EHV & HV Shunt Reactor Protection

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Shunt Reactor

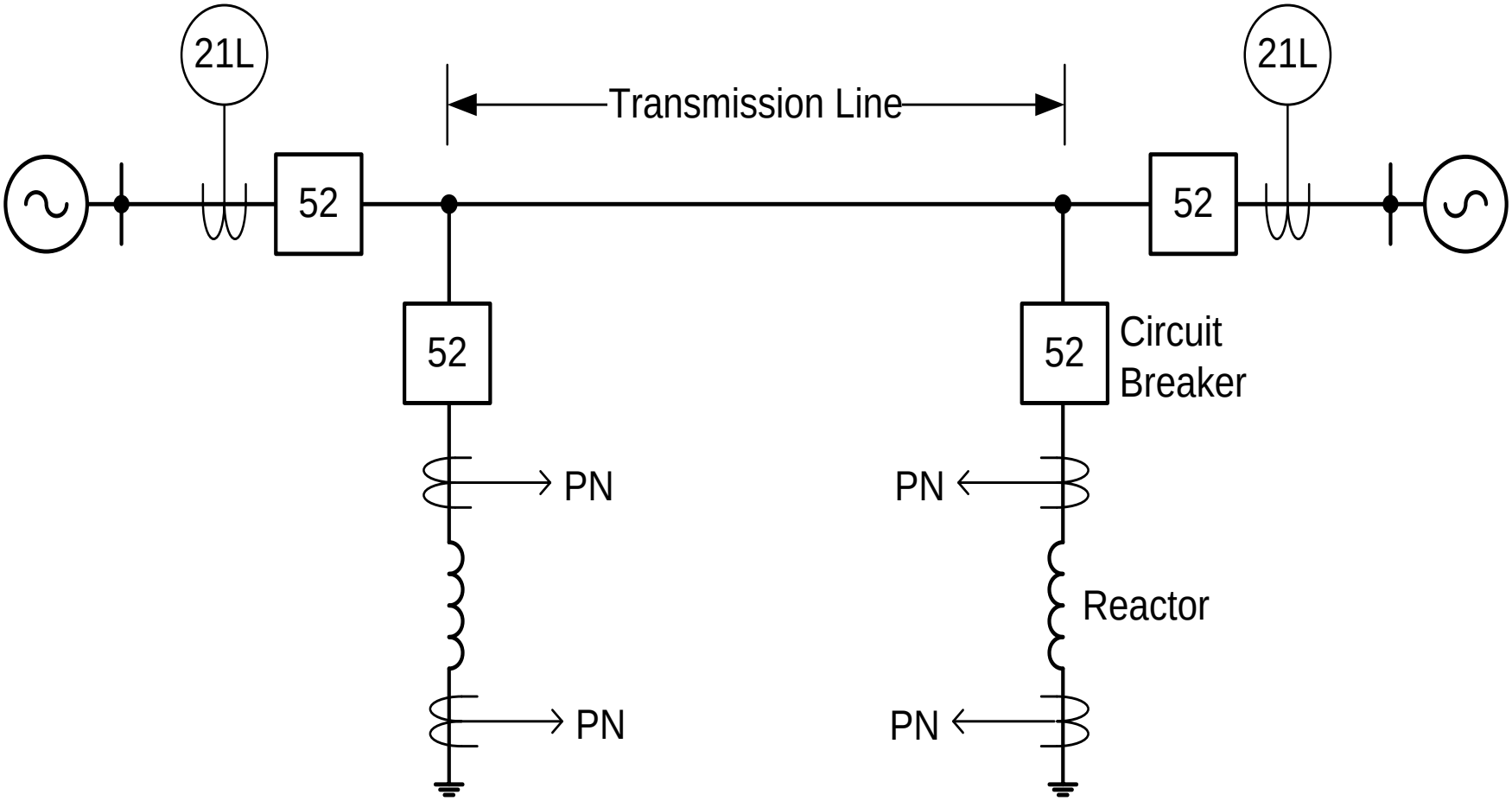
The shunt reactor as a component of the power system is used to compensate for the effects of high charging currents of long transmission lines and cables.

Shunt Reactor

Shunt Reactor Connections to EHV/HV kV

Most shunt reactors are permanently connected through a switching device (disconnect switch or circuit breaker) at the ends of EHV/HV kV transmission lines to limit fundamental-frequency temporary overvoltages and energization overvoltages (switching transients).

Line Connected Shunt Reactor



Hazards to a Reactor

The principal hazards to a reactor are similar to that for a transformer:

- *bushing and isolation failures (resulting in large changes in the magnitude of phase current)*
- *turn-to turn faults within winding, (resulting in small changes in the magnitude of phase current),*
- *Miscellaneous failures (such as low oil, loss of cooling, pole disagreement, …)*

Reactor Protection

Protection of reactors are basically the same as for transformers with the size and importance to the system including:

- *Reactor Electrical Protection*
- *Reactor non-electrical protection*

BC Hydro Protection Philosophy

- *BC Hydro system is to provide reliable protection for all possible faults using both electrical and non-electrical devices.*

- *Reliable protection system is both dependable and secure*

Reliability

- ***Dependability***

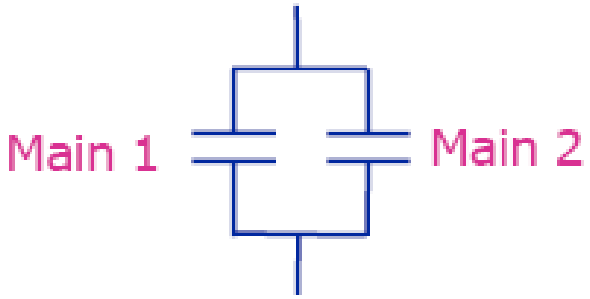
A dependable protection system operates when required.

- ***Security***

A secure protection system does not operate for normal system operation or when not required to operate to clear a fault.

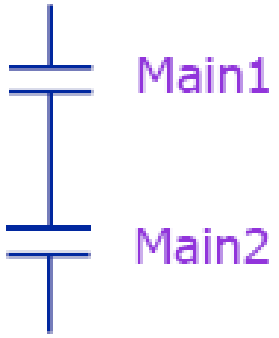
Reliability

DEPENDABILITY



The certainty of operation in response to system trouble

SECURITY



The ability of the system to avoid misoperation with or without faults

Additional Power system protection Philosophy

- ***Sensitivity***

Protection shall have adequate sensitivity to detect faults, considering a single system contingency or fault resistance which results in reduced operating quantities to the protection.

- ***Selectivity***

Protection systems should remove from service the minimum number of system elements necessary to clear a fault.

Continue

- ***Speed***

Protection systems should provide fault clearing in a minimum time, considering time delays required to achieve security and selectivity.

- ***Loadability***

Protection should not limit the load carrying capability of major equipment such as transmission lines, transformers, circuit breakers, disconnect switches.

Continue

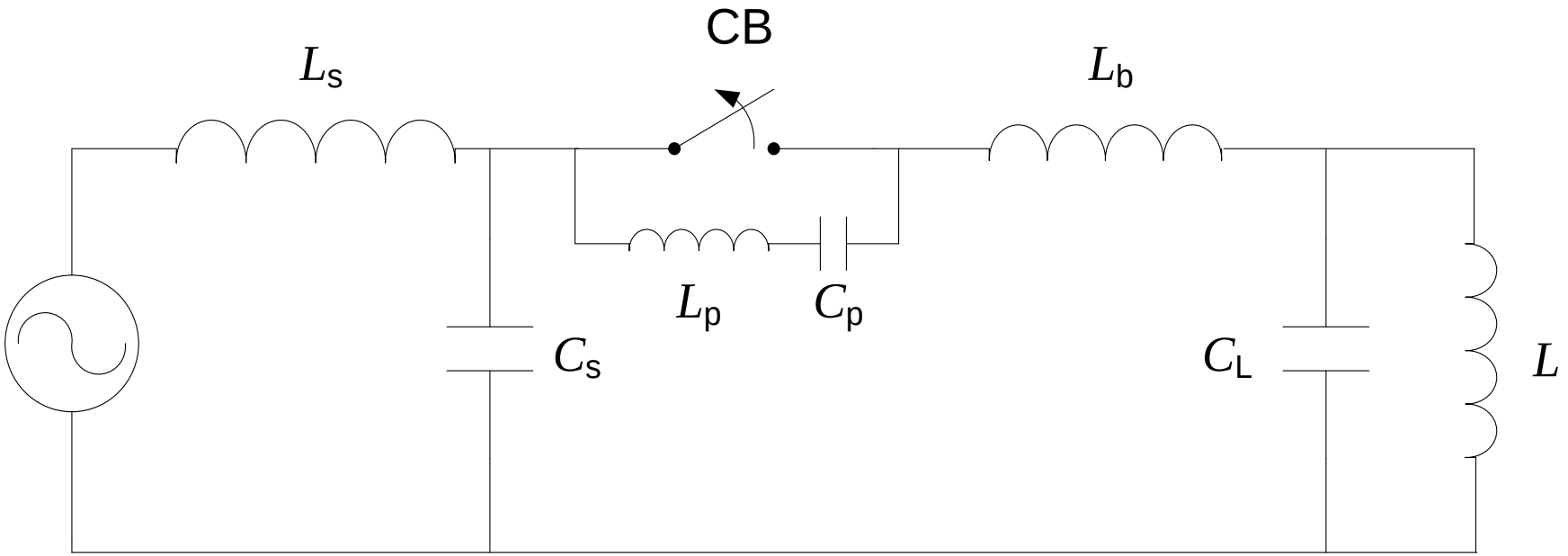
- ***Isolation***

Isolation of a system component is intended to prevent its re-energization until an inspection has been completed. Isolation is accomplished by opening the circuit breakers and/or disconnect switches closest to the system component, with lockout block closing of those devices

Shunt Reactor Operation Characteristics

- Shunt Reactor Current is mainly inductive and it is small (10%-15% of nominal currents)
- Shunt Reactors are frequently switched and during the periods of the system operations
  - *with low loads it is energized; and*
  - *with the rise of load it is de-energized*
- Switching operations result in EMT and some mechanical effects.

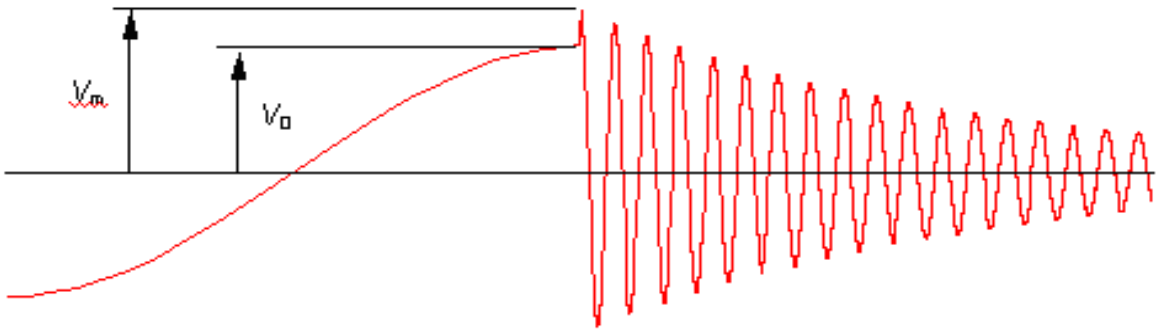
Inductive – Shunt Reactor De-energisation



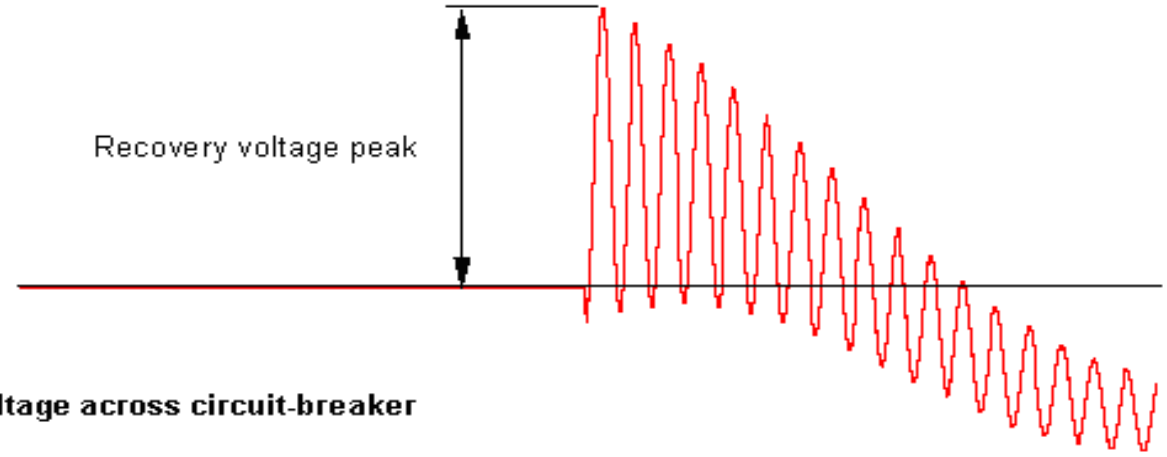
Interactive process characterised by:

- ***Current chopping (interaction of arc with capacitance in parallel with the CB)***
- ***Relatively high frequency recovery voltage on load side***
- ***Reignitions (can normally not be avoided)***

Shunt Reactor De-energisation - Voltages

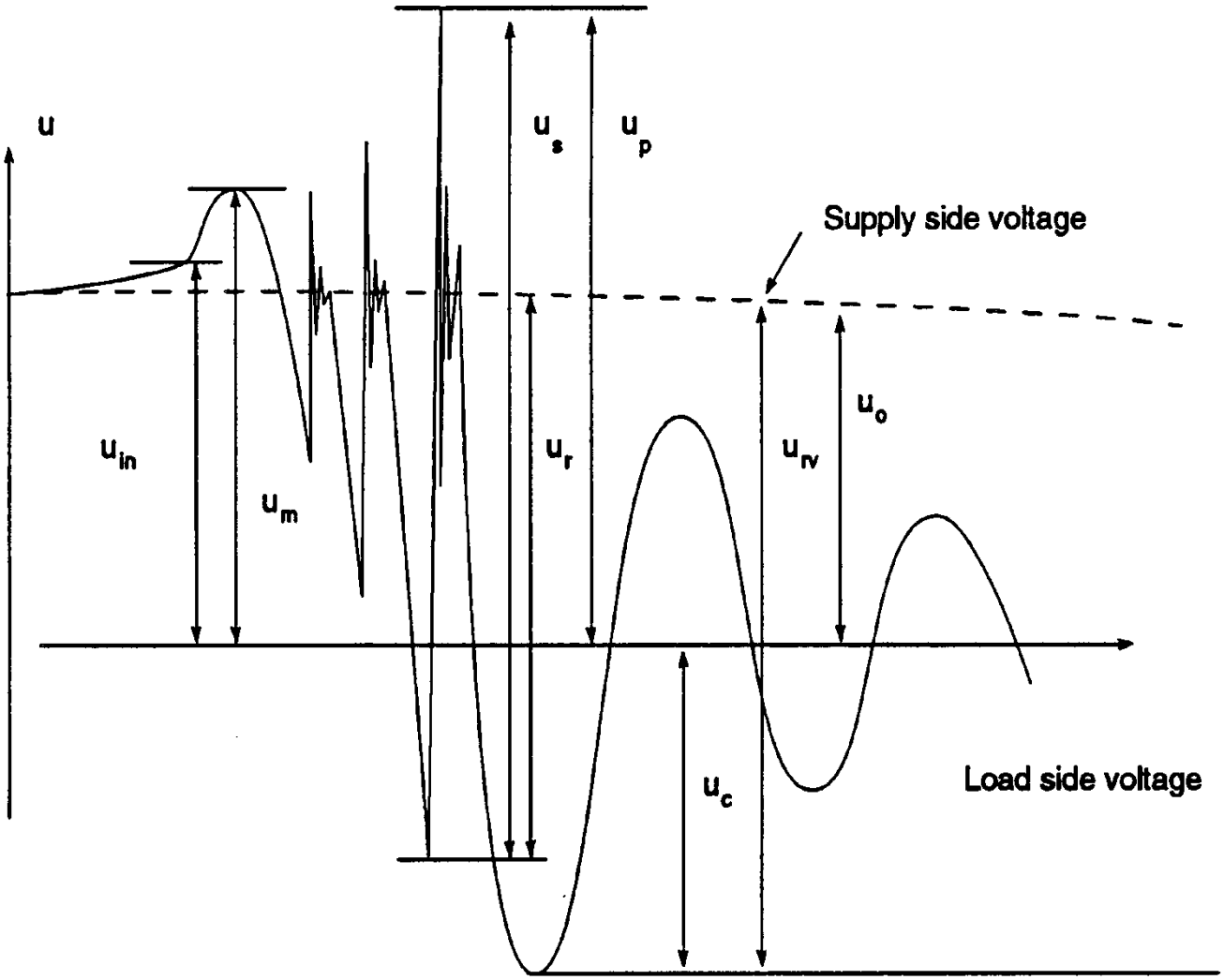


Load side voltage



Voltage across circuit-breaker

Shunt Reactor De-energisation - Reignitions



Reactor Primary Protection

- ***Primary protection includes differential and overcurrent protection.***
  - ***Differential protection scheme is high-impedance differential protection and is connected to dedicated current transformers.***
  - **Applied as a primary protection for faults**
    - **between windings of different phase**
    - **winding-to-core**
    - **Winding-to-winding faults**
  - ***Does not detect interturn faults.***

- *Backup protection for reactor faults is provided also by an inverse time neutral overcurrent protection to detect high-magnitude winding-to-ground (winding-to-tank) faults.*
- *It does not have to be directional but should override maximum contribution to external faults (HV bus and lines) and unequal current transformer saturation.*

Reactor Standby Protection

- ***Standby protection includes overcurrent protection and non-electrical protective devices.***
  - ***Non-electrical devices will be connected for alarm and trip***

Major concern

- ***Sensitivity and Security***

Reactor protection must detect minimum interturn faults, winding to ground faults and core faults and must be selective to prevent unnecessary trips and reactor isolation for external faults or transients on energizing and de-energizing the reactor.

Interturn faults

Interturn faults are extremely difficult to detect

- ***Detection of those faults depends on the grounding of reactor.***
  - ***If reactor is supplied from a grounded system, and its neutral is solidly grounded, this reduction in impedance causes an increase in current magnitude in the particular phase, resulting in a zero sequence current flowing through the neutral to ground.***

Interturn Faults Detection

- ***Used the neutral ground overcurrent elements, connected to separate neutral CTs, supervised by the zero-sequence voltage polarized directional element.***
- ***Directional neutral ground protection scheme includes an "Inrush Tripping Suppressor" (ITS) scheme that***
  - ***disables tripping on de-energization,***
  - ***disable several seconds following energization.***

Inrush Tripping Suppression Logic

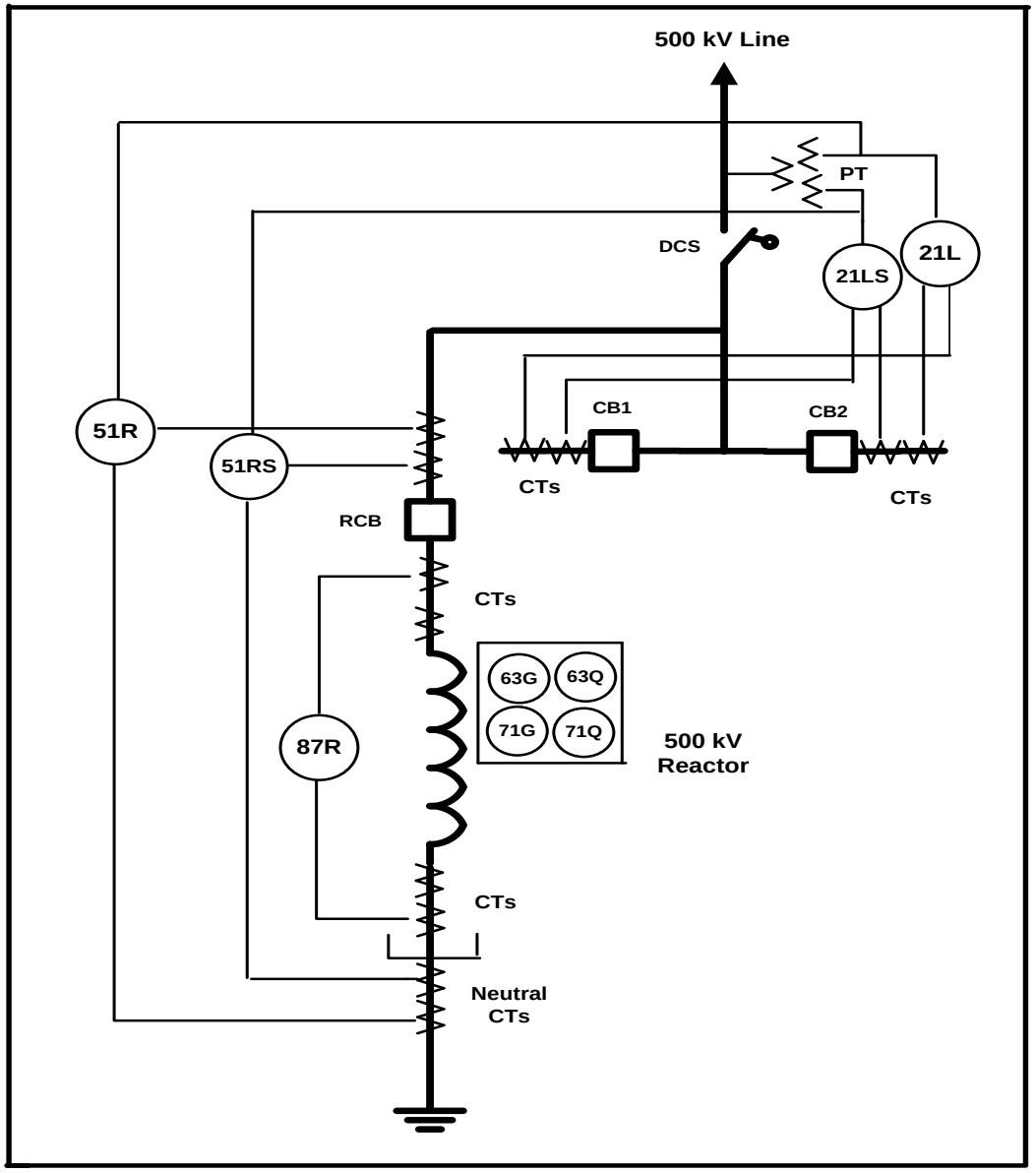
***Inrush Tripping Suppression* (ITS) feature is implemented using phase overcurrent elements to avoid false tripping by sensitive protection elements on energizing the reactor.**

(ITS blocks the ground overcurrent tripping on deenergization of the reactor and retains the blocking function for a few seconds after energization).

Turn-to-Turn Protection Scheme

- **Directionalized to see zero sequence current flow into the reactor.**
  (This device should not operate for external faults)
- **The setting is about 5-10 % of reactor rating**
  (This setting could be slightly desensitized because of the directional element's sensitivity).
- **Inrush Tripping Suppression (ITS)**
  (to avoid false tripping by sensitive protection elements on energizing the reactor)
- **Tripping is time delayed by 15 cycles**
  (Time delay is necessary to avoid race between reset of ITS logic and transient pick up of the 67N element).

Present BCH 500 kV Shunt Reactor One Line Diagram

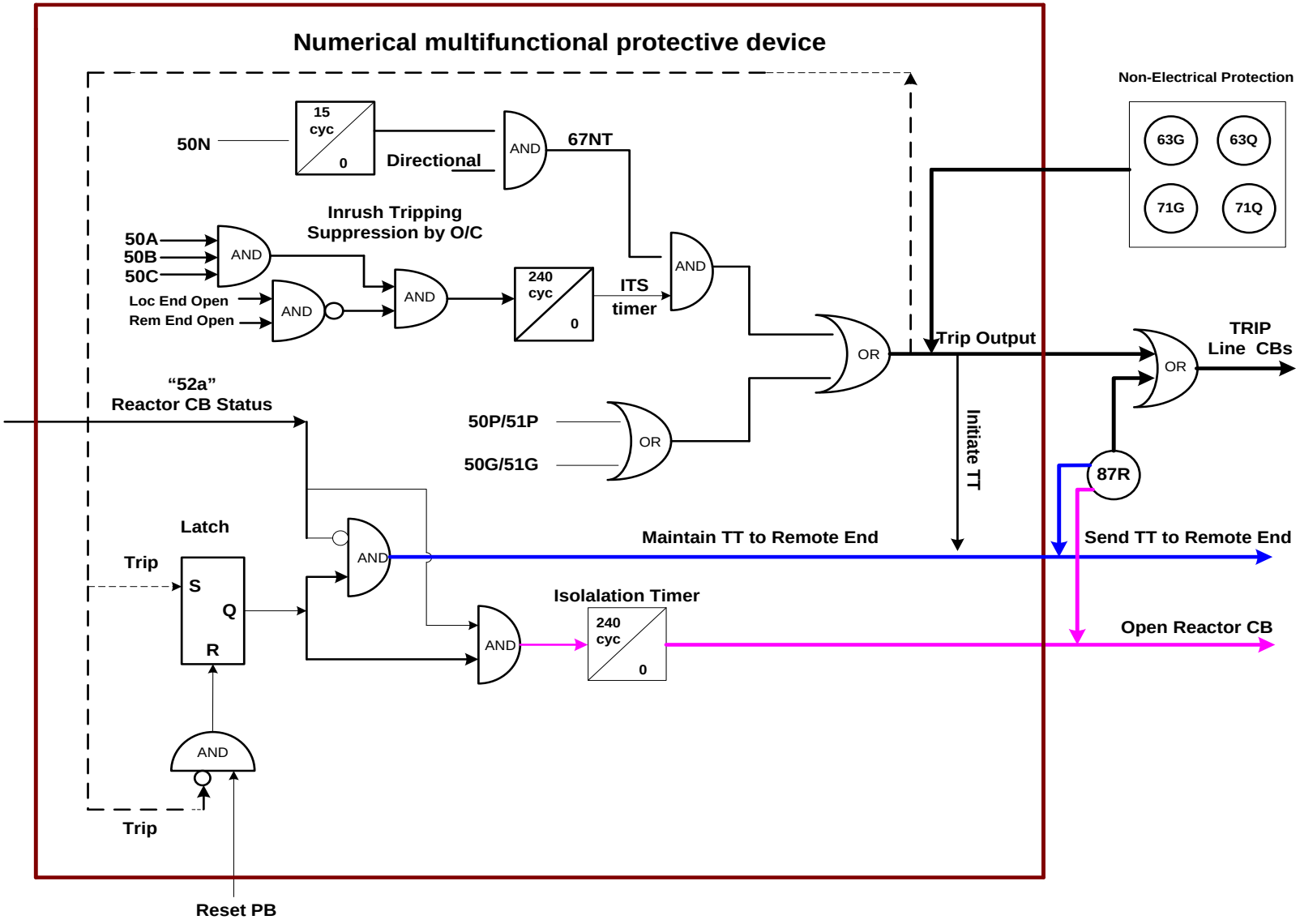


Reactor Protection Tripping

Protection tripping for reactor faults is similar to that for transformers.

- ***In new installations, tripping from the sudden pressure relay should be supervised by the sensitive ground directional relay, as recommended in BC Hydro internal report "The Model 11 Gas Relay - Performance Analysis and Recommendations"***

BC Hydro Reactor Protection Scheme



Note: 50 elements measure reactor current

Finally - Why do we have protection?