HYPERSIM

Real-Time Digital Power System Simulator

Warning: we are working on updating this manual to correspond to the new Windows interface

10.1 ELECTRONIC SWITCHES

A – Introduction

In HYPERSIM, a switch is modeled as a variable resistance, very low if the switch is closed and very high if the switch is open. The control signal of the switch may be provided by: an internal source, by an external source through digital inputs, or the control system module or by Simulink. In addition to the switch control signal, the opening and the closing of the switch depends on the voltage across the switch and the current through the switch.

B – Icon and Diagram of Electronic Switches

The following icon and diagram are used to represent electronic switches:

.

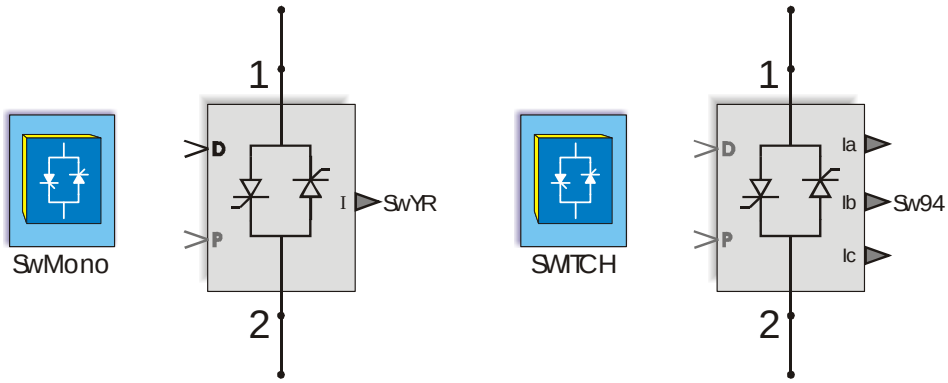

Figure 10 - 1 Icons and diagrams of electronic switches

10.1.1 Parameter Description

A – General Parameters

Connection (Series = S Delta = D) – If “S” (serial), each member of the switch is in series with one phase of the network. If “D” (delta), each member of the switch is connected between two phases of the network;

Note : The Delta connection is not functional at this time.

B –Switch Parameters

Type: – Set the type of the switch used. Each phase may use a different type of switch. Some type requires two command signals per phase because they are designed from two distinct elements.

Available types are:

- Ideal switch:
  The conduction and blocking depend on the command signal.
- Breaker:
  The command signal set the blocking. The conduction depends on the command signal and the current intensity.
- Thyristor:
  The blocking is set by the command signal and the current intensity. The firing is set by the command signal and the voltage at the thyristor terminals.
- Back-to-back thyristor:
  The blocking of each thyristor is set by its own command signal and current intensity. The firing is set by its own command signal and the voltage at each thyristor terminals.Two command signals per phase are required.
- Back-to-back thyristor and diode:
  The thyristor blocking is set by the command signal and the current intensity. The firing is set by the command signal and the voltage at the thyristor terminals.
  The diode blocking is set only by the current intensity through the diode and the firing by the voltage at the diode terminals only

Note : Using a diode command signal will force the diode to fire. Sometimes, this technique is used to ease the simulation.

- Diode:
  The diode blocking is set only by the current intensity through the diode and the firing by the voltage at the diode terminals only.
- GTO:
  The GTO blocking is set by the command signal if the current is acceptable. The GTO firing is set by the command signal and the voltage at the GTO terminals.
- Back-to-back GTO and diode:
  The GTO blocking is set by the command signal if the current is acceptable. The GTO firing is set by the command signal and the voltage at the GTO terminals.
  The diode blocking is set only by the current intensity through the diode and the firing by the voltage at the diode terminals only.

Note : Using a diode command signal will force the diode to fire. Sometimes, this technique is used to ease the simulation.

C –Fail signal reset

Default zero reset. If the “ENABLE” button is grey, the FailSig_*label* is reset to zero. This signal is produced if the switch (diode, thyristor or GTO) has reach its normal or reverse breakdown voltage or if an untimely firing had happened.

D – Steady state condition

State of the switches in steady state on a per phase basis. “0” if the switch is open and “1” if the switch is to be closed.

E – Precision Valve

Commissioning of the high precision switching (diode, thyristor or GTO). Compensate the digital error as a result of the switch state change accordingly to the calculation time step.

10.1.2 Other Parameters

A – Open State Resistances

Resistances of phases A, B and C of the switch in open state (ohm);

B – Closed State Resistances

Resistances of phases A, B and C of the switch in closed state (ohm);

C – Holding Current

Current threshold value below which the valve is automatically blocked. Not relevant for the ideal switch (A);

D – Snubber Capacitance

Capacitance of the RC snubber branch in parallel with the valve (F);

E – Snubber Resistance

Resistance of the RC snubber branch in parallel with the valve (ohm);

F – Forward Break Overvoltage

Highest value of overvoltage across a blocked valve. Relevant only for the diode, the GTO and the thyristor (V);

G – Reverse Break Overvoltage

Highest value of over-voltage across a valve. Relevant only for the diode, the thyristor and the GTO (V);

H – Turn-off Time.

Lowest time interval during which the voltage across the valve must stay negative to avoid the valve being fired again when the forward voltage turns positive. Relevant only for thyristor (s);

I – GTO Maximum Breakable Current

Maximal value of the GTO current that can be turned off by the GTO turn off command. Relevant only for the GTO (A);

J – Forward Voltage Drop

Minimal forward voltage for which valve firing is possible. Relevant only for the diode, the thyristor and the GTO (V);

10.1.3 Commands

Establishes the control order origin; external, control block or from Simulink.

A – External The command signals are from the digital inputs.

B – Block of Commands

The command signals are from the “Control Block” input placed on the switch icon.

- The “P” connector, on the icon (see Figure 10 - 1), allows users to send 0 or 1 command to all the switches. You must send to this connector a whole value where each bit corresponds to the command signal from each switch. The less significant bits (1, 2, 3) correspond to the phases A, B, and C switches in their forward breakdown voltage condition. The 4, 5, and 6 bits correspond to the phases A, B, and C switches in their reverse condition. Therefore, the whole value of bit 5 on the P connector is “000101” in binary value and commands the firing of the A and C phases in the forward breakdown voltage condition of the switch.
- The “D” connector on the icon (see Figure 10 - 1), allows users to set a delay to each switching. This function is available only if the “High precision” switch has been selected. A decimal value between 0.0 and 1.0 must be applied to this connector for each transition of one of the switches. The 0.0 value means no delay and a 0.5 value means a 50% delay accordingly to the actual calculation time step used.

C – Simulink The command signals are from an HyperLink block. The following information must be supplied:

- Directory: the full path of the directory where the Simulink model is stored;
- Model name: the name of the Simulink model;
- Execution time: estimated or calculated execution time of the Simulink model.

10.1.4 List of Available Signals

At acquisition, the following signals are made available by **sensors**:

- Ia,b,c_*label*: Current through the switch (pu);
- cmd12,a,b,c_*label*: Firing command for the “1 to 2” component of the switch;
- cmd21,a,b,c_*label*: Firing command for the “2 to 1” component of the switch;
- state12,a,b,c_*label*: State of the “1 to 2” component of the switch;
- state21,a,b,c_*label*: State of the “2 to 1” component of the switch;
- FailSig,a,b,c_*label*: Alarm signal from the switch whose meanings are the following:
  - **1**: Violation of the extinction time limit Tq for Thyristor12.
  - (Automatically reset to zero after 1 calculation time step)
  - **1** :Violation of the extinction time limit Tq for Thyristor21.
  - (Automatically reset to zero after 1 calculation time step)
  - **2**:Thyristor12 reverse voltage higher than Rbov. (Reset only by Fail Reset=1)
  - **2**:Thyristor21 reverse voltage higher than Rbov. (Reset only by Fail Reset=1)
  - **3**:Thyristor12 forward voltage higher than Fbov. (Reset only by Fail Reset=1)

– **3**: Thyristor21 forward voltage higher than Fbov. (Reset only by Fail Reset=1)

- P_*label:* Control signal from the Control System module.

A – Electronic Switches Command Panel

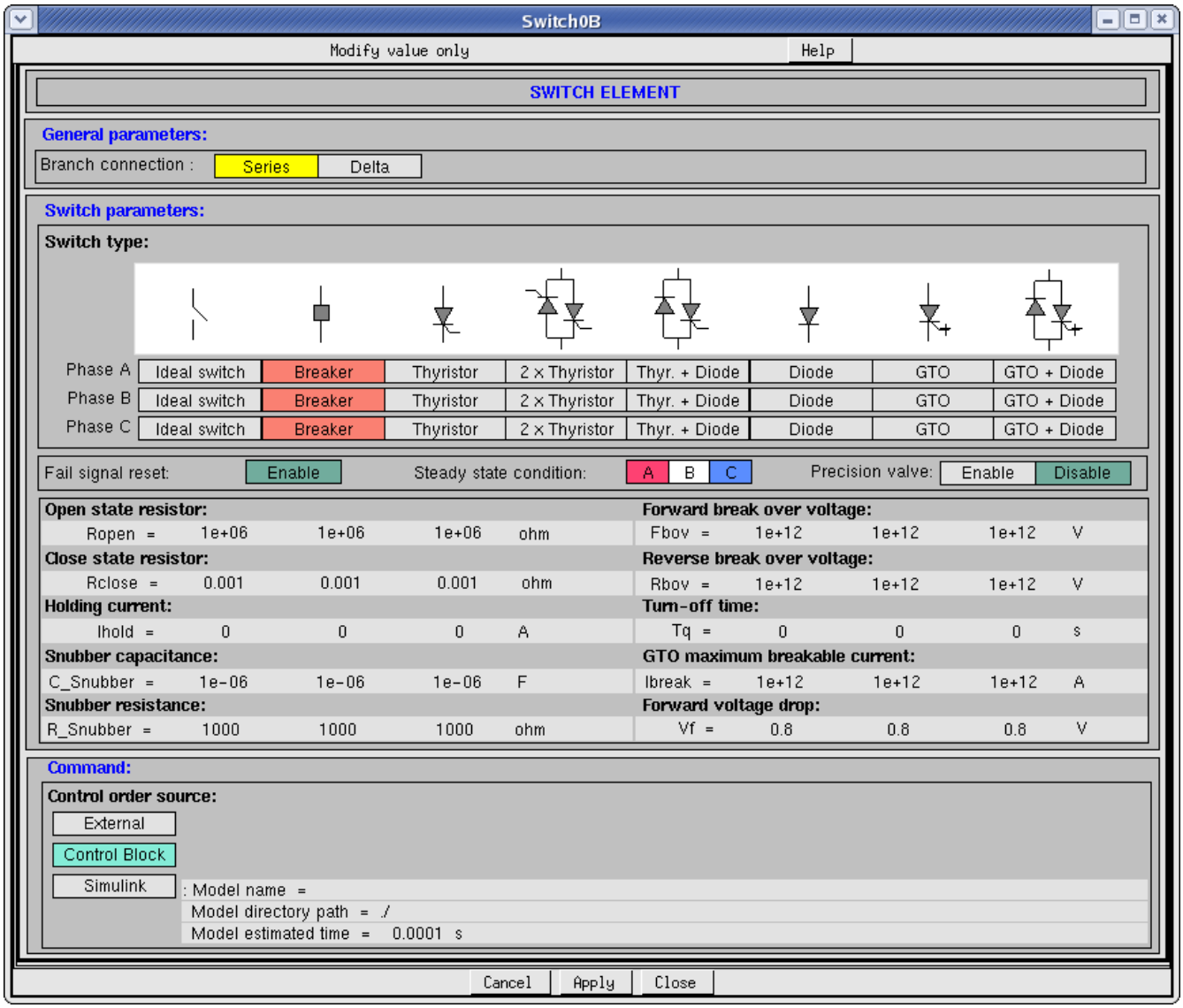

Figure 10 - 2 Electronic switches command panel

10.2 SERIAL BREAKER AND SHUNT FAULT BREAKER

10.2.1 Shunt and Serial Breakers

A – Introduction

The breaker is simulated as a variable resistance, very low if the breaker is closed and very high if the breaker is open. The control signals of the breaker may be provided by an internal timing control, by an external source through control block digital inputs or by Simulink.

B – Icons and Diagrams Representing Breakers

There are two types of breakers: the serial breaker and the fault breaker. The icon and the diagram of serial breakers are shown in Figure 10 - 3 while those of fault breakers are shown in Figure 10 - 3

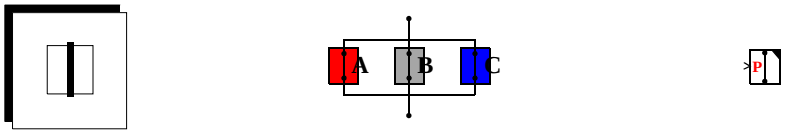

Figure 10 - 3 Icon and diagram of a serial breaker

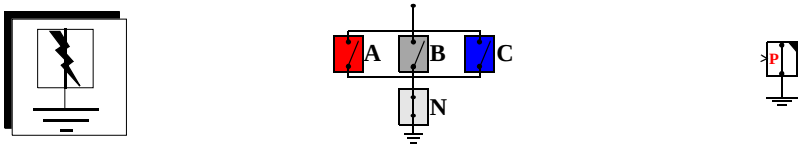

Figure 10 - 4 Icon and diagram of a fault breaker

C – Parameter Description

The data forms of a serial breaker and of a fault breaker are shown in Figures 10 - 5, 10 - 6 and Figures 10 - 7, 10 - 8 respectively.

D – General Parameters

- SI or pu" units.
  - SI for international units of elements (ohms, farad, henry etc.);
  - pu to set the values in pu.
- Base units:
  - Base MVA: base power (MVA);
  - Base Volt: base voltage (kV);
  - Base Freq: base frequency (Hz).
- Connection:
  - for the serial breaker (Serial=S): Only series connection is valid. In this case each branch of the serial breaker is in series with one phase of the network;
  - for the fault breaker (Yg): Only "Yg" connection is valid. In this case the connection of the three phase fault breaker is as shown in Figure 10 - 9;

Note : The Delta connection options (D) in the data forms of the serial breaker and of the fault breaker are not functional at this time.

- Type (Breaker = 0, Switch = 1):
  - if "0", the breaker opens as soon as the current in the breaker is lower than the I margin current after the command to open is issued;
  - if "1", the breaker behaves like an ordinary switch and opens immediately after the command to open is issued.

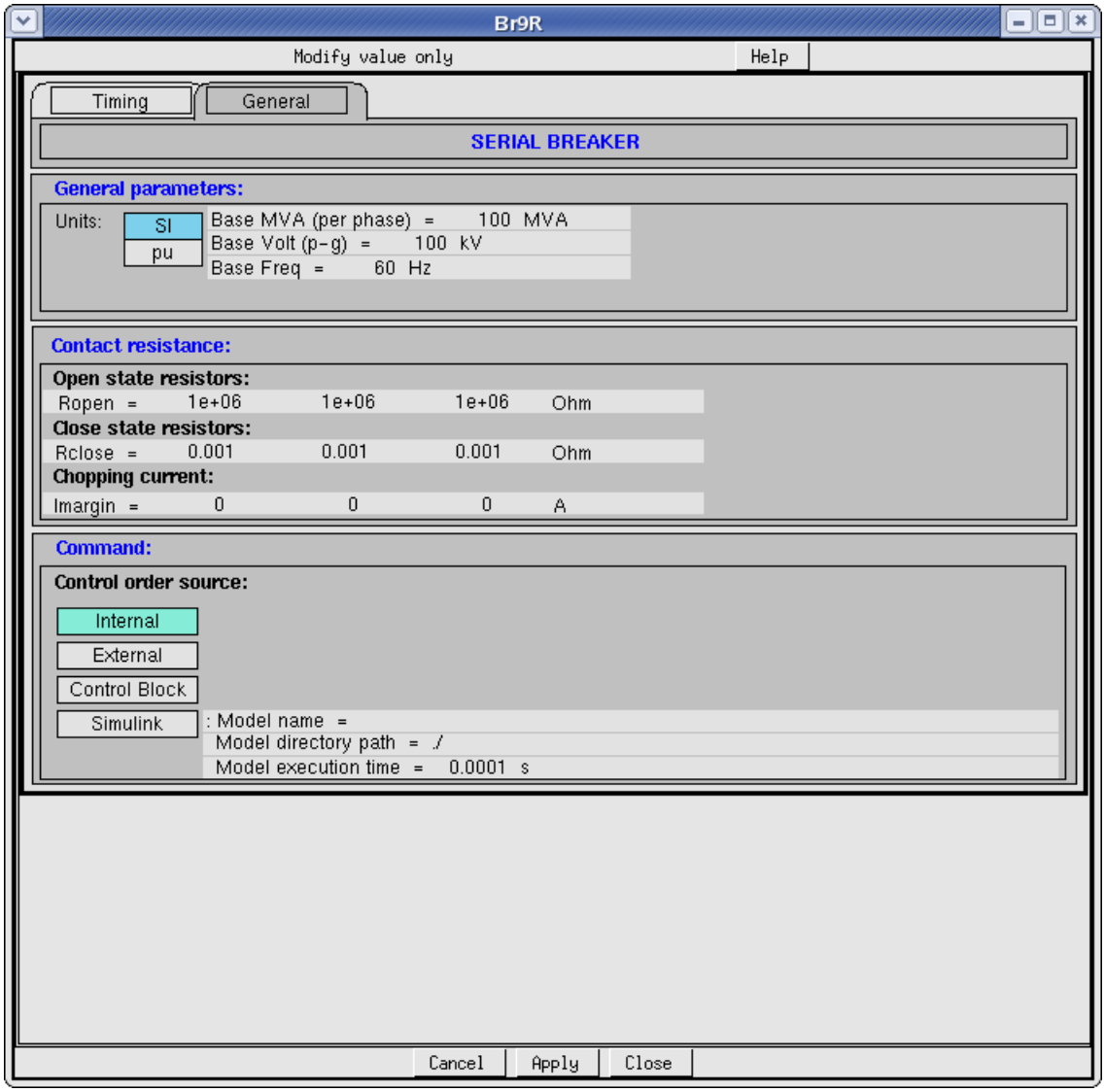

Figure 10 - 5 Data form for serial breakers (general)

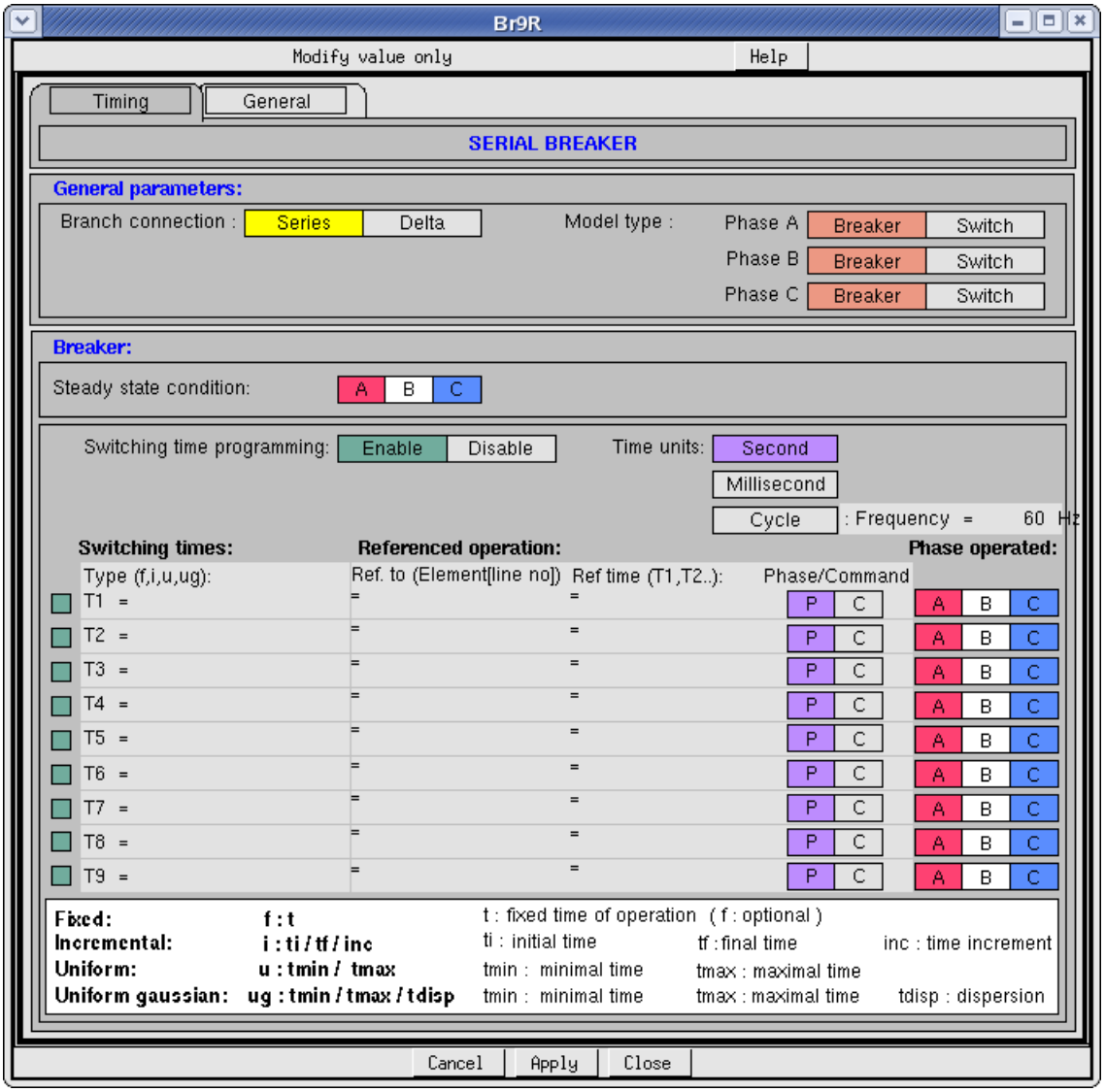

Figure 10 - 6 Data form for serial breakers (timing)

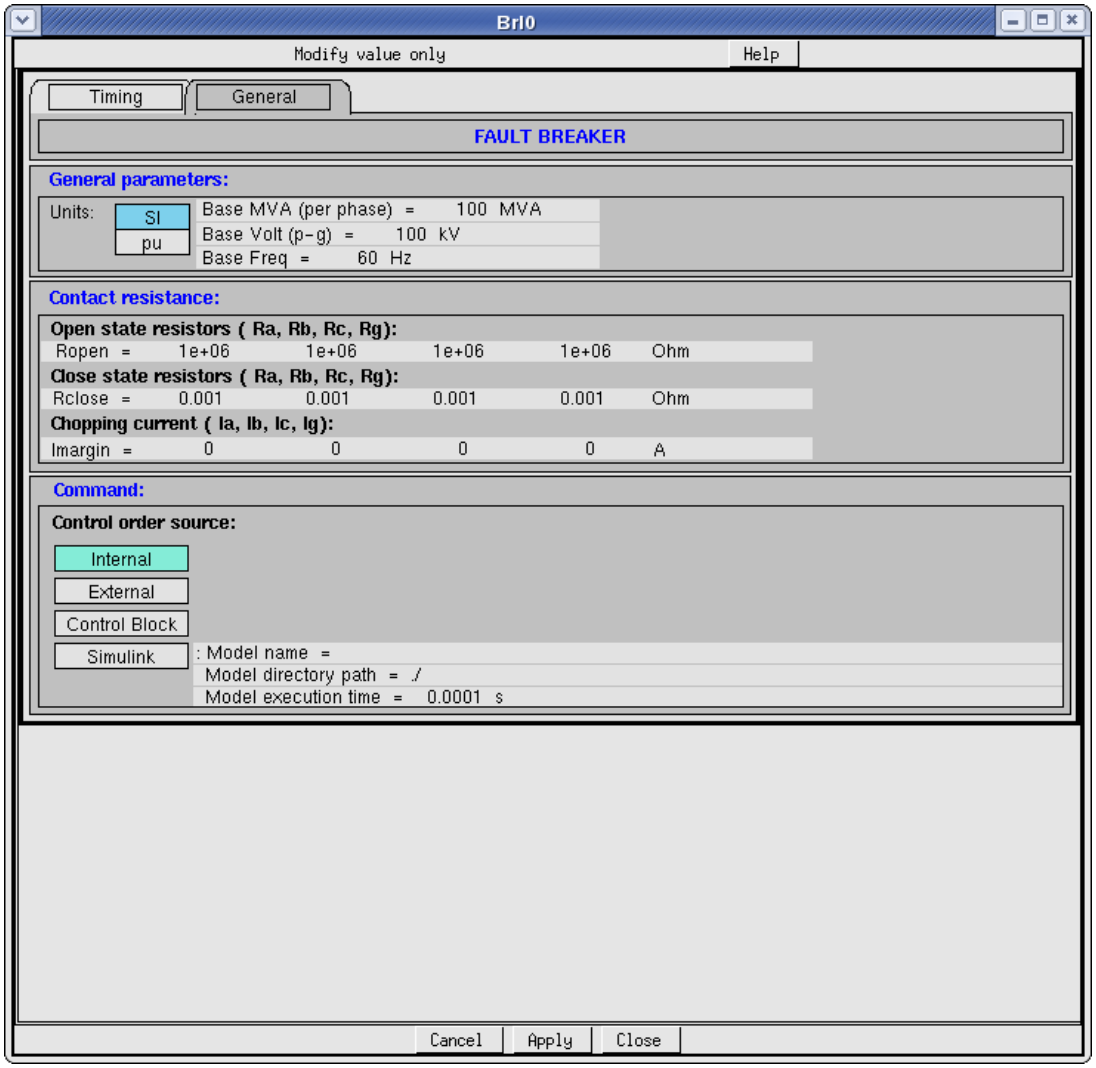

Figure 10 - 7 Data form for fault breakers (general)

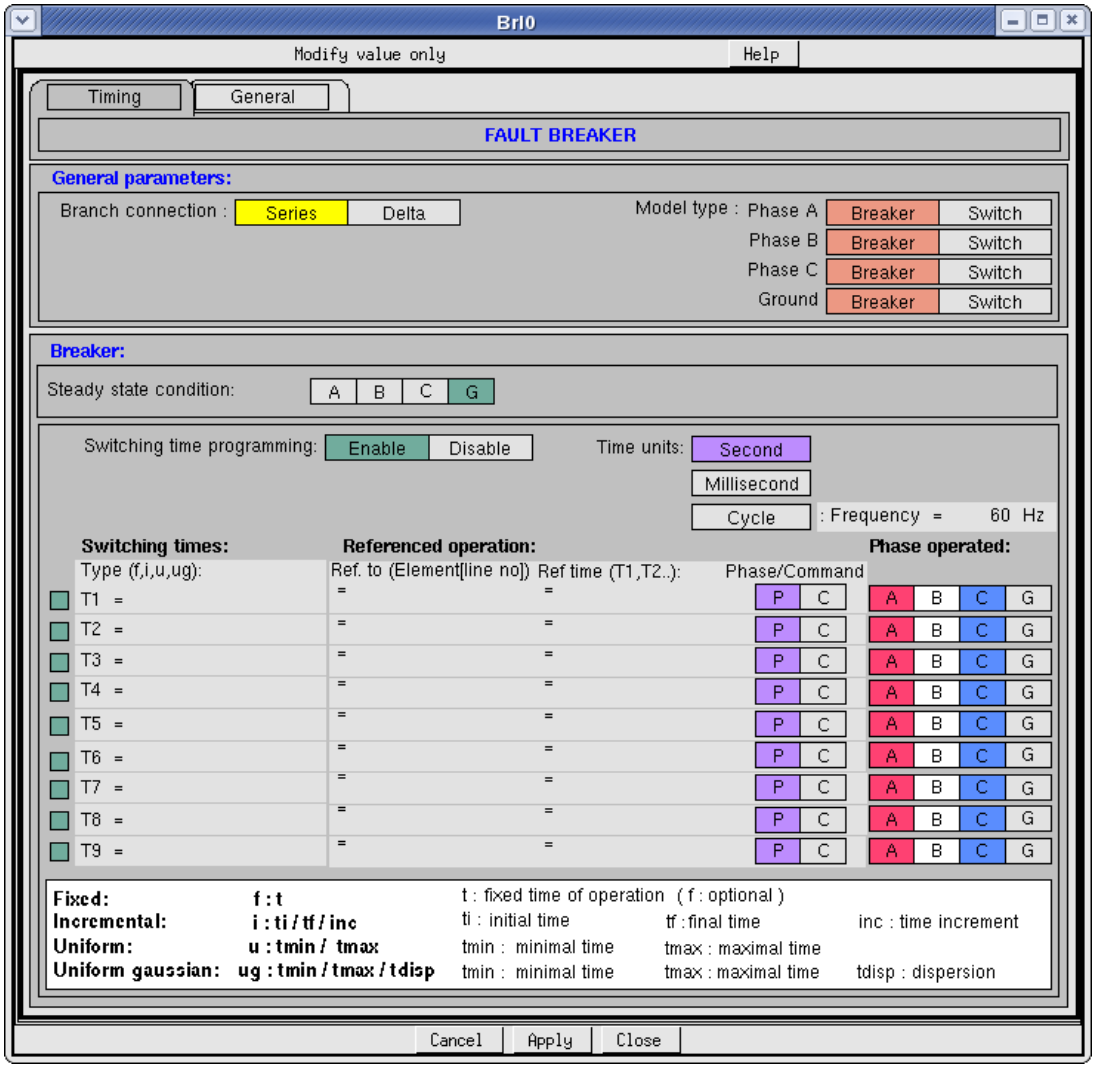

Figure 10 - 8 Data form for fault breakers (timing)

10.2.2 Breaker

A – Open State Resistor

Resistances of phase breakers A, B, C and ground breaker in open state (ohm).

B – Closed State Resistor

Resistances of phase breakers A, B, C and ground breaker in closed state (ohm).

C – I margin Current absolute value below which the breaker is allowed to open (A).

D – Steady State Condition

State of phase breakers A, B, C and ground breaker in steady state. “Colored” if the breaker is open and “Grey”, if the breaker is closed.

E – Switching Time Programming

Enable or disable the time of operation programed.

F – Time Units

Second, millisecond or cycle is available. (For cycle the frequency is mandatory)

G –Phase Operated

Specify which among the phase breakers A, B, C and ground breaker can change state if data acquisition is made with the “switching” enabled in Spectrum. For changes of state to happen, operation times T1 and T2 below must be such that T1<T2.

H – T1 Operation Time

Relative time (with respect to synchronization) when the state of a phase breaker or a ground breaker changes (s or ms).

T1: Initial status or transition time from low to high (t1) or high to low (t2) with fix, incremental or random variation types.

All timings specified with these two parameters are in cycles from the fundamental frequency set in the element control panel.

If a parameter field is blank or contains “-” no switching will happen for this parameter.

Low: initial digital output status is 0 *open;*

High: initial digital output status is 1 *close*.

I – T2 Operation Time

Relative time (with respect to synchronization) when the state of the phase breaker or a ground breaker returns to the steady state position (s or ms).

J – Control Order Source

- Specifies the origin of the control signal (Internal = 0, External = 1, Simulink = 2):
  - Internal: HYPERSIM;
  - External: Digital inputs;
  - Control block: from HYPERSIM control block;
  - Simulink: HyperLink bloc;

    Directory: The complete path of the directory where the Simulink model is stored;

    Model name: name of the Simulink model;

    Execution time: Estimated or measured execution time of the Simulink model.

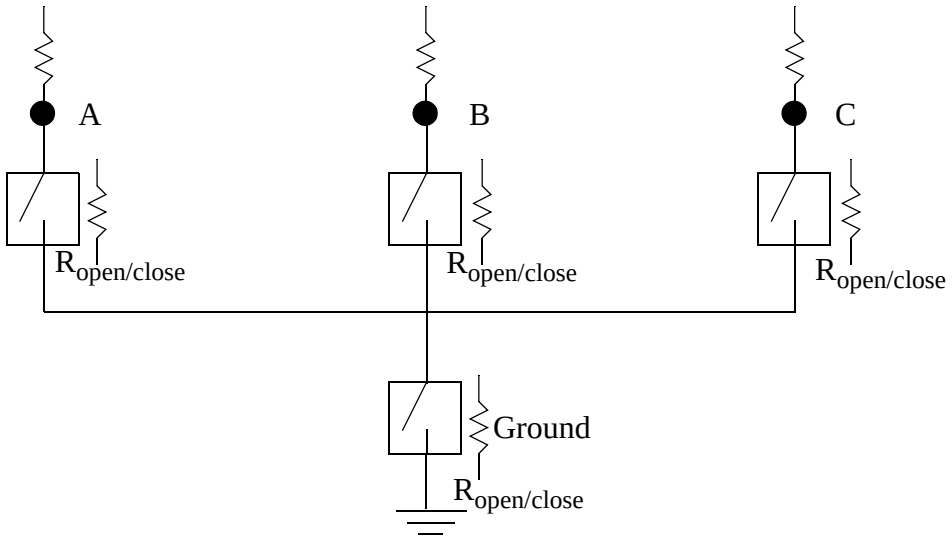

Figure 10 - 9 Connection of the triple H-bridge converter

K – List of Available Signals

At acquisition, the following signals are made available by **sensors**:

- Com_*label*_a,b,c: Phase breaker commands (pu)
- Com_*label*_n: Ground connected breaker command (pu) (for fault breaker only)
- I_*label*_a,b,c: Phase breaker currents (pu)
- I_*label*_n: Ground connected breaker current (pu) (for fault breaker only)

10.3 TRIPLE-LEVEL CONVERTER IN H CONFIGURATION

A – Introduction

HYPERSIM provides a two-triple-level converter in H configuration. There are 4 switches per phase for a total of 12. The control signals of the switches can originate from an external source via digital input, a system control module (control block) or Simulink.

10.3.1 Icon and Diagram of a 2 Triple-Level Converter in H Configuration

The following icon and diagram are used to represent a 2 triple-level converter in H configuration.

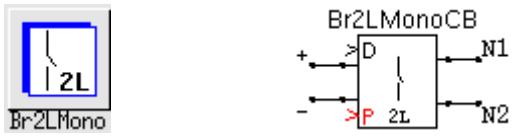

Figure 10 - 10 Icon and diagram of a 2 triple-level converter in H Configuration

10.3.2 Parameter Description

Figure 10 - 11 shows the control panel for a 2 triple-level converter in H configuration.

10.3.3 Switch Parameters

A – Type

Specifies the type of switch. The types available are the following:

- Breaker:
  Blocking is set by the control signal. Conduction depends on the control signal and the current level in the breaker.
- Ideal Switch:
  Blocking and conduction are set by the control signal.
- Thyristor:
  Blocking is set by the control signal and the current level. Firing depends on the control signal and the voltage at the thyristor terminals
- Diode
  The diode blocking depends only on the current level across it. The diode firing depends only on the voltage at its terminals.
- Back-to-Back GTO and Diode
  Blocking of the GTO is set by the control signal if the current level is acceptable. Firing of the GTO depends on the control signal and the voltage at the GTO terminals.
  The diode blocking depends only on the current level across it. The diode firing depends only on the voltage at its terminals.

Note : The firing of the diode can be forced by sending to it a control signal. This technique is sometimes used to facilitate the simulation.

B – Fail Signal Reset

– Fail Signal Reset. If “Enable” is grey, the FailSig_*label* alarm signal is reset. This signal is generated if the switch (diode, thyristor, GTO) has reached the forward or reverse breakdown voltage or if false firing has occurred.

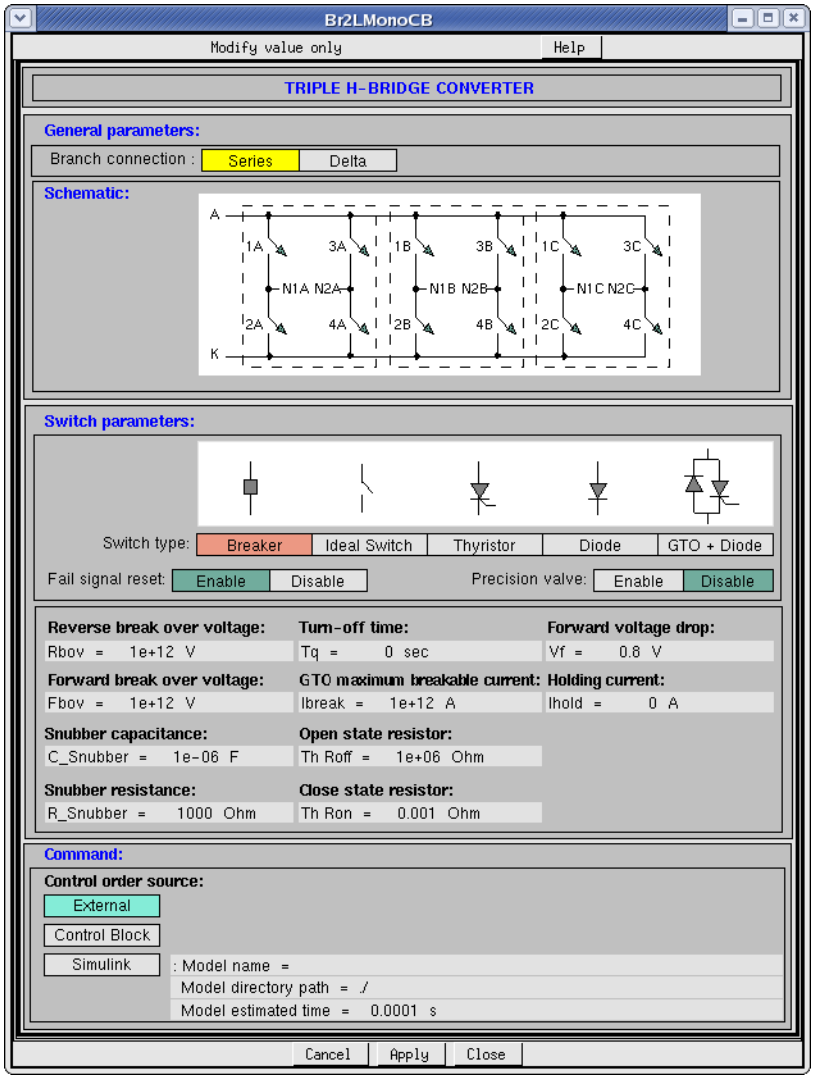

Figure 10 - 11 Control Panel of a 2 Triple H-Bridge Converter

C – Other Parameters

1 –Reverse Break Overvoltage

– Reverse break over-voltage: Highest value of the reverse voltage in a blocked valve. Applies only to diodes, thyristors and GTO (V).

2 –Forward Break Overvoltage

– Forward break over-voltage: Highest value of the forward voltage in a blocked valve. Applies only to thyristors and GTO (V).

3 –Snubber Resistance

– Snubber resistance: resistance of RC branch in parallel with the valve (ohm).

4 –Snubber Capacitance
– Snubber capacitance: capacitance of RC branch in parallel with the valve (F).

5 –Turn-off Time
– Turn-off time: Shortest time interval during which the voltage in the valve must be negative to avoid being fired again when the voltage becomes positive. Applies only to thyristors (s).

6 –GTO Maximum Breakable Current
– GTO maximum breakable current: Maximum GTO current value that can be turned off by the corresponding GTO command. Applies only to GTO (A).

7 –Open State Resistor
– Open state resistor: resistances for phases A, B and C of the open switch (ohm).

8 –Closed State Resistor
– Closed state resistor: resistances for phases A, B and C of the closed switch (ohm).

9 –Forward Voltage Drop
– Forward voltage drop: minimum forward voltage at which it is possible to fire the valves. Applies only to diodes, thyristors and GTO (V).

10 –Holding Current
– Holding current: Current threshold below which the valve is automatically blocked. Does not apply to ideal switches (A).

10.3.4 Control Order Source

- Specifies the source of the control signal: external, via control blocks or using Simulink.

A – External
- The control signals originate from digital input.

B – Control Block
- The control signals originate from the “control block” input on the switch icon.

C – Simulink
- The control signals originate from a HyperLink block. The following information must be provided:
  - Directory: full path of the directory where the Simulink model is saved;
  - Name of model: name of Simulink model;
  - Execution time: estimated or measured execution time of Simulink model.

10.3.5 List of Available Signals

At acquisition, the following signals are made available by the sensors:

- vValve1,2,3,4(A,B,C)_*label*: Voltage in the switch;
- iValve1,2,3,4(A,B,C)_*label*: Current in the switch;
- cmd12Ext1,2,3,4(A,B,C)_*label*: Firing command for the “1 to 2” component of the switch;
- cmd21Ext1,2,3,4(A,B,C)_*label*: Firing command for the “2 to 1” component of the switch;
- State12_1,2,3,4(A,B,C)_*label*: State of the “1 to 2” component of the switch;
- State21_1,2,3,4(A,B,C)_*label*: State of the “2 to 1” component of the switch;

- FailSig1,2,3,4(A,B,C)_*label*: Alarm signal of the switch with the following meanings:
  - **1**: Violation of extinction time limit Tq for Thyristor 12. (Automatically reset after one calculation time step).
  - **1**: Violation of extinction time limit Tq for Thyristor 21. (Automatically reset after one calculation time step).
  - **2**: Reverse voltage of Thyristor 12 greater than Rbov. (Reset only if fail signal reset = Enable (Grey).
  - **2**: Reverse voltage of Thyristor 21 greater than Rbov. (Reset only if fail signal reset = Enable (Grey).
  - **3**: Forward voltage of Thyristor 12 greater than Fbov. (Reset only if fail signal reset = Enable (Grey).
  - **3**: Forward voltage of Thyristor 21 greater than Fbov. (Reset only if fail signal reset = Enable (Grey).
- P_*label:* Control signal of control module.
- D_*label:* Control signal of control module.

10.4 THREE-LEVEL CONVERTER

A – Introduction

HYPERSIM provides for a three-level or Neutral Point Clamped (NPC) converter bridge equivalent. The NPC converter is composed of 4 controlled (Q1,Q2, Q3, Q4) switches and 6 diodes per phase. The control signals of the switches can originate from an external source via digital input, a system control module (control block) or Simulink. The model emulates the NPC converter by using an ideal three-level switch (P N, M) per phase - The control signals of the equivalent three-level switches are generated by the model, based on an integrated logic and the control signals provided externally. In the blocked mode, when the control pulses are ab sent, the bridge diodes are also emulated.

10.4.1 Icon and Diagram of a 2 Triple-Level Converter in H Configuration

The following icon and diagram are used to represent a three-level converter.

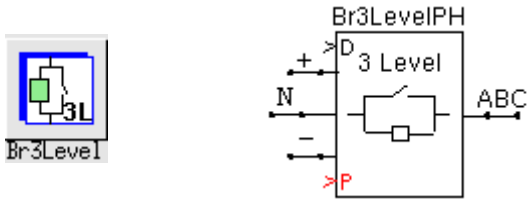

Figure 10 - 12 Icon and Diagram of a three-level converter

10.4.2 Parameter Description

Figure 10.13 shows the control panel for a three-level converter bridge.

10.4.3 Switch Parameters

A – Type Specifies the type of switch. The type available is the following:

- Back-to-Back ideal Switch and Diode
- Blocking and conduction are set by a control signal. B Fail Signal Reset

B – Other Parameters

1 Reverse Break Overvoltage – Does not apply to the actual model. Highest value of the reverse voltage in a blocked valve. Applies only to diodes, thyristors and GTO.

2 Forward Break Overvoltage – Does not apply to the actual model. Highest value of the forward voltage in a blocked valve. Applies only to thyristors and GTO.

3 Snubber Resistance – Resistance of RC branch in parallel with the valve.

4 Snubber Capacitance – Capacitance of RC branch in parallel with the valve.

5 Turn-off Time – Does not apply to the actual model. Shortest time interval during which the voltage in the valve must be negative to avoid being fired again when the voltage becomes positive. Applies only to thyristors.

6 GTO Maximum Breakable Current – Does not apply to the actual model. Maximum GTO current value that can be turned off by the corresponding GTO command. Applies only to GTO.

7 Open State Resistor – Resistances for phases A, B and C of the open switch.

8 Closed State Resistor – Resistances for phases A, B and C of the closed switch.

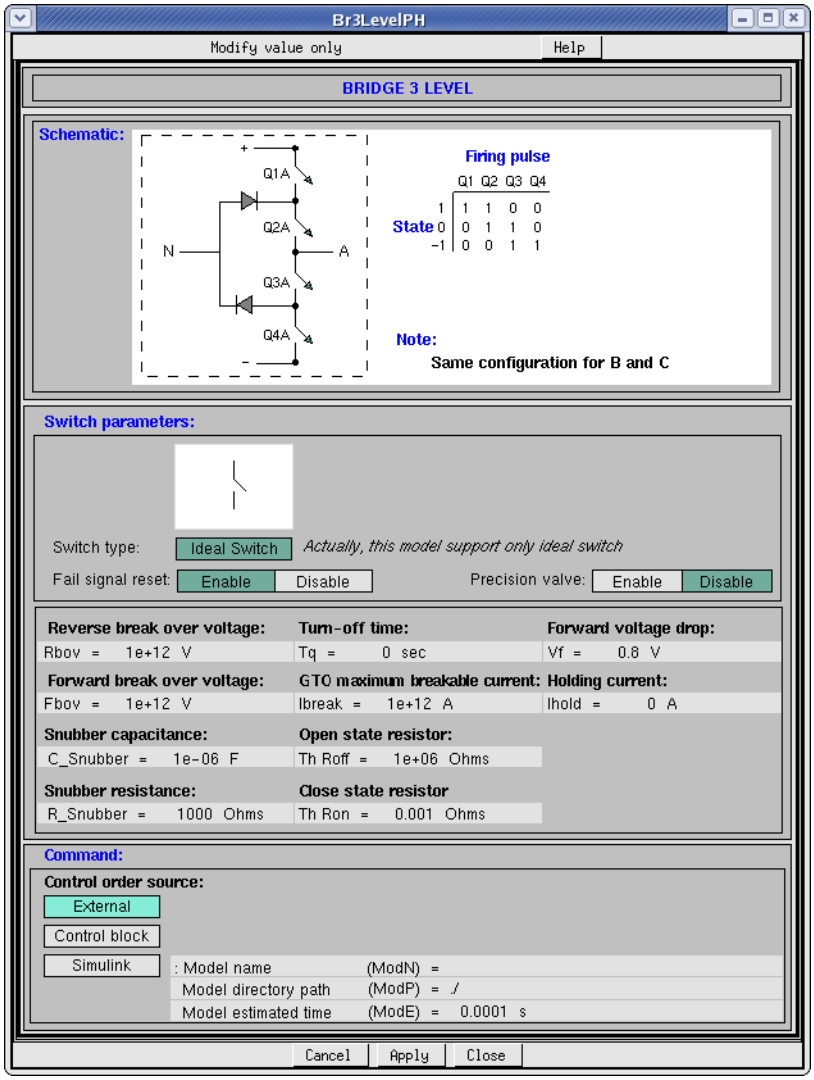

Figure 10 - 13 Control Panel of a three-level Bridge or NPC Converter

9 Forward Voltage Drop – Does not apply to the actual mode!, minimum forward volt age at which it is possible to fire the valves. Applies only to diodes, thyristors and GTO

10 Holding Current – Does not apply to the actual model. Current threshold below which the valve is automatically blocked. Does not apply to ideal switches.

10.4.4 Control Order Source

Specifies the source of the control signal: external, via control blocks or using Simulink.

A – External The control signals originate from digital input.

B – Control Block The control signals originate from the “control block input on the switch icon.

C –Simulink The control signals originate from a 1 block. The following information must be provided:

- — Directory: full path of the directory where the Simulink model is saved;
- — Name of model: name of Simulink model;
- — Execution time: estimated or measured execution time of Simulink model.

10.4.5 List of Available Signals

At acquisition, the following signals are made available by the sensors:

- vValveP,N,M(A,B,C)_*label*: Voltage across the equivalent switch (V);
- iValveP,N,M(A,B,C)_*label*: Current in the equivalent switch (A);
- cmdl 2ExtQl,Q2,Q3,Q4(A,B,C))_*label*: Firing command for the ‘1 to 2” component of the switch;
- State 12P,N,M(A,B,C)_*label*: State of the “Ito 2” component of the equivalent switch (Logic);
- FailSigl,2,3,4(A,B,C)_*label*: Does not apply to the actual model. Alarm signal of the switch with the following meanings:

  1: Violation of extinction time limit Tq for Thyristor 12. (Automatically reset after one calculation time step).

  1: Violation of extinction time limit Tq for Thyristor 21. (Automatically reset after one calculation time step).

  2: Reverse voltage of Thyristor 12 greater than Rbov. (Reset only if fail signal reset Enable (Grey).

  2: Reverse voltage of Thyristor 21 greater than Rhov. (Reset only if fail signal reset = Enable (Grey).

  3: Forward voltage of Thyristor 12 greater than Fbov. (Reset only if fail signal reset = Enable (Grey).

  3: Forward voltage of Thyristor 21 greater than Fbov. (Reset only if fail signal reset = Enable (Grey).

- P_*label*: Control signal of control module (Binary code).
- D_*label*: Does not apply to the actual model. Control signal of control module (% step).