in a line connected to an atmospheric-pressure boundary condition to simulate a pipe break.

TRACE Control System Models

- The control system in TRACE is general and flexible.
  - The generality and flexibility inherent to the defining form for the control procedure will require you to think through the modeling details and control specifications to construct the desired control-procedure model.

TRACE Control System Models



- A TRACE control system is comprised of four basic building blocks: signal variables, trips, control blocks, and component-action tables.

TRACE Control System Models

- Used to control behavior of thermal and hydraulic components
  - VALVE flow areas, FILL flow rates, HTSTR powers
- Used to calculate convenience output variables
  - Pressure drops, collapsed levels, component masses

Signal Variables

Signal variables are modeled-system parameters with real values that the user selects as signals for application in the TRACE control procedure.

- They are equivalent to the signals that an operator receives from the various detectors throughout a plant. Examples include core power, coolant temperature, fuel temperature, pump speed, valve position, etc.

134 types of signal variables are available.

In general, each signal variable type can take on one of six different functional forms:

- The exact value of the desired parameter without any permutation,
- The difference in some parameter between two different cells in a component,
- The difference in a parameter since the last timestep,
- The minimum or maximum over some range of cells in a single component, and
- The volume average of a parameter over some range of cells in a single component

It is worth stressing that not every signal type supports every functional form.

Signal Variables

Most common usage of signal variables is to retrieve calculated parameters (pressures, void fractions, densities, etc.) for use in trips and control blocks.

A signal variable might be set up, for example, to represent the pressure in the TRACE hydrodynamic cell at the top of a PWR pressurizer. That signal variable could then be used in a trip to test if the pressure exceeds the relief valve opening setpoint (with the trip then used to control the VALVE model).

Control Blocks

A Control Block is a mathematical function that operates on zero or more inputs defined by signal variables or other control blocks

The output of a control block may be used as

1) input to another control block or signal variable,
2) a trip parameter,
3) an independent variable for component-action tables

The input and output signals are always real-valued parameters, even those that are logical (0.0 or 1.0) in nature.

Control Blocks

Parameters that may be controlled by a control blocks:

Parameters that can be Controlled	Component
Pressure and fluid-state boundary condition	BREAK
Velocity or mass-flow and fluid-state boundary cond.	FILL
Reactor-core programmed reactivity or neutronic power	POWER
Reactor-core axial-power shape	POWER
Energy deposition directly in the coolant	PIPE,TEE,TURB,FLPOWER
Energy generation in the hydro-component wall	PIPE,TEE,PUMP,VALVE
Pump-impeller rotational speed	PUMP
Turbine power demand	TURB
Valve flow-area fraction or relative stem position	VALVE

Control Blocks

The desired logic of a control system can be defined and evaluated by coupling control blocks in series and/or in parallel with a control-logic network.

- System parameters defined by signal variables usually provide input signals for some, if not all, of the control blocks.

Depending upon the specific control block type of interest, the initial value of a control block's output signal can either be:

- user-specified (using the control block constant defined by the CBCON2 input variable) or
- evaluated internally by TRACE based upon assumed initial steady-state conditions of the modeled system.

Warning: A control block that is implicitly coupled to itself through its input/output signals may be in a signal loop of control blocks all of which TRACE cannot initialize internally.

- TRACE provides a warning message when this is encountered and aborts the calculation after all input data have been processed. The user can remedy this by specifying a non-zero value for CBCON2 to initialize the output signal from one of the control blocks in the signal loop. The desired output signal from a control-logic network usually is from the final control block in the control-block evaluation procedure.

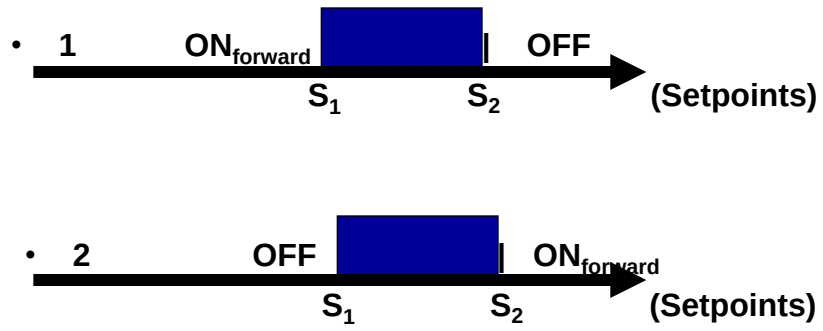
Trips

A Trip is a logical operator with an output status that is specified as $ON_{forward}$, OFF or $ON_{reverse}$, with corresponding numerical values of 1.0, 0.0 and -1.0.

Trips test the current value of an independent variable against a set of criteria (involving user-input setpoints and time delays) to determine a current value for the trip status.

The test criteria is specified according to trip type (11 trip types are available). For example, the two most commonly-used trips are Types 1 and 2, which have a status of $ON_{forward}$ or OFF.

In the deadband between S1 and S2, the status of the trip does not change value from when it entered the deadband.



Example use : trip reactor if the loop flow rate falls below 12,000 kg/s

Example use: open a relief valve if the pressure exceeds 16 MPa and reclose the valve if the pressure subsequently falls below 15 MPa

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Trips test the current value of an independent variable against a set of criteria (involving user-input setpoints and time delays) to determine a current value for the trip status.

The test criteria is specified according to the signal-range type (11 types are available). For example, the two most commonly-used signal-range type trips are Types 1 and 2, which have a status of $ON_{forward}$ or OFF.

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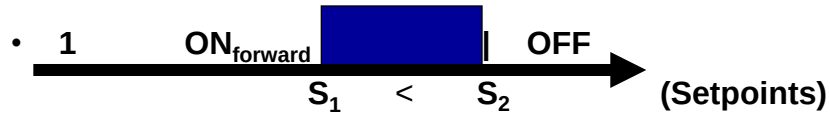

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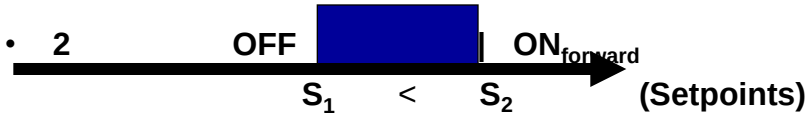


Example use: open a relief valve if the pressure exceeds 16 MPa and reclose the valve if the pressure subsequently falls below 15 MPa

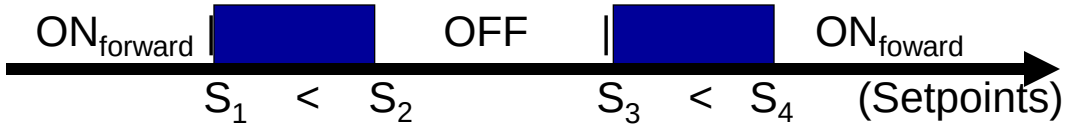
Trips

Signal-range Types 3, 4 and 5 increase the number of setpoints. Changing the trip type from positive to negative (e.g., from 3 to -3) changes $ON_{forward}$ to $ON_{reverse}$ and changes $ON_{reverse}$ to $ON_{forward}$

- 3

- 4

- 5



Trips

Signal-range Types 6 through 11 provide RELAP5-format style trips for TRACE system models that have been developed or converted from RELAP5 system models.

- 6 Signal .EQ. Setpoint
- 7 Signal .NE. Setpoint
- 8 Signal .LT. Setpoint
- 9 Signal .GT. Setpoint
- 10 Signal .LE. Setpoint
- 11 Signal .GE. Setpoint

Trips

Trip numbers can be either positive or negative

- Positive trip ID numbers have their trip set status evaluated only during the transient calculation. During the steady-state calculation the input value of the trip set status (on or off) is used
- Negative trip ID numbers have their trip set status evaluated during both the steady-state and transient calculations

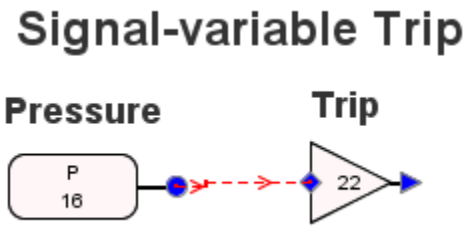
There are four different trip-signal types:

1. Signal-variable trip
2. Signal-expression trip
3. Trip-controlled trip
4. Simple setpoint trip – selected when the signal-range type is 6 to 11

Trips

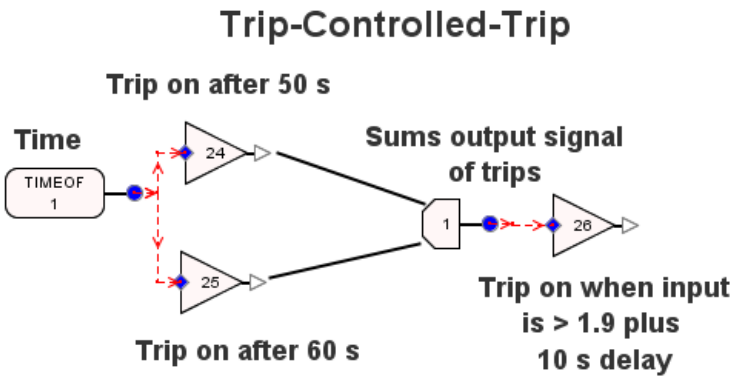
Signal-variable trips use signal variables or control blocks as the input for the trip action

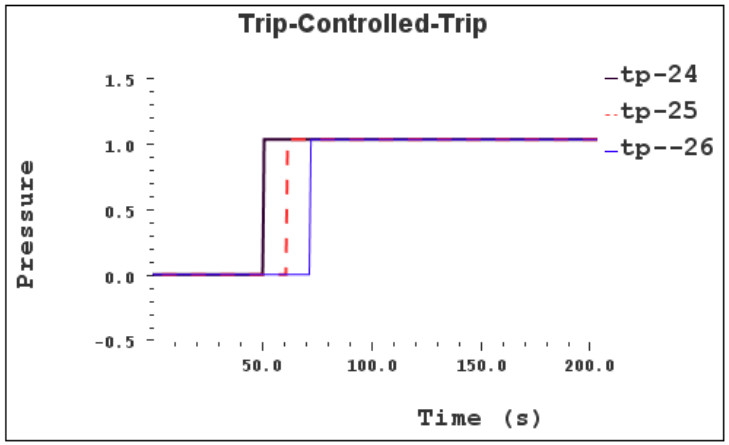
Example:



Trip-controlled trips use other trips as the input for the trip action

Example:

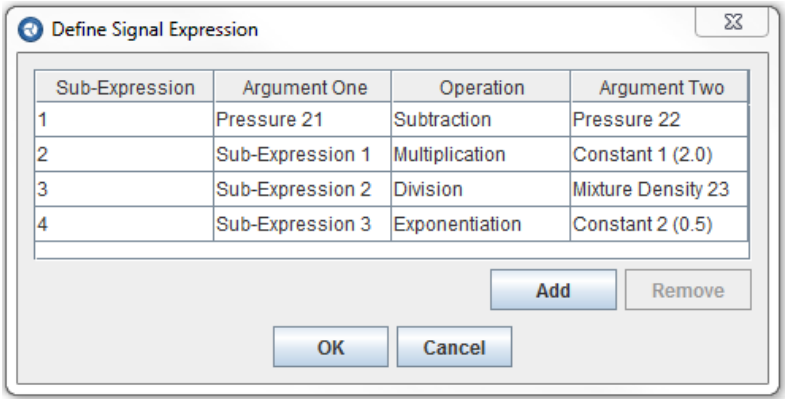


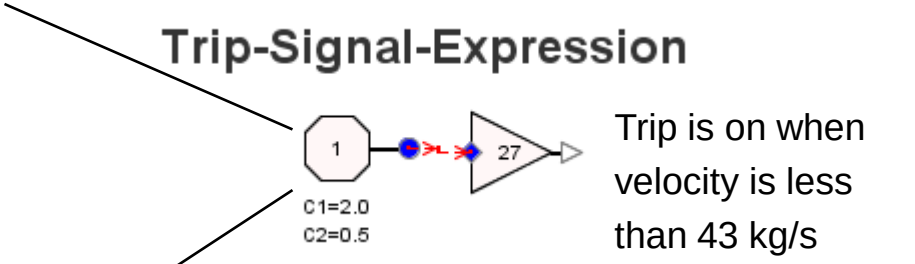


Trips

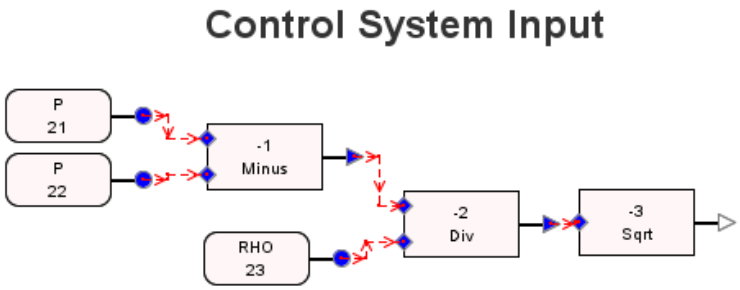
Signal-expression trips use built-in functions to solve mathematical equations that are used as input for the trip action

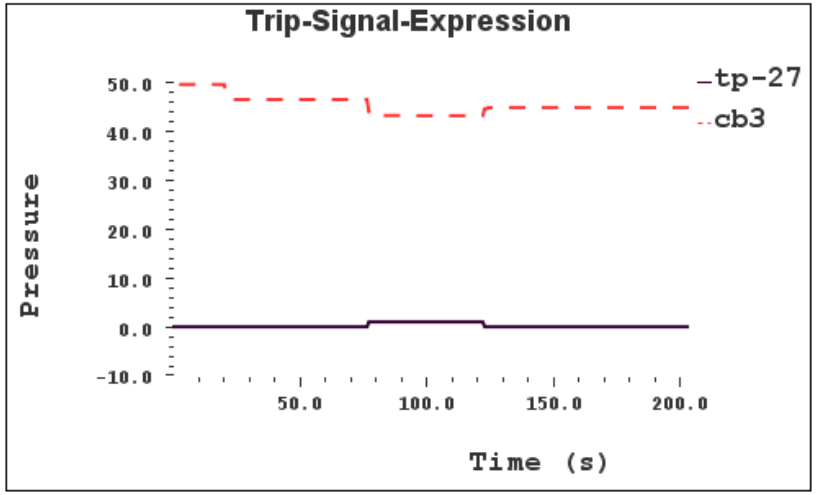
Example: velocity = (2*DP/rho)^0.5





Trip is on when velocity is less than 43 kg/s





Questions?

Any questions on TRACE control system models?