This webinar brought to you by The Relion® Product Family
Next Generation Protection and Control IEDs from ABB

Relion®. The perfect choice for every application.

The widest range of products for power systems protection, control, measurement and supervision. Interoperable and future-proof solutions designed to implement the core values of the IEC 61850 standard. ABB's leading-edge technology, global application knowledge and experienced support network ensures complete confidence that your system performs reliably - in any situation.

ABB Protective Relay School Webinar Series

Disclaimer

ABB is pleased to provide you with technical information regarding protective relays. The material included is not intended to be a complete presentation of all potential problems and solutions related to this topic. The content is generic and may not be applicable for circumstances or equipment at any specific facility. By participating in ABB's web-based Protective Relay School, you agree that ABB is providing this information to you on an informational basis only and makes no warranties, representations or guarantees as to the efficacy or commercial utility of the information for any specific application or purpose, and ABB is not responsible for any action taken in reliance on the information contained herein. ABB consultants and service representatives are available to study specific operations and make recommendations on improving safety, efficiency and profitability. Contact an ABB sales representative for further information.

ABB Protective Relay School Webinar Series

Generator Protection Fundamentals

Mike Kockott

September 10, 2013

Power and productivity
for a better world™

Presenter

Mike Kockott

Mike is a Senior Engineer, Product Specialist for the Relion family 670 and 650 product series. He is located in Raleigh, North Carolina. Mike has been part of the NAM SA Products team for 9 months. Prior to this he worked as a Senior Applications Specialist / Senior Regional Technical Manager for 12 years at the SA Product factory in Västerås, Sweden.

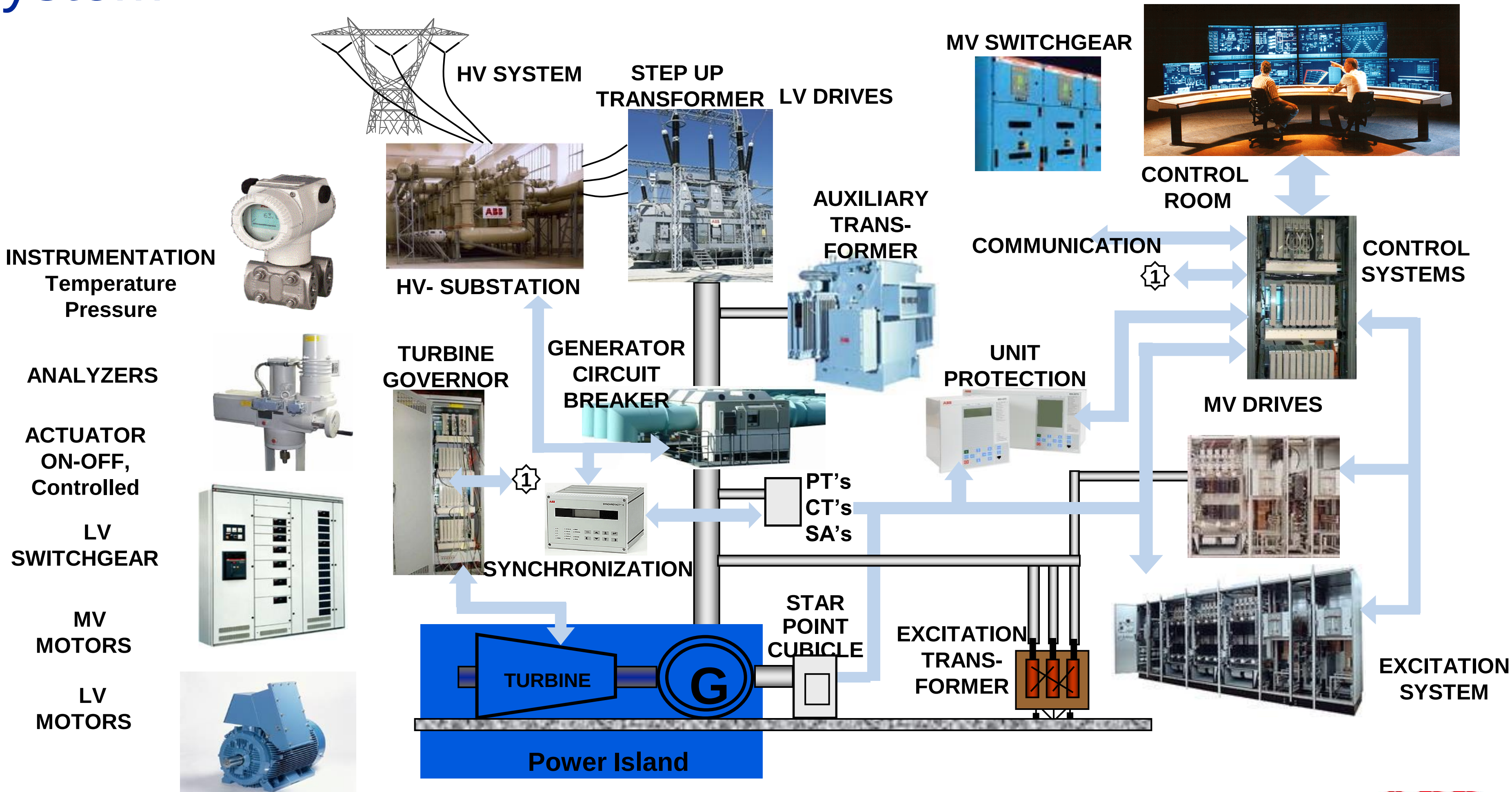
Prior to joining ABB SAP in Sweden in 2000, Mike was Chief Consultant, Protection (Transmission) at Eskom (national power utility, South Africa). Mike joined Eskom as a training engineer in 1983.

Mike graduated from the University of Cape Town with BSc (electrical engineering) degree (with honors) in 1980.

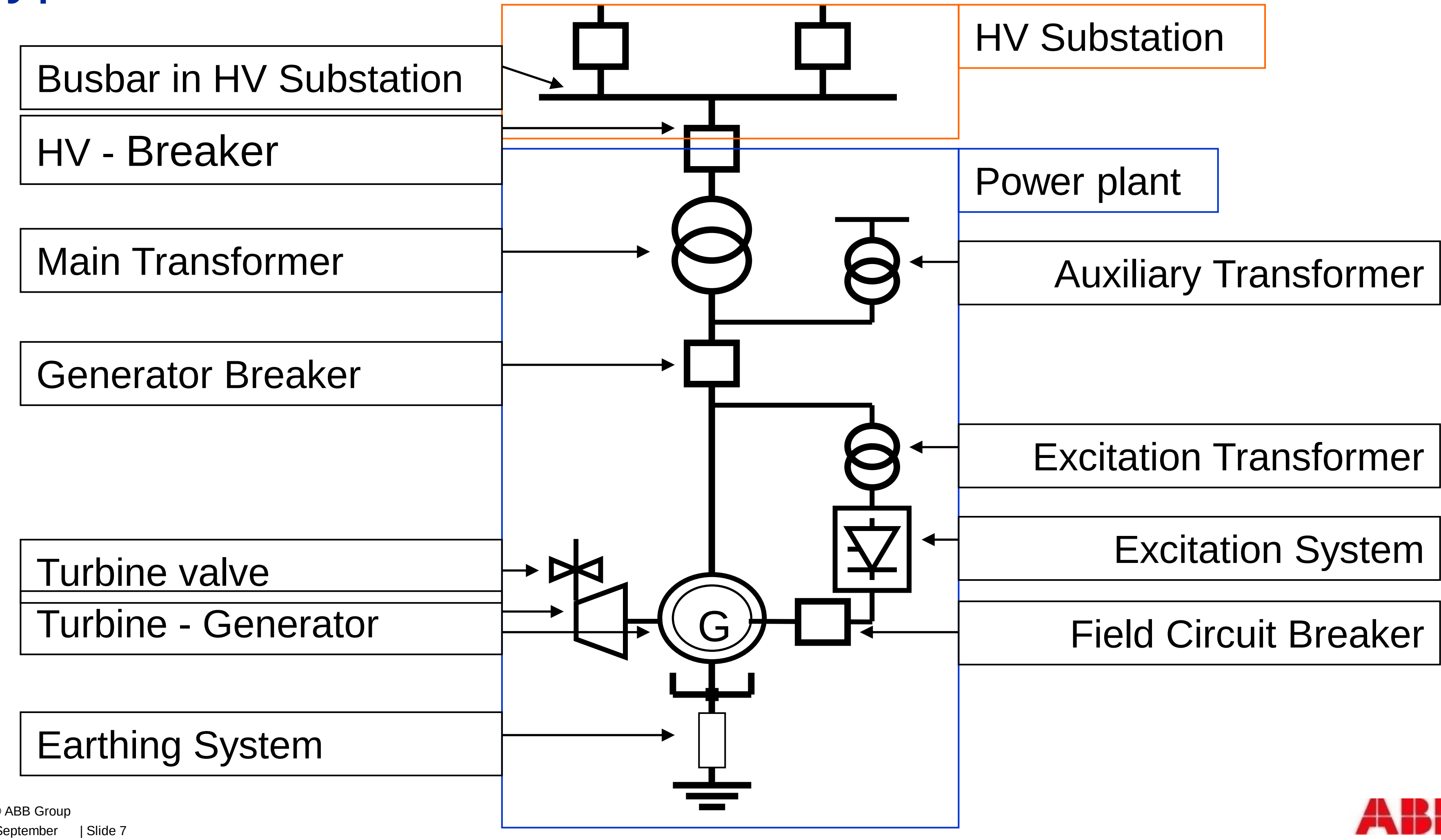
Learning objectives

- Power Generation fundamentals
- Generator Faults
- Generator Abnormal Conditions
- Typical Generator Protections

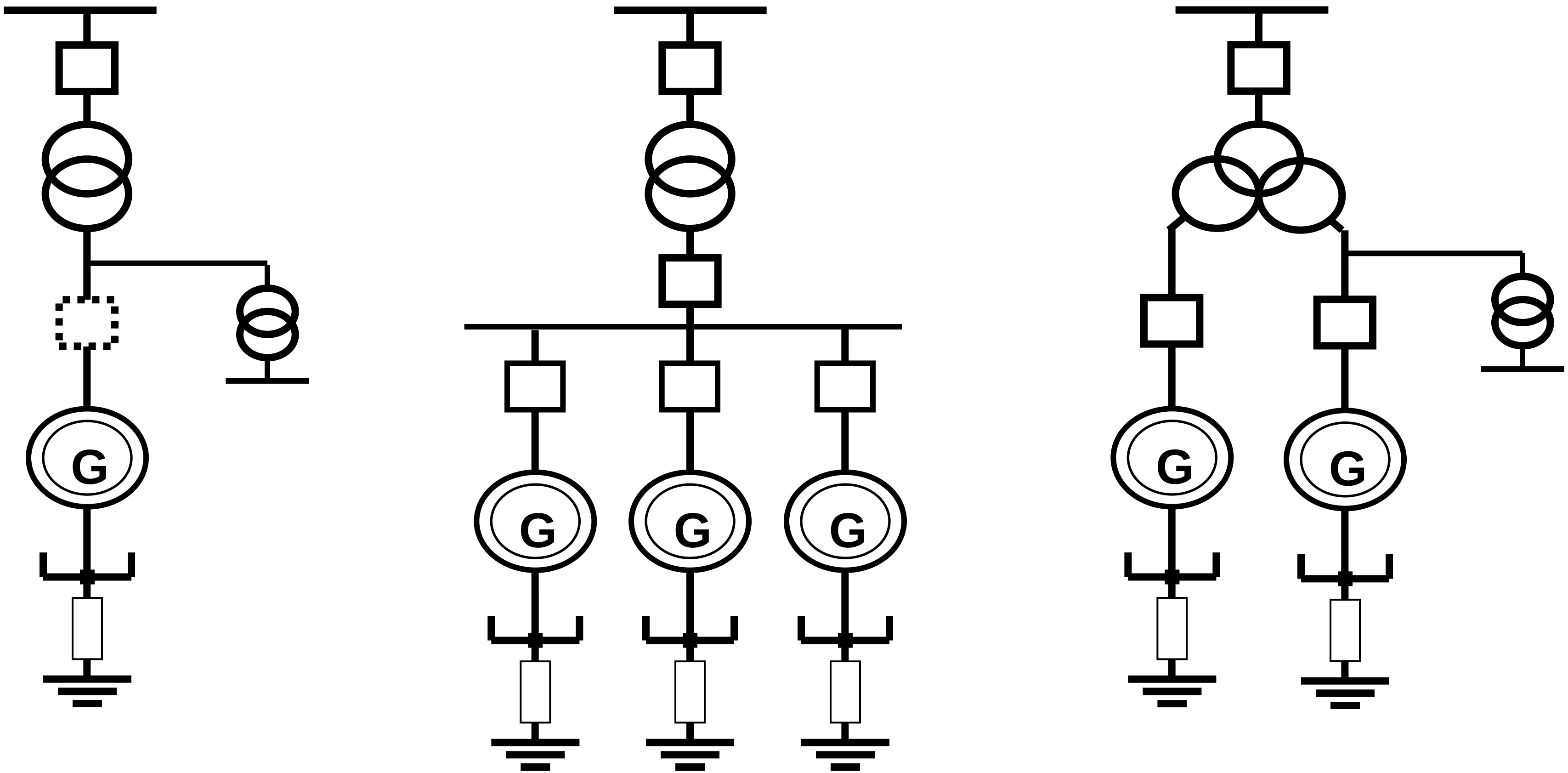
Power station is the most complex part of the power system



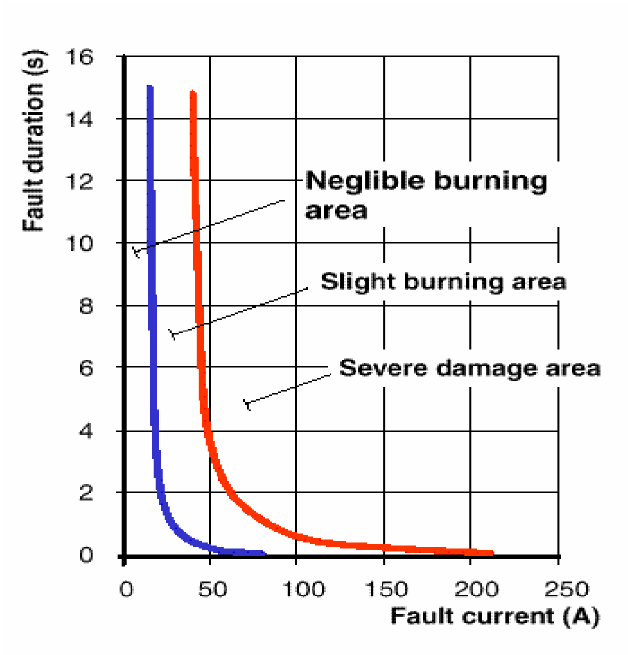
Typical Parts of a Power Plant



Different power plants electrical equipment layouts

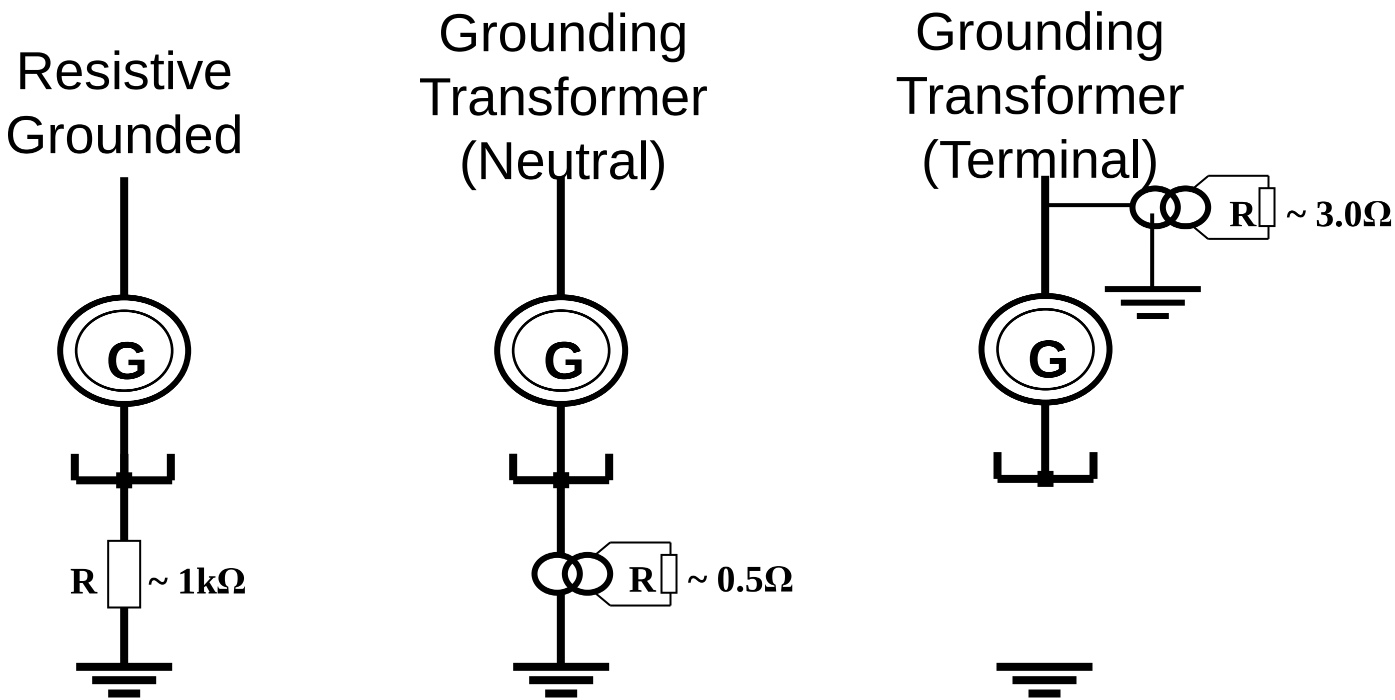


Damage to the stator core in case of earth-fault

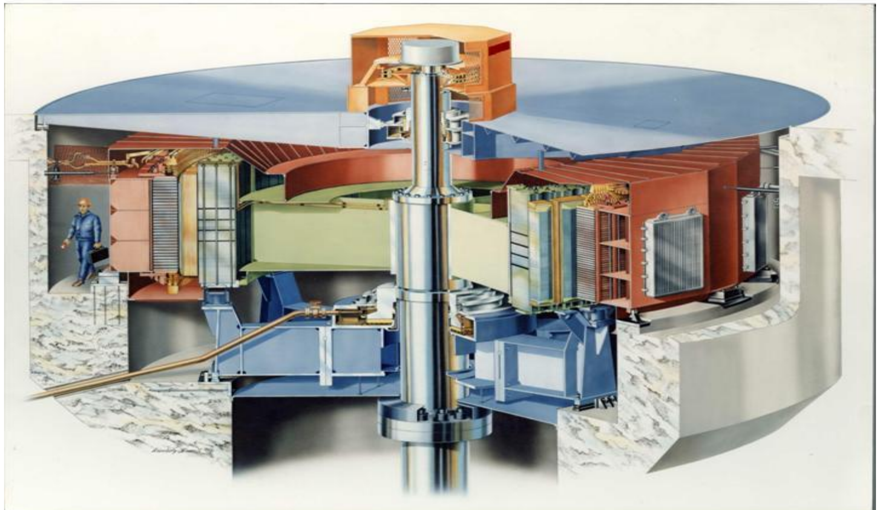


- Practically all unit connected generators are high-impedance earthed
- Only industrial generators may be low-impedance earthed

Stator winding earthing practices



Possible faults

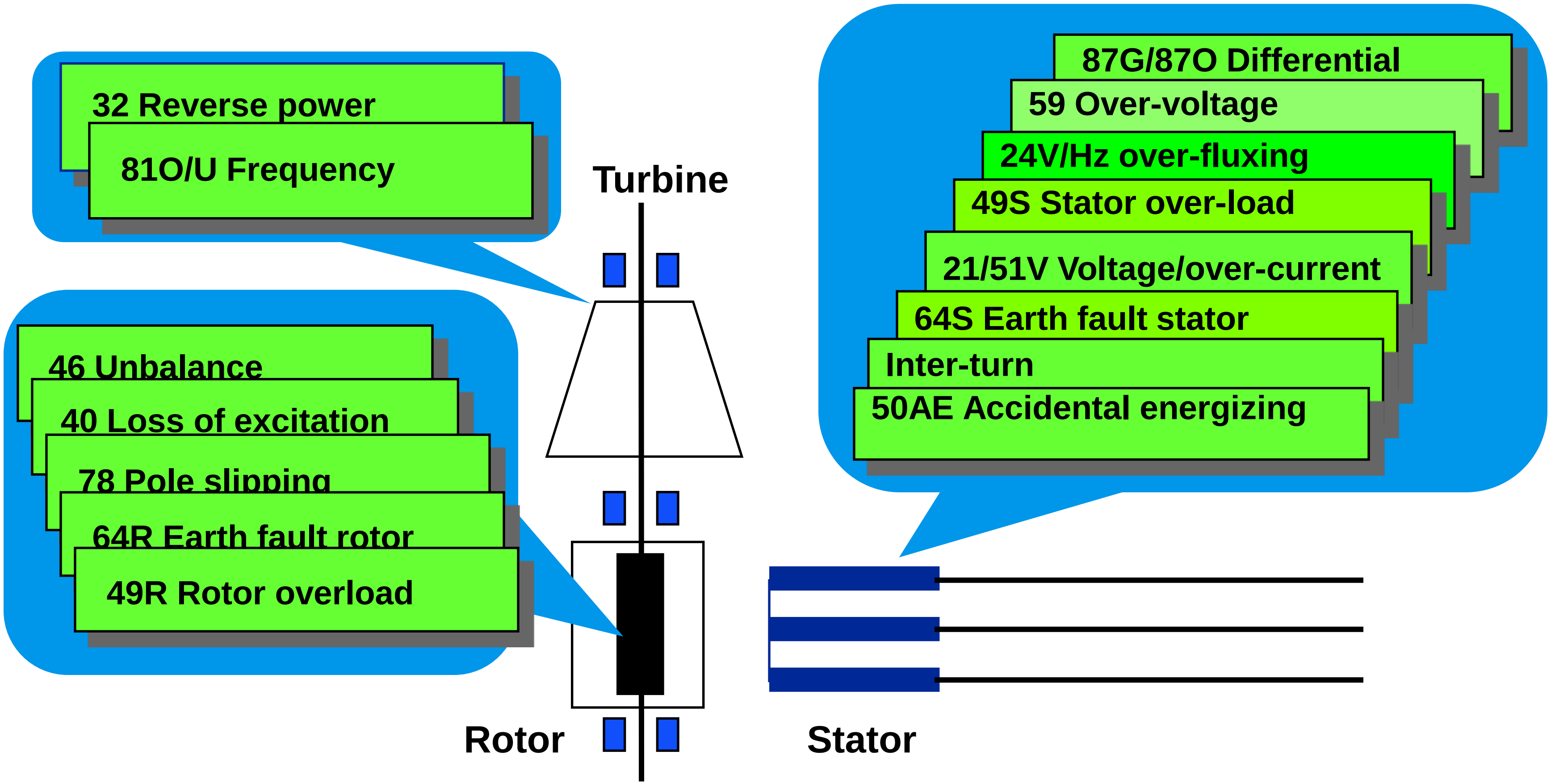


- Stator Earth Faults
- Rotor Earth Faults
- Stator Short Circuits
- Stator/Rotor Interturn faults
- Unit transformer faults
- External faults

Abnormal operating condition

- overcurrent/overload
- unbalanced load
- overtemperature
- over- and undervoltage
- over- and underexcitation
- over- and underfrequency
- over-fluxing
- asynchronous running
- out of step
- generator motoring
- failures in the machine control system (i.e. AVR or governor failure)
- failures in the machine cooling system
- failures in the primary equipment (i.e. breaker head flashover)
- open phase

Allocation of protection functions



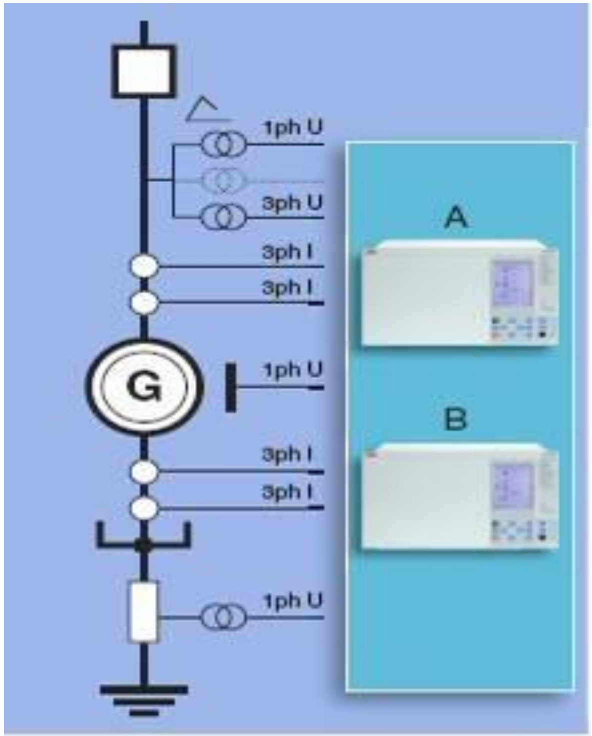
Function allocations with older generation relays

- Older type of design:
  - M1 and M2 with different function allocations

Table 3: Example on relay functions divided into two function groups

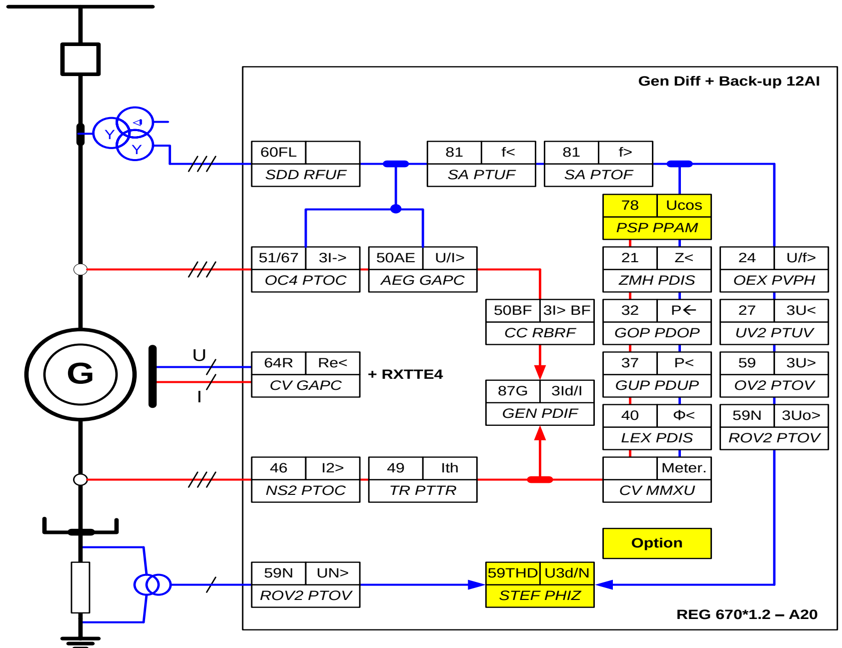
Type of fault	ANSI	Protection function	System	
Generator stator			**A**	**B**
Short circuit	87G	Generator differential	X	
	21	Minimum impedance or alternatively		X
	51/27	Overcurrent/undervoltage for thyristor magnetisation		X
	51	Overcurrent		X
Dissymmetry	46	Negative sequence overcurrent		X
Stator overload	49	Thermal overload	X	
Stator earth fault	59	95% stator earth fault	X	X
Loss of excitation	40	Reactive current and phase angle		X
Motoring	32	Reverse power Redundant protection used for large generators	 X	X X
Overspeed	81	Max. frequency	X	
Turbine blade fatique	81	Min. frequency	X	
Interturn fault	59 or 51N		X	(X)
Overvoltage	59	Overvoltage		X
Over magnetization	24	V/Hz	X	
Low voltage	27	Undervoltage		X
Inadvertent breaker closing (Dead-machine protection)	50/27	Overcurrent with low voltage		X
Shaft current	-	Overcurrent, fixed time		X
Generator rotor				
Rotor overload	49	Thermal overload		X
Rotor earth fault	64R	Injected AC Injected DC	X	 X
Step-up (Block) transformer				
Short circuit/earth fault	87T	Differential protection	X	
Overcurrent	50/51	Time overcurrent with instantaneous function		X
Breaker failure protection	50BFR			X
Earth fault differential prot.	87D		X	
Over magnetization prot.	24	V/Hz		X

Generator protection with modern IEDs



- Generator/transformer protection with integrated IEDs
- Mainly function duplication used
  - Most functions duplicated
- Duplication not used for small machines only

Generator protection



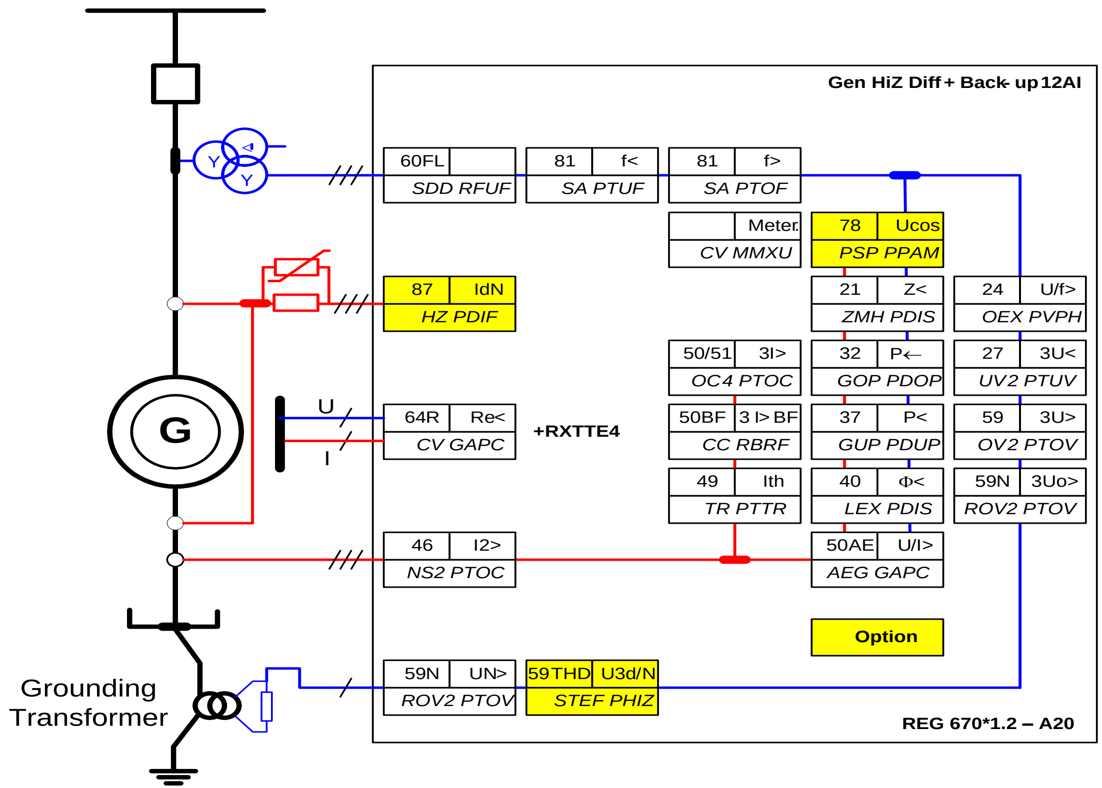
Other functions available from the function library

25	50 3I>>	51/27 U</I>	32N P0->	64S R_{SE}<
SES RSYN	PH PIOC	CV GAPC	SDE PSDE	STTI PHIZ
52PD PD	51/67 3I>	51V I>/U	87CT I2d/I	64R R_{RE}<
CC RPLD	OC4 PTOC	CV GAPC	CCS RDIF	ROTI PHIZ

Function alternatives for 87G/GEN PDIF

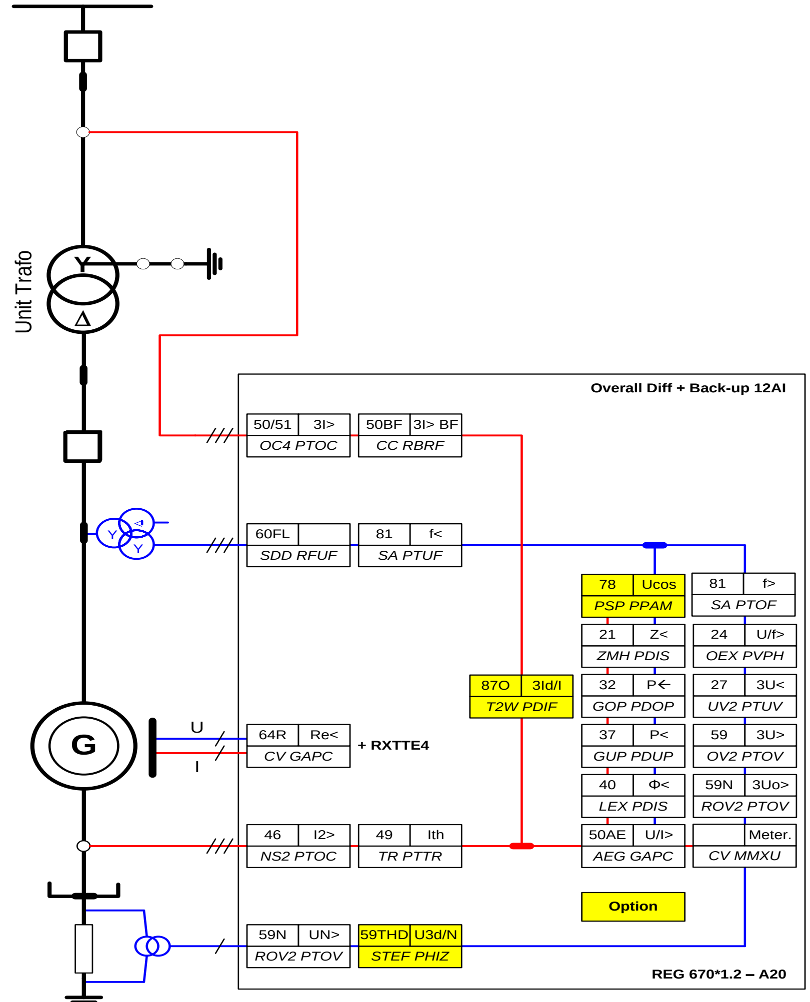
87T 3Id/I	87 IdN
T2W PDIF	HZ PDIF

Generator protection with 87HZ



- Fast and sensitive differential protection against short-circuits
- Requires dedicated and identical CT cores on both sides of the generator
- Requires external resistor and metrosil

Generator protection with 87T

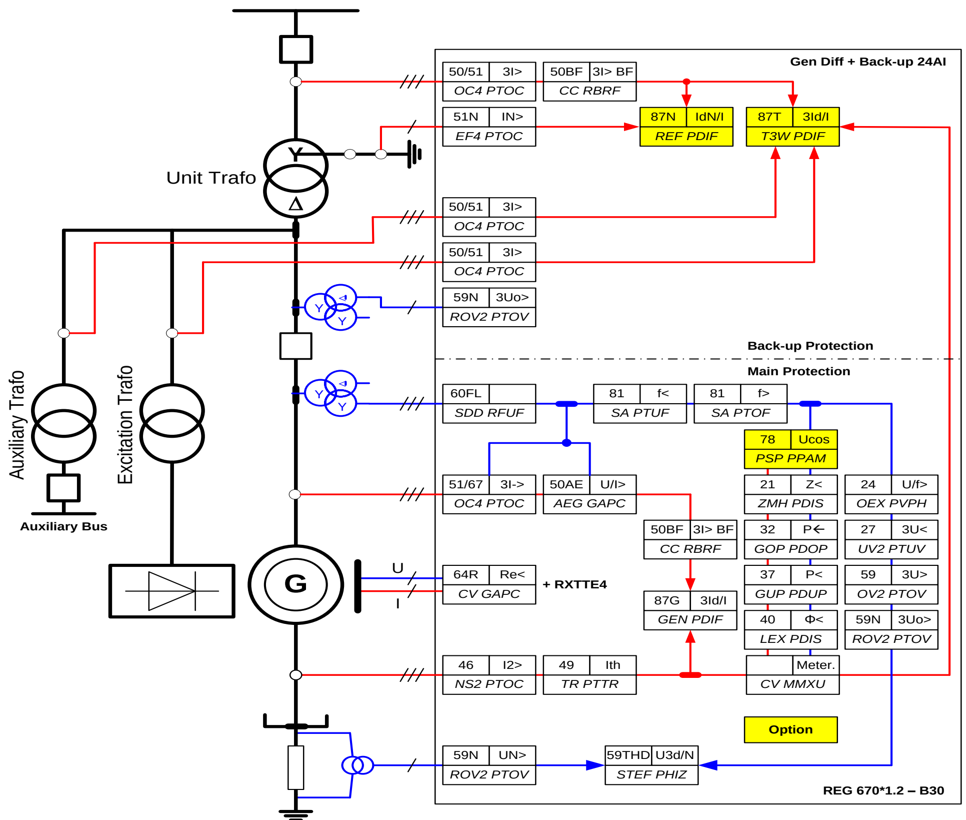


Complete Protection Scheme

- Generator M1 & M2 protection
  - Two identical IEDs with 87G (low/high impedance based)

- Complete Unit Protection for Smaller Machines
  - One with 87G
  - One with 87T or 87O

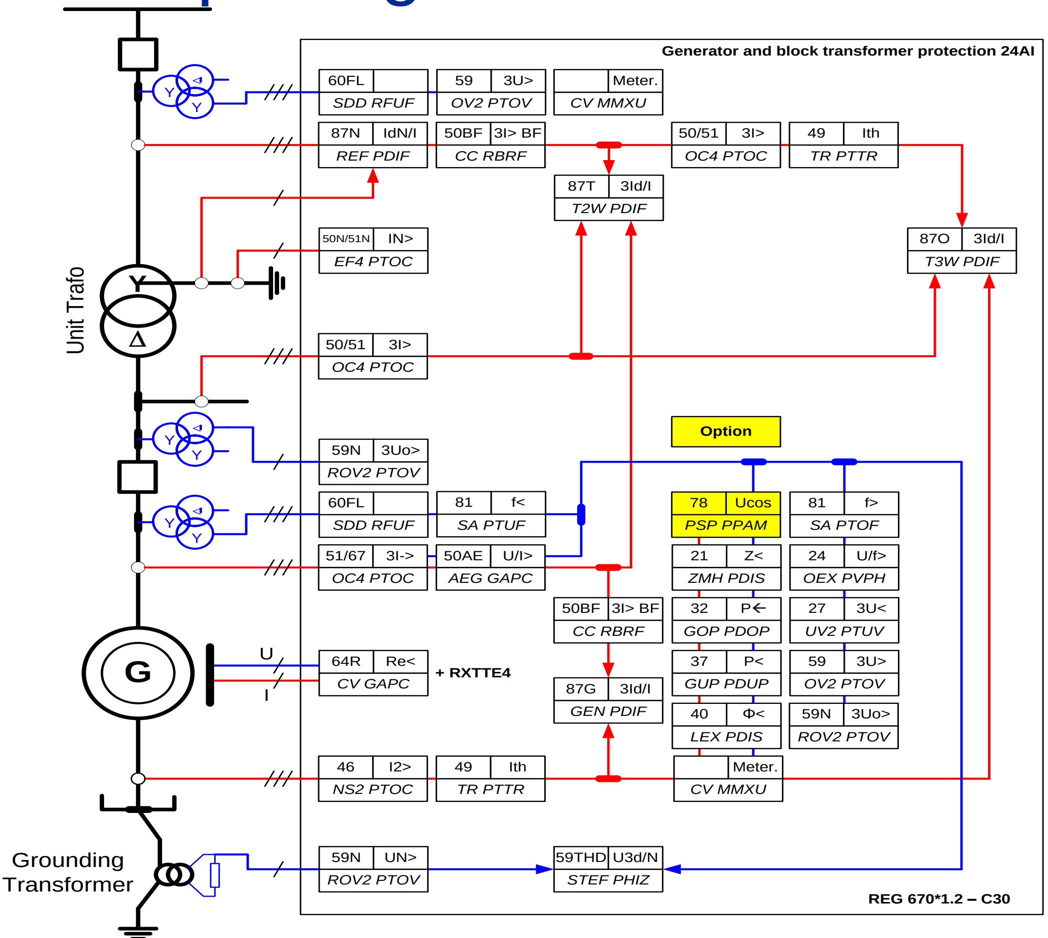
Generator protection & optional transformer protection



Other functions available from the function library

25 SES RSYN	50 3I>> PH PIOC	51/27 U</I> CV GAPC	64S R_{SE}< STTI PHIZ	87T 3Id/I T2W PDIF
52PD PD CC RPLD	87CT I2d/I CCS RDIF	51V I>/U CV GAPC	64R R_{RE}< ROTI PHIZ	32N P0-> SDE PSDE

Complete generator-transformer unit protection



Other functions available from the function library

25 SES RSYN	50 3I>> PH PIOC	51/27 U</I> CV GAPC	32N P0-> SDE PSDE	64S R_{SE}< STTI PHIZ
52PD PD CC RPLD	51/67 3I> OC4 PTOC	51V I>/U CV GAPC	87CT I2d/I CCS RDIF	64R R_{RE}< ROTI PHIZ

Stator short circuit

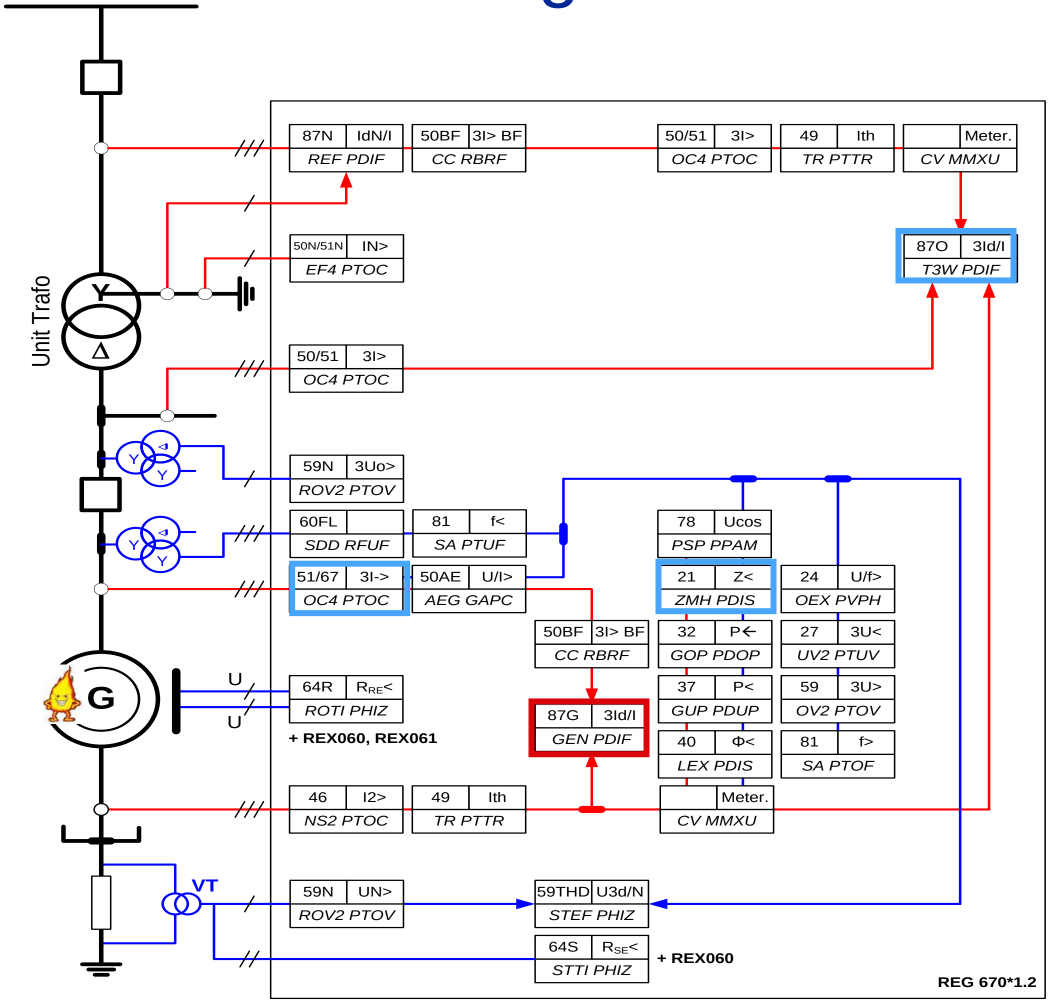
- Consequence of stator short circuit
  - Insulation, windings and stator core can be damaged
  - Large forces, caused by large fault currents, can give damage to other components in the plant
  - Risk of explosion and fire
  - Mechanical stress on generator- and turbine shafts

Detection of stator short circuits

- Protection functions
  - Generator differential protection
  - Block (unit) differential protection
  - Directional negative sequence overcurrent protection
  - Under impedance protection
  - Phase overcurrent protection
  - Voltage dependent phase overcurrent protection
  - Under voltage protection
  - Phase overcurrent protection of the block transformer

Phase to phase fault in the stator winding

- Endangering condition
  - Overcurrent
- Protected object
  - Stator winding
- Consequences
  - Heating
  - Forces
  - Smelted stator core



Main Protection Function

Reserve Protection Function

Generator differential protection

- Unstabilized differential protection level
- Stabilized differential protection level
  - Harmonic blocking
- Negative sequence unrestrained
  - Combination: bias differential and negative sequence internal/external discriminator; increases speed and security
- Negative sequence sensitive differential protection

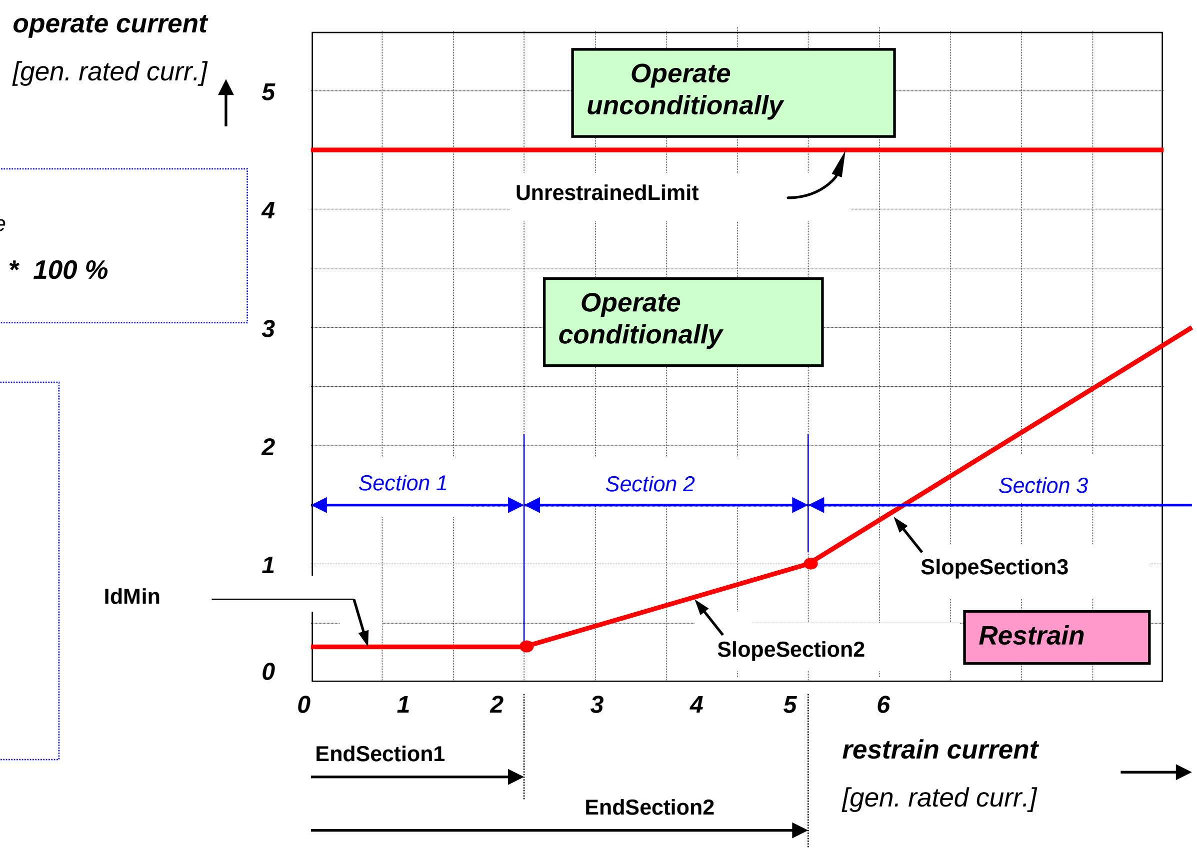
Differential protection characteristics

$$slope = \frac{\Delta I_{operate}}{\Delta I_{restrain}} * 100\ \%$$

The restrained characteristic is defined by the settings:

****

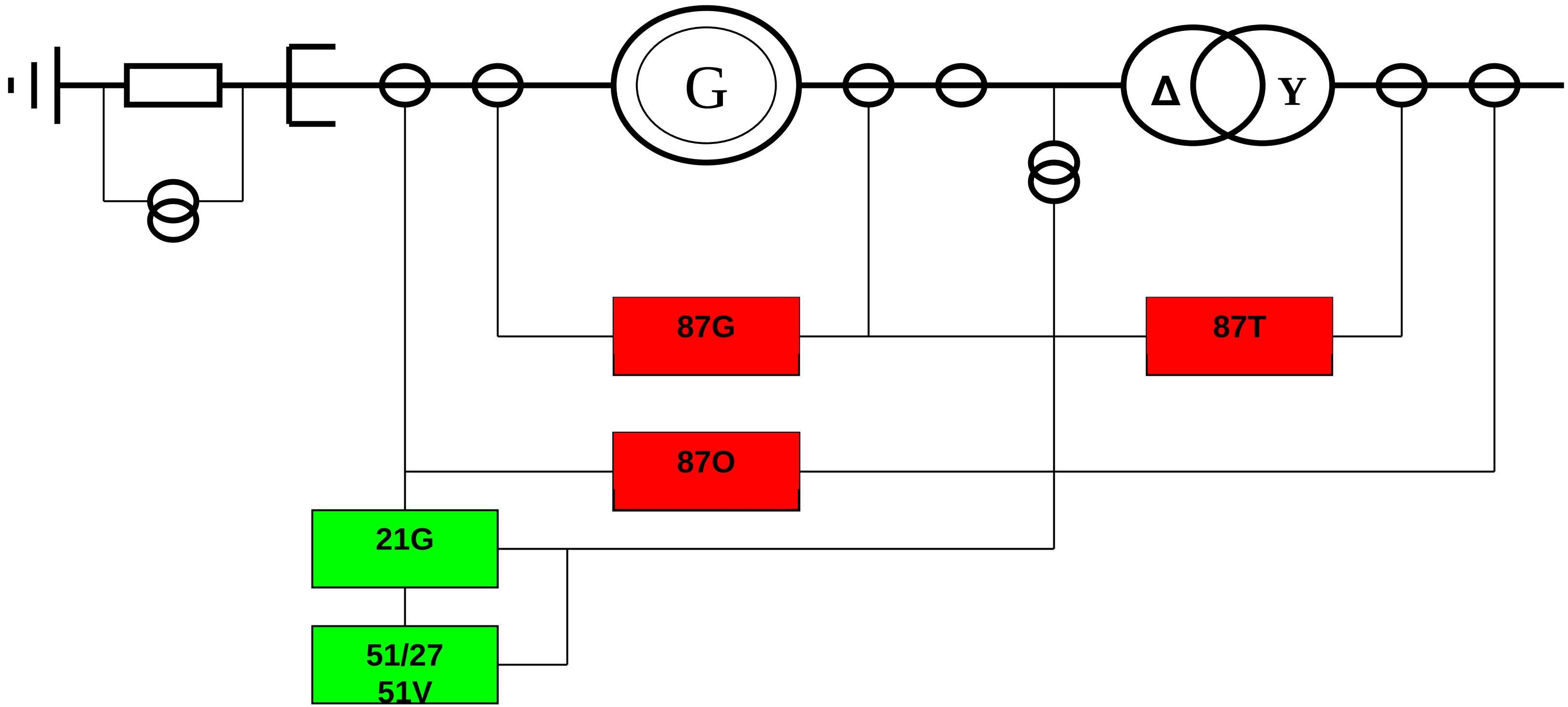
1. IdMin
2. EndSection1
3. EndSection2
4. SlopeSection2
5. SlopeSection3



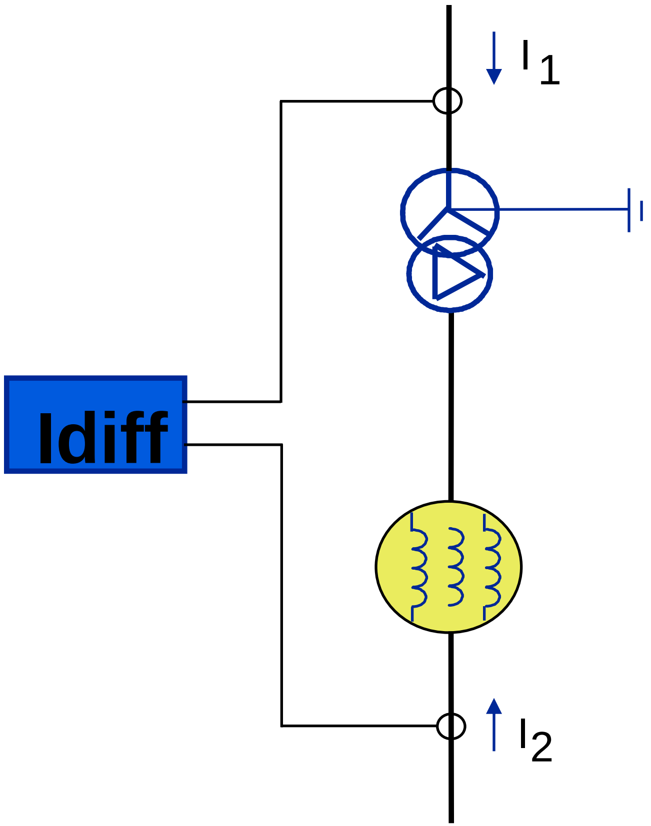
Generator differential protection

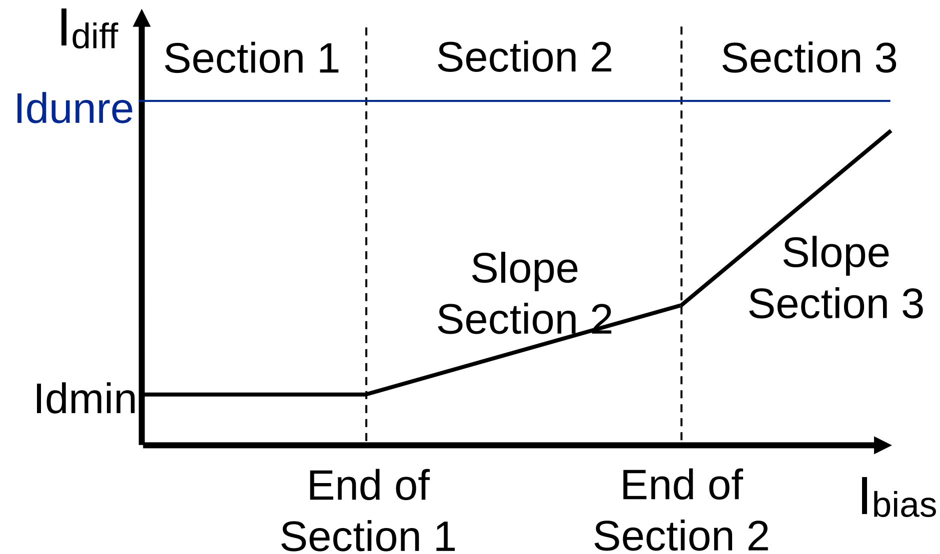
- Shall trip
  - Turbine: close down active power
  - Generator breaker: if available
  - Field breaker
  - Unit breaker: If no generator breaker
  - Fire protection

Different differential protection functions can be used



Overall or transformer differential protection (87O/87T)





Generator unit (overall) differential protection

- Identical to transformer differential protection
  - Zero sequence current elimination
  - Vector group compensation
  - Transformer ratio compensation
  - Unstabilized differential protection
  - Stabilized differential protection
    - Harmonic blocking
    - Waveform blocking
  - Negative sequence unrestrained
    - Combination: bias differential and negative sequence internal/external discriminator
  - Negative sequence sensitive differential protection

Transformer (overall) differential protection

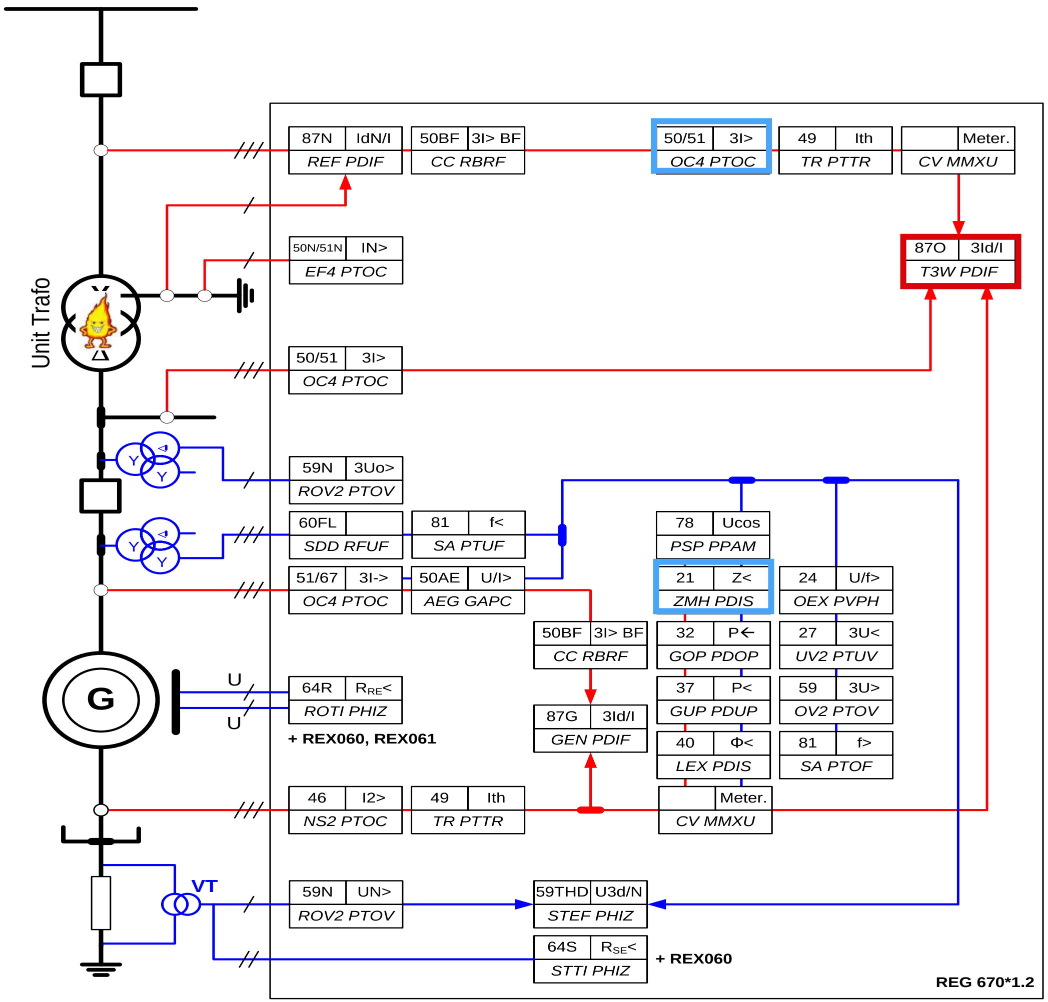
- Shall trip
  - Turbine: close down active power
  - Generator breaker: if available
  - Field breaker
  - Unit breaker

Phase to phase fault in the transformer winding

- Endangering condition
  - Overcurrent
- Protected object
  - Transformer windings
- Consequences
  - Heating
  - Forces
  - Smelted trafo core

Main Protection Function

Reserve Protection Function

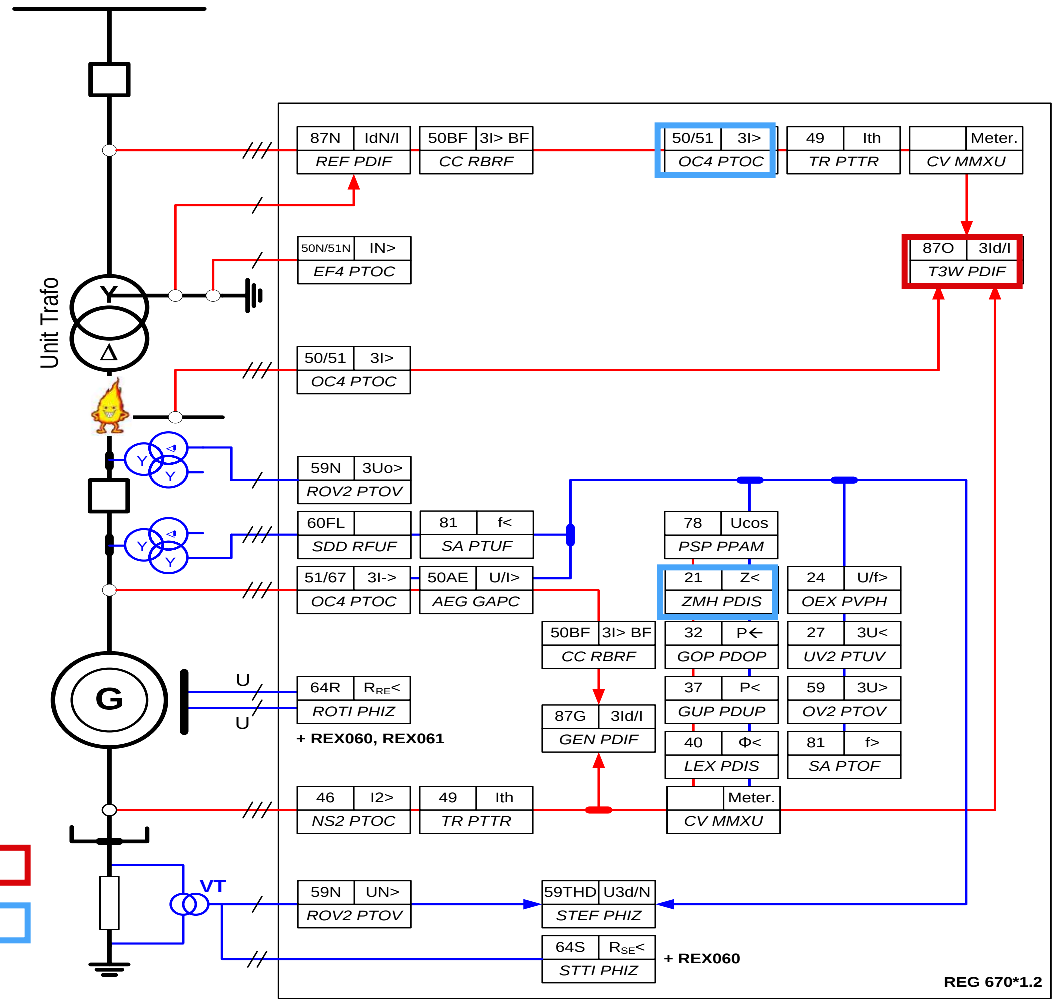


Phase to phase fault at the generator buswork 1

- Endangering condition
  - Overcurrent
- Protected object
  - Buswork, other equipment
- Consequences
  - Heating
  - Forces
  - Mechanical damages

Main Protection Function

Reserve Protection Function

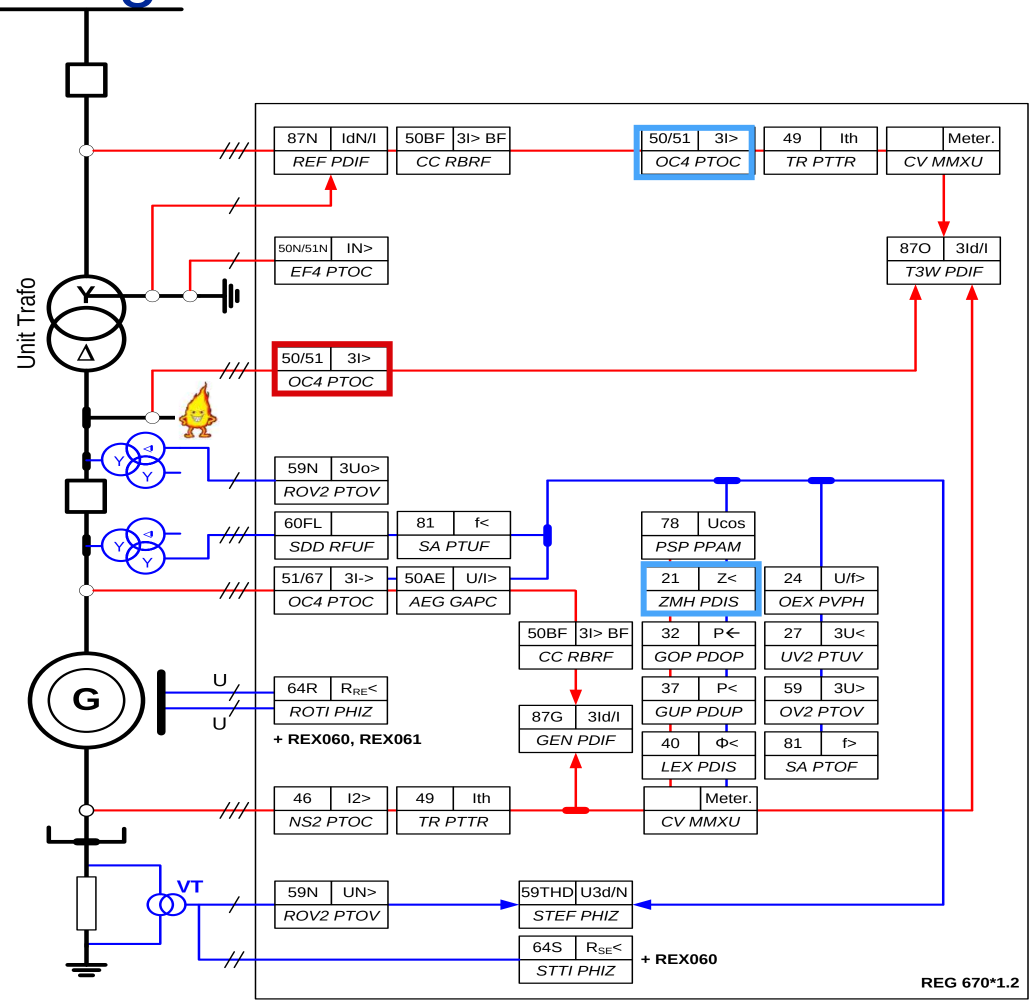


Phase to phase fault at the generator buswork 2

- Endangering condition
  - Overcurrent
- Protected object
  - Buswork, other equipment
- Consequences
  - heating
  - forces
  - mechanical damages

Main Protection Function

Reserve Protection Function

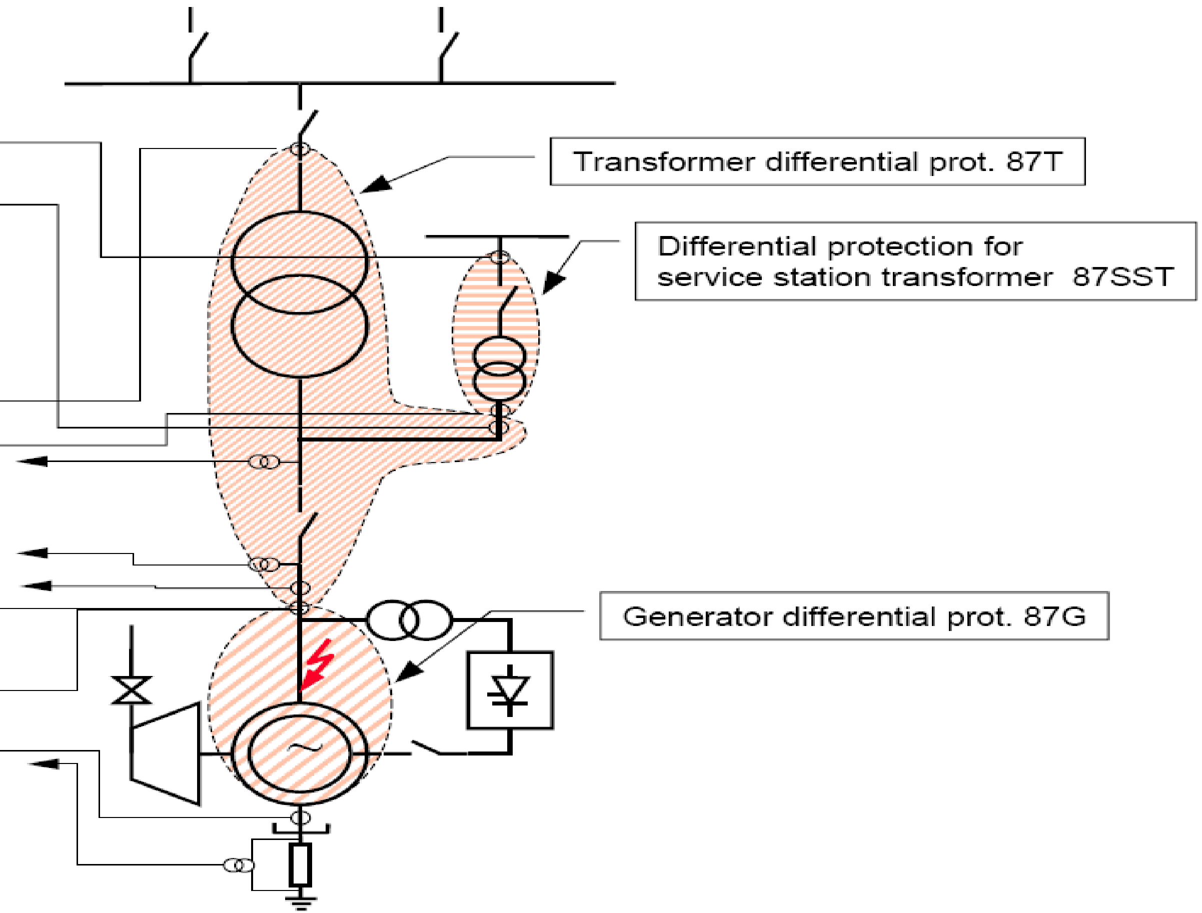


Short circuit protection: Differential protection (87)

Aux. Transformer Differential 87SST

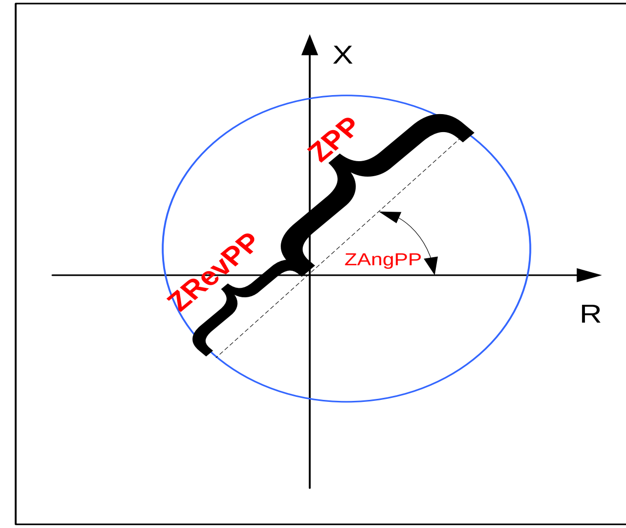
Unit Transformer Differential 87T

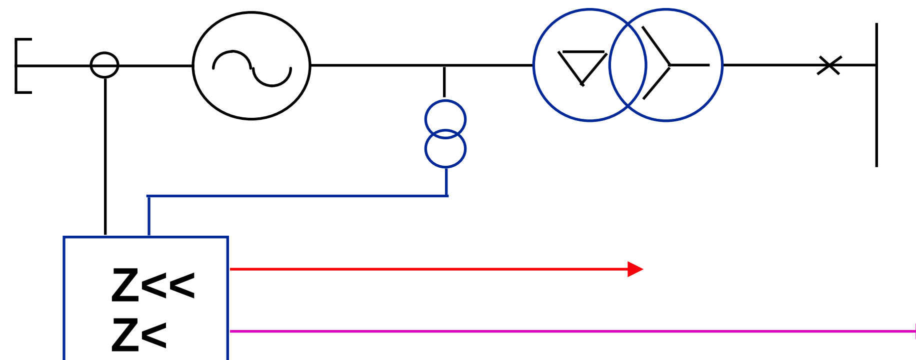
Generator Diff 87G



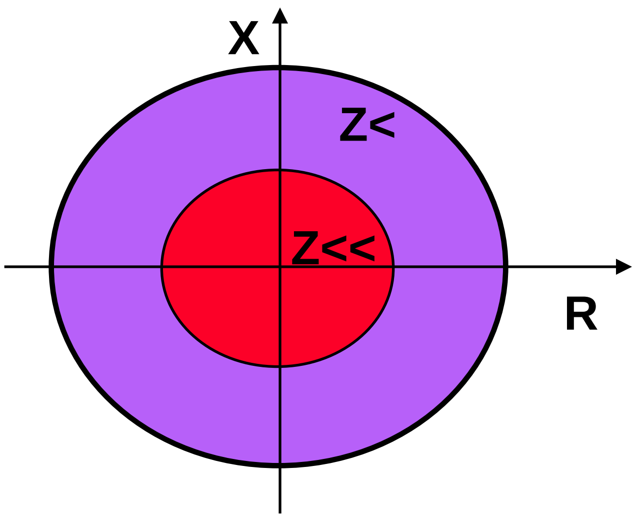
Under-impedance protection

- Backup protection for internal short circuits in the generator or the unit transformer
- Backup or main protection for fault at the busbar where the plant is connected to the power system
- Backup protection for line-faults at lines out from the power plant
- Up to 3-zones with offset mho characteristic

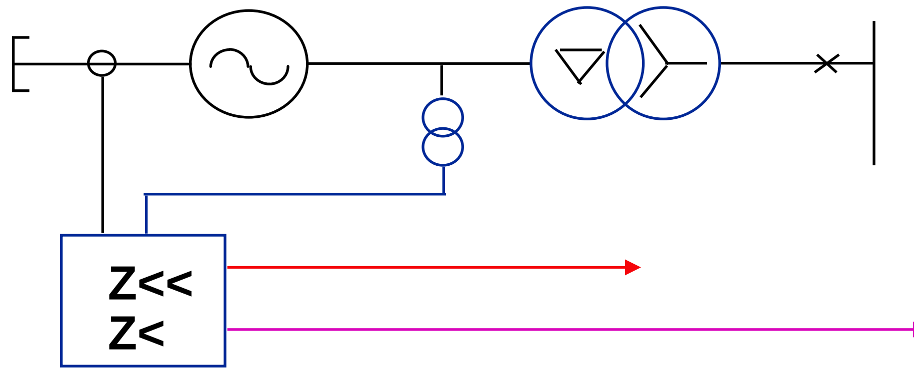




Under-impedance protection (21)



- Offset mho characteristic with up to three zones (two zones shown only)
  - Zone 1:Generator and trafo back up
  - Zone 2: External faults back up



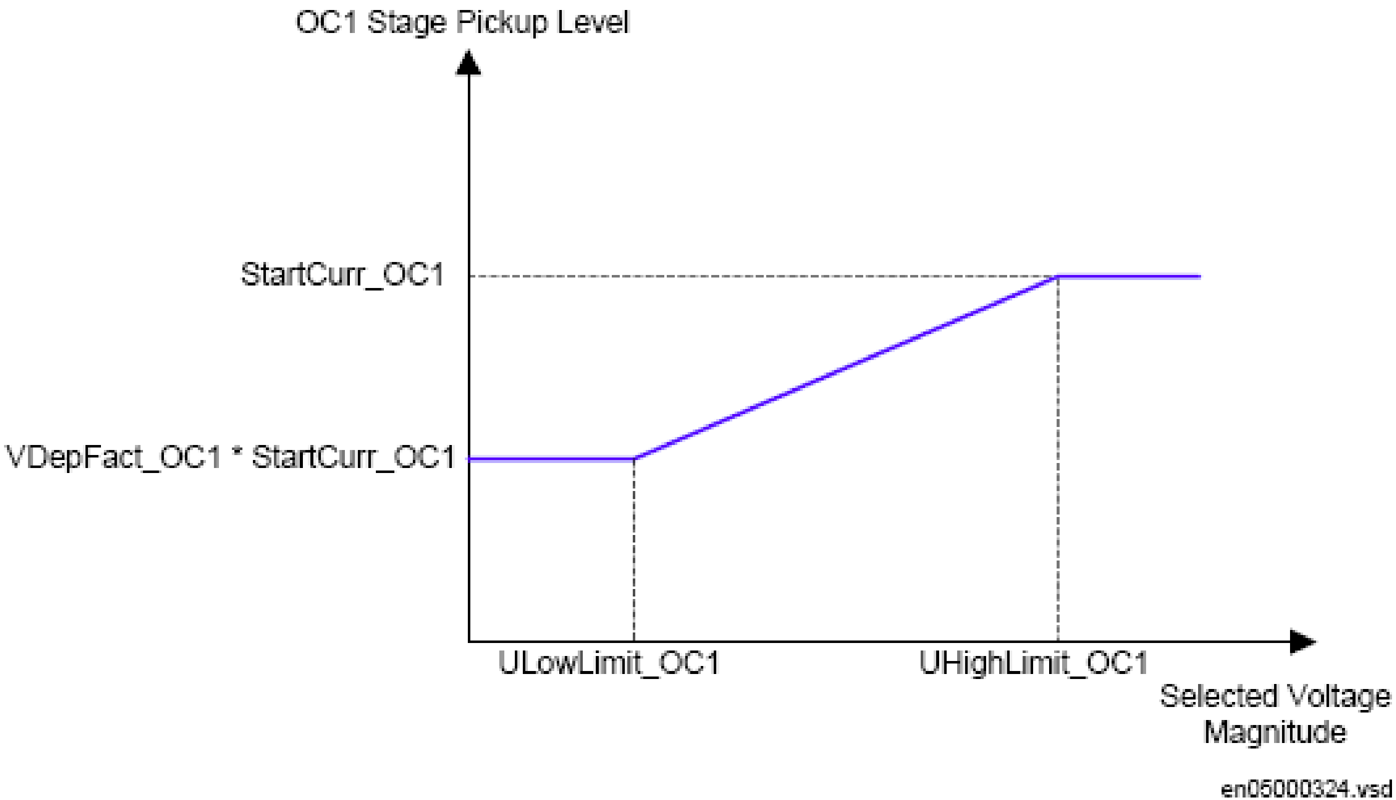
Phase overcurrent protection

- Backup protection for internal short circuits in the generator or the unit transformer
- Backup or main protection for fault at the busbar where the plant is connected to the power system
- Backup protection for line-faults at lines out from the power plant

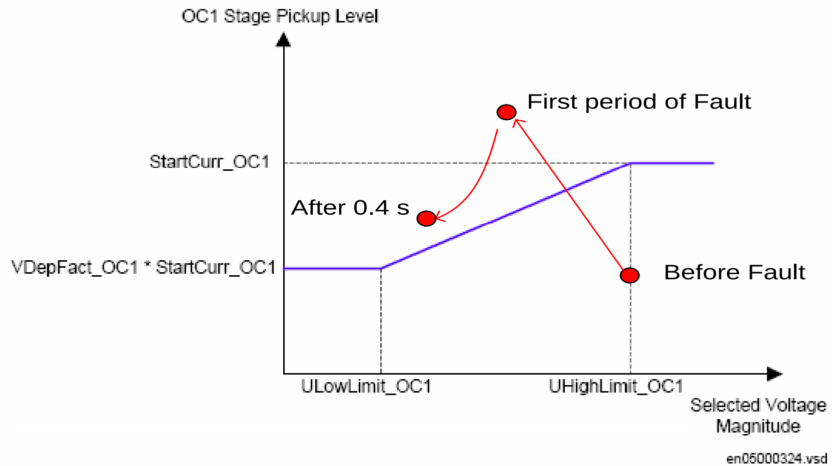
Generator short circuit current

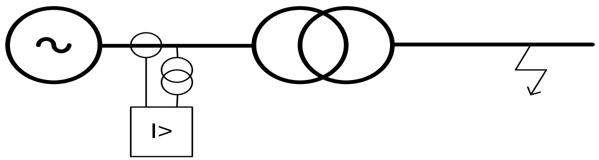
- The fault current from the generator change during fault sequence
  - Change of generator reactance X_d'' -> X_d' -> X_d
  - Dependent of the excitation system

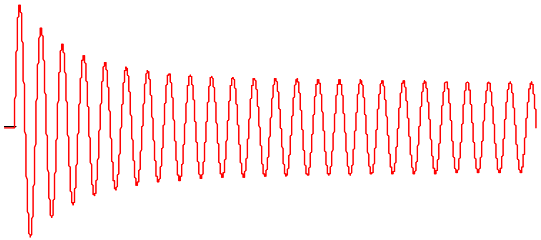
Voltage dependent phase overcurrent protection



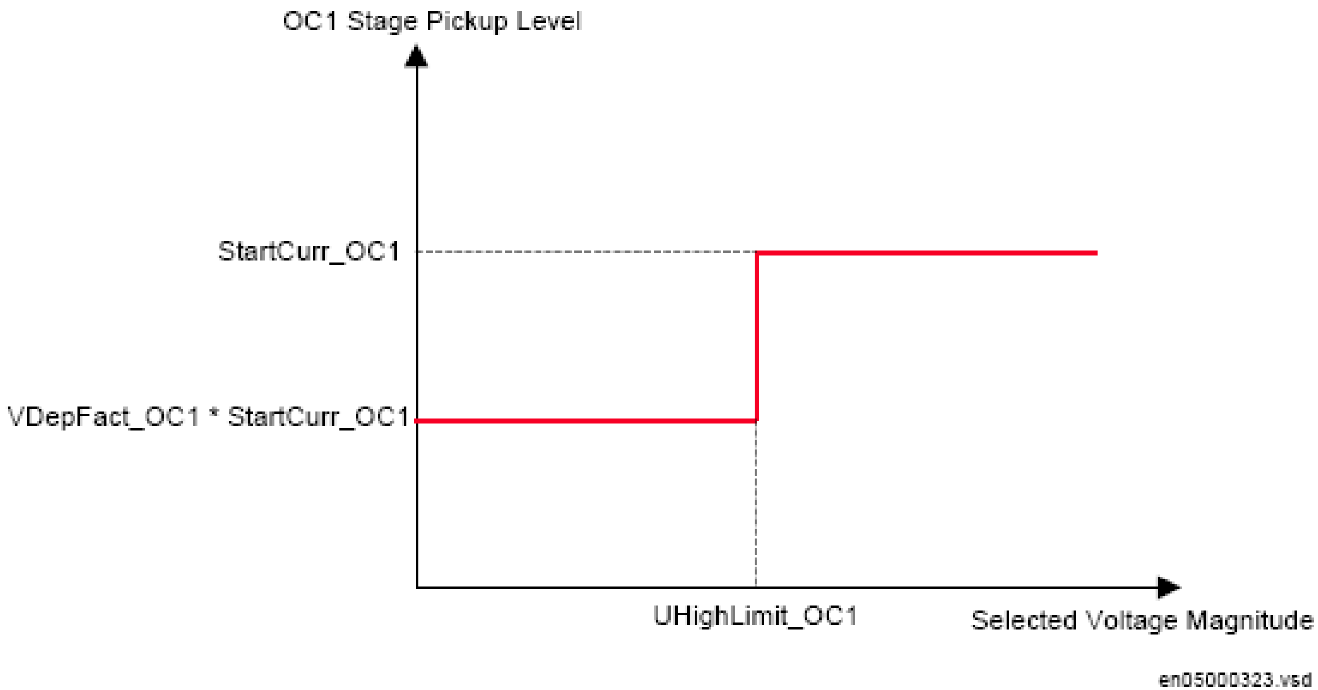
External short circuit







Voltage controlled phase overcurrent protection

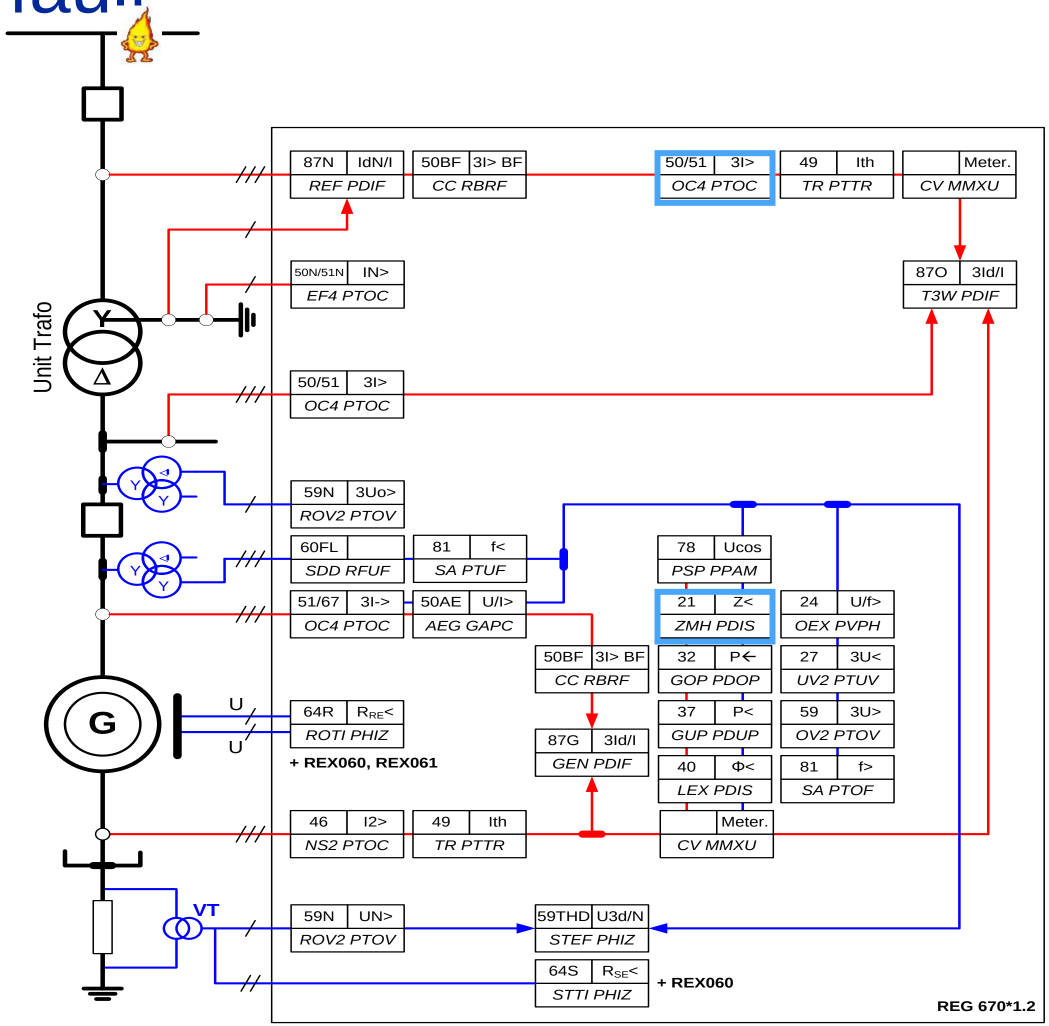


External phase-to-phase fault

- Endangering condition
  - Overcurrent
- Protected object
  - External power system parts.
- Consequences
  - Heating
  - Forces
  - Mechanical damages

Main Protection Function

Reserve Protection Function

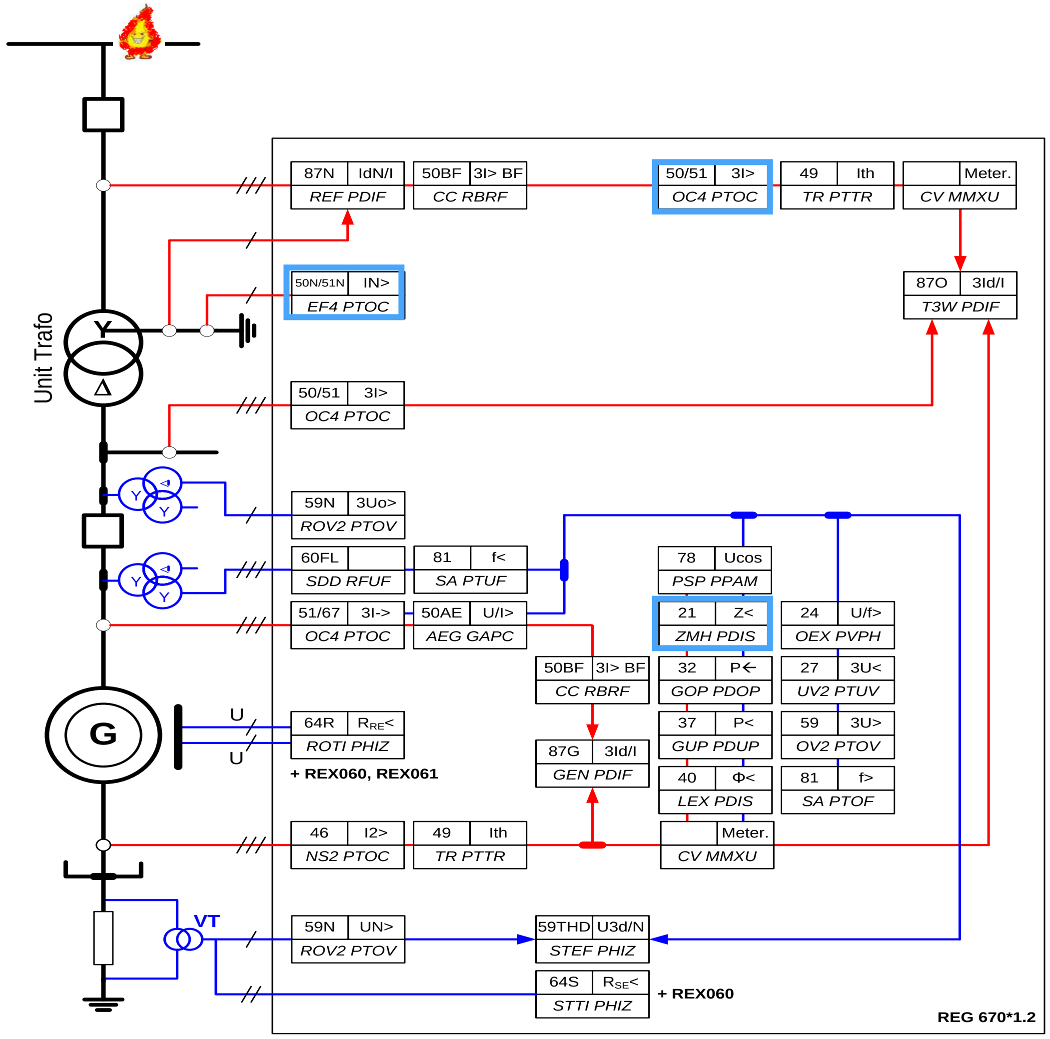


External earth fault

- Endangering condition
  - Overcurrent
- Protected object
  - External power system parts.
- Consequences
  - Heating
  - Forces
  - Mechanical damages

Main Protection Function

Reserve Protection Function

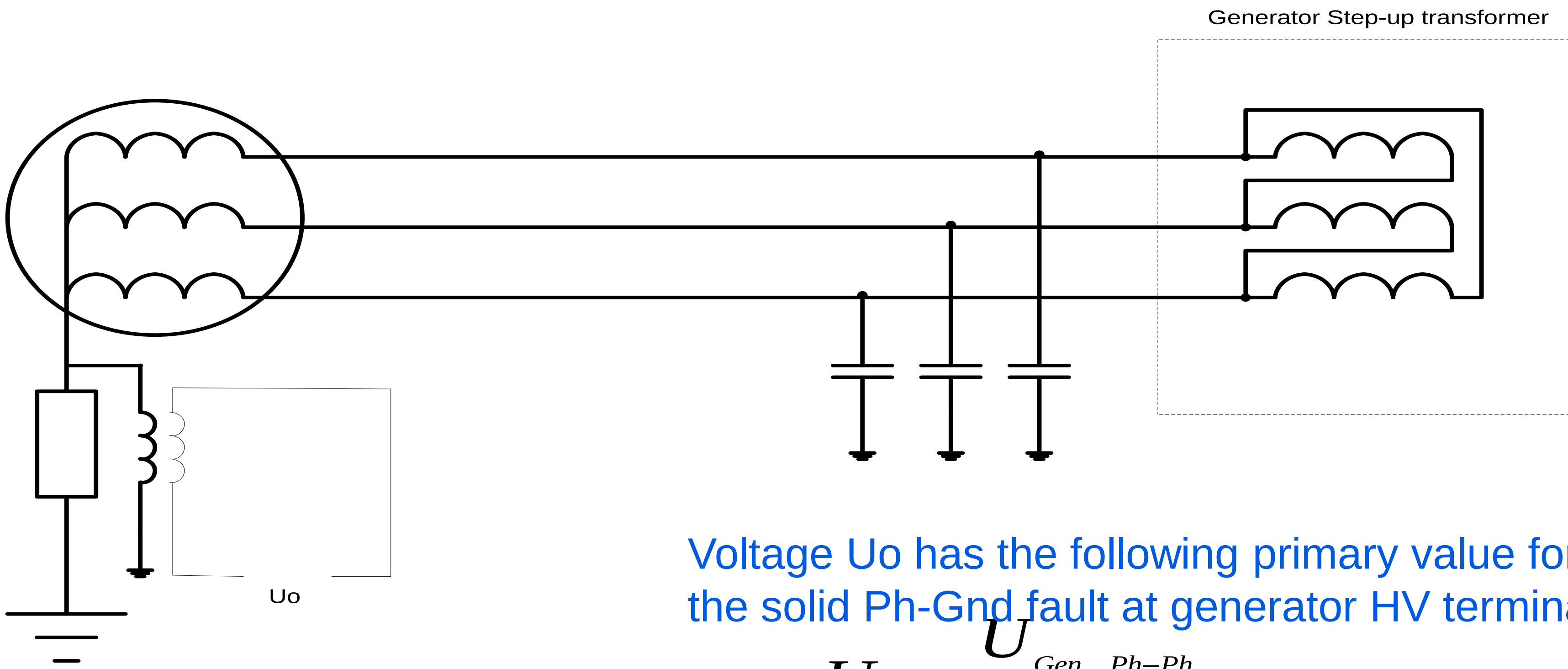


Stator earth fault

- Damages on the stator iron
- Increased voltage on “healthy phases”
- Small fault currents
- Sensitivity requirements on fault clearance
- The fault resistance is normally low at stator earth fault
- The residual voltage and earth fault current is highly dependent on fault location in the generator

Voltage based 95 % stator earth fault protection

Neutral point voltage transformer used to measure Uo voltage

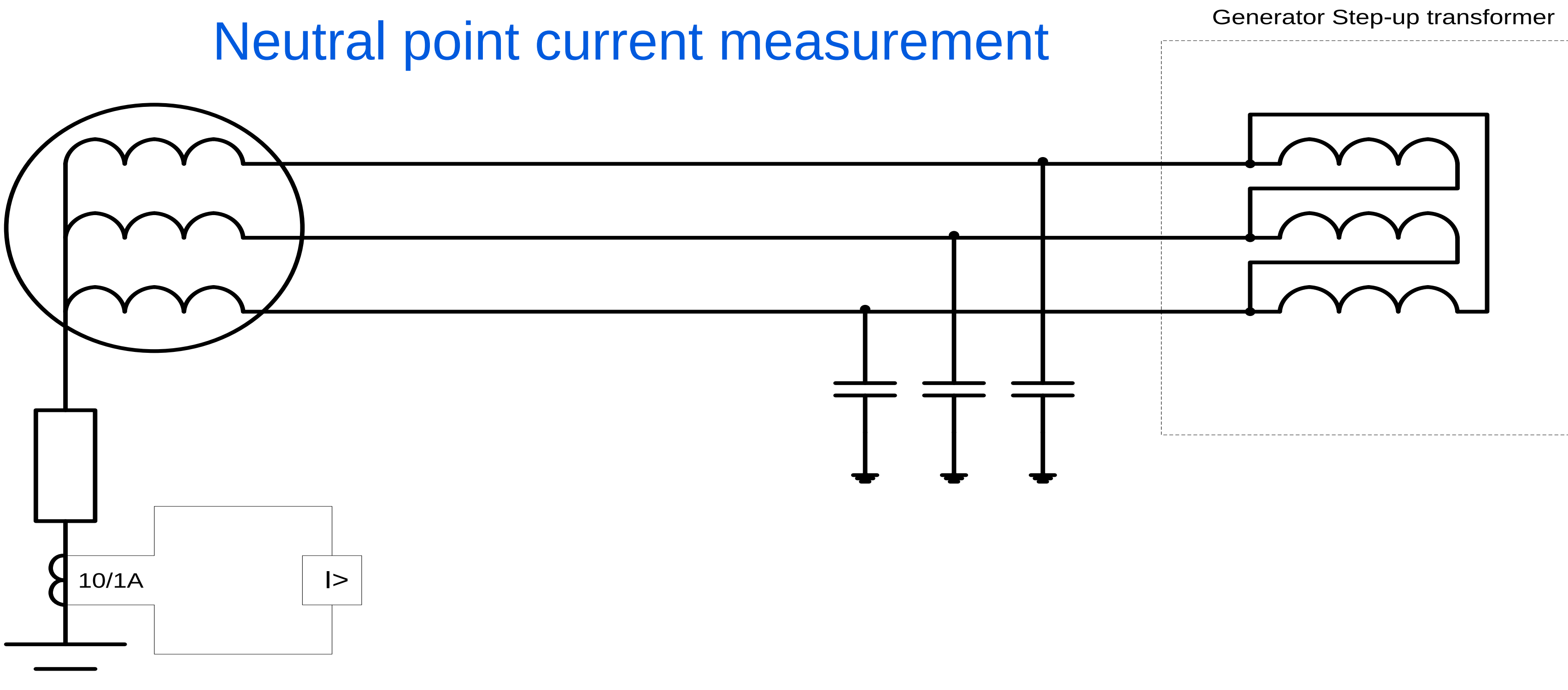


Voltage Uo has the following primary value for the solid Ph-Gnd fault at generator HV terminals

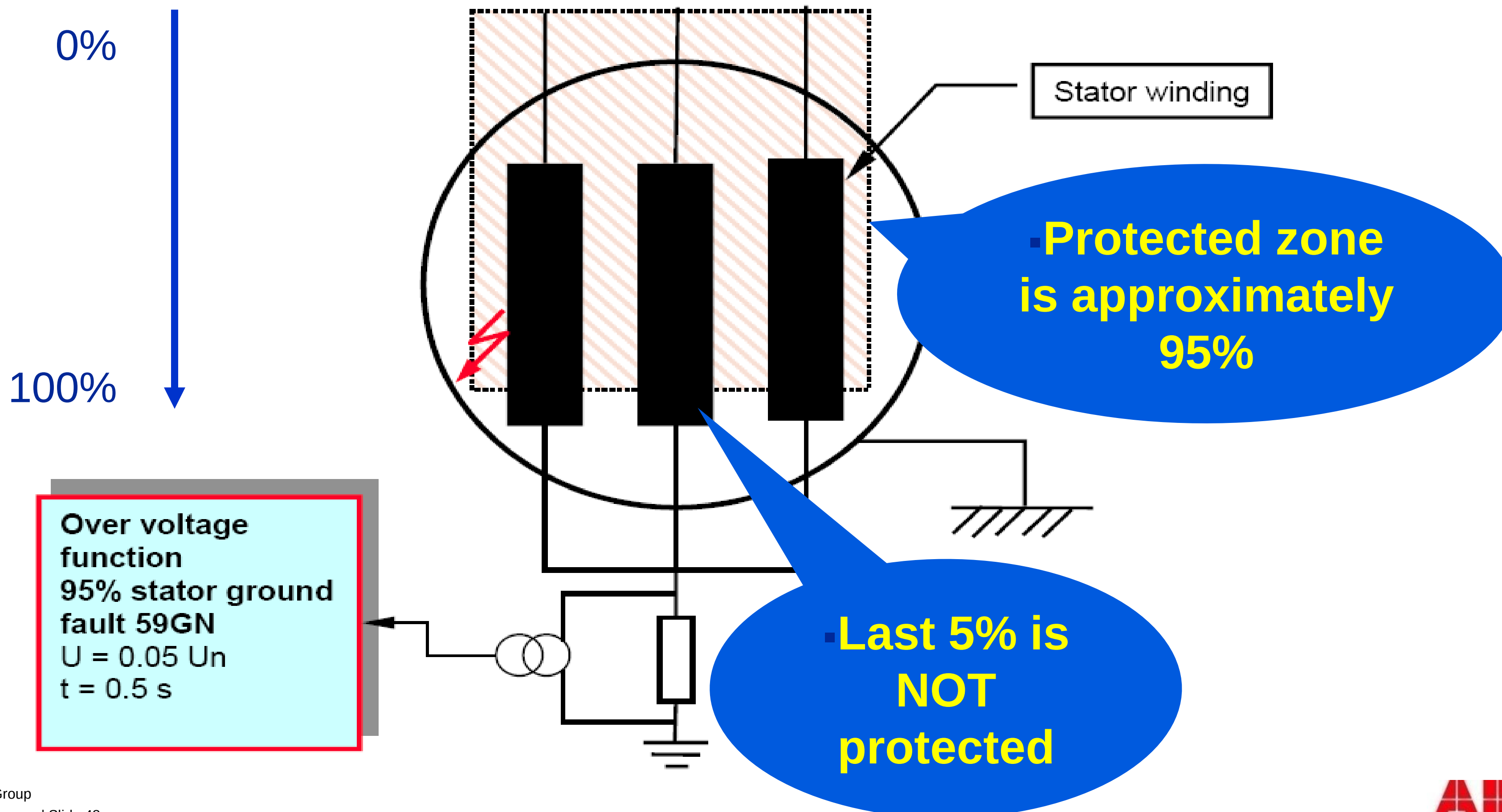
$$Uo = \frac{U_{Gen\_Ph-Ph}}{\sqrt{3}}$$

Current based 95 % stator earth fault protection

Neutral point current measurement



Why 95 % and 100% stator ground fault protection?

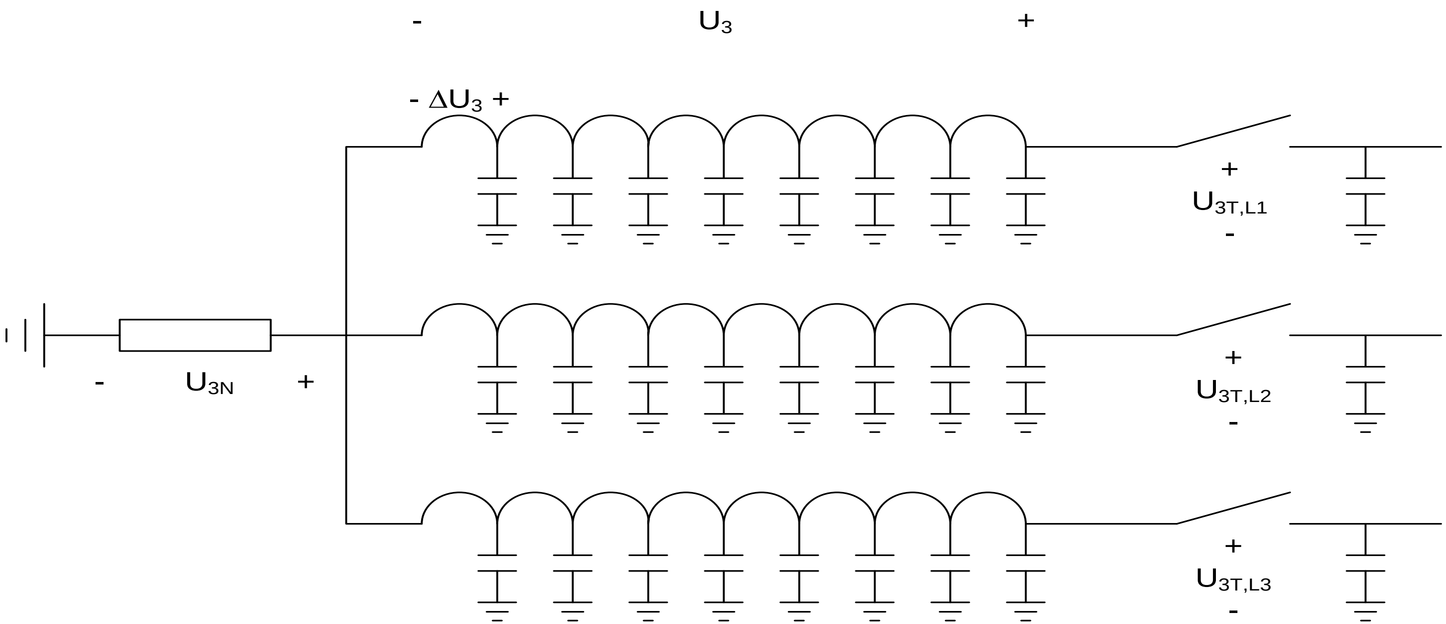


Possible 100 % stator earth fault protection solutions

- Measurement of the ”natural” third harmonic voltage induced in the generator can be used to protect against EF close to the generator neutral point
(i.e. 3rd harmonic based principle; 59THD)

- Neutral point voltage injection where the injected voltage has non-harmonic frequency
(i.e. injection principle; 64S)

3rd harmonic voltages

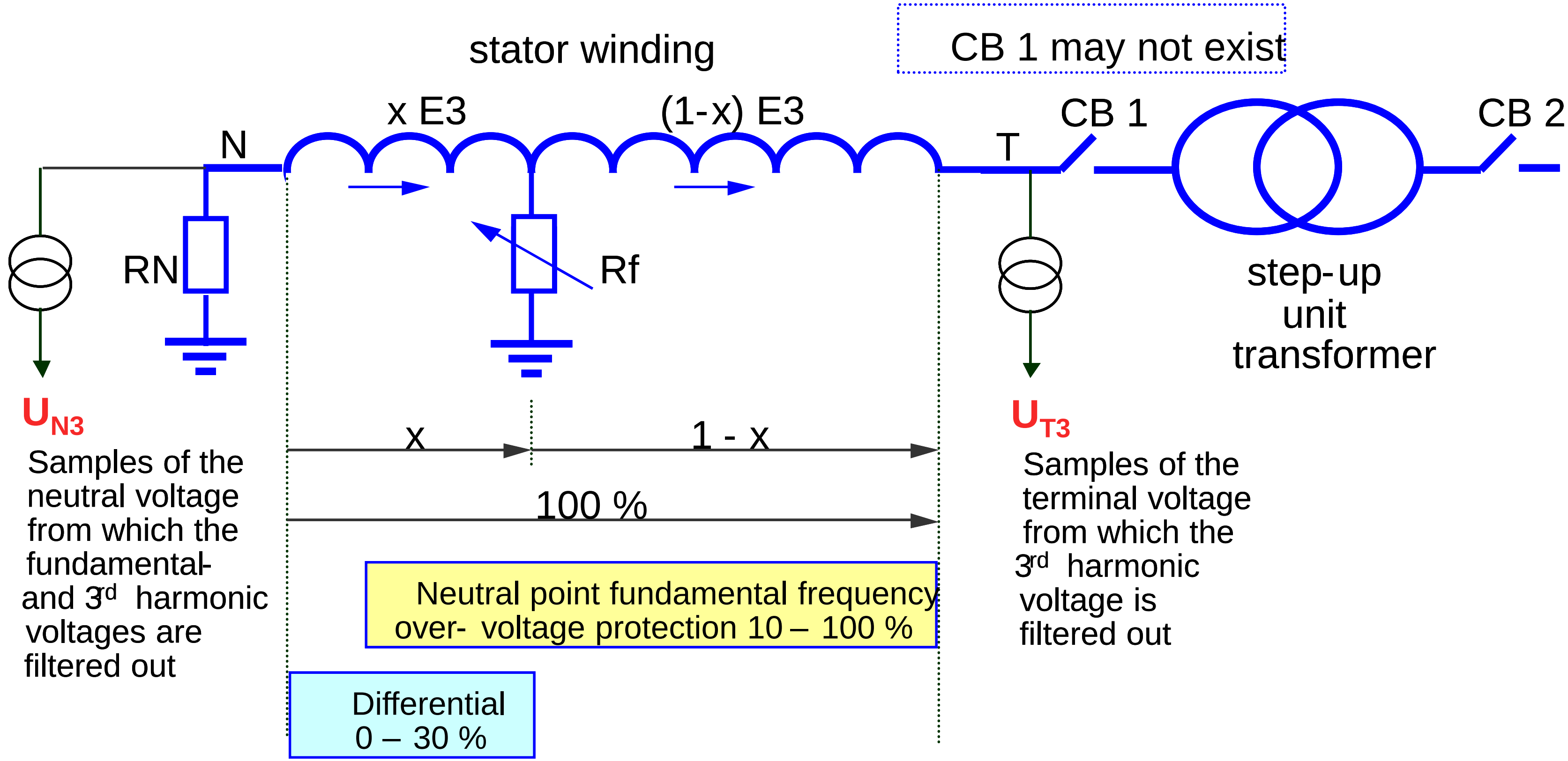


3rd harmonic 100% stator ground fault

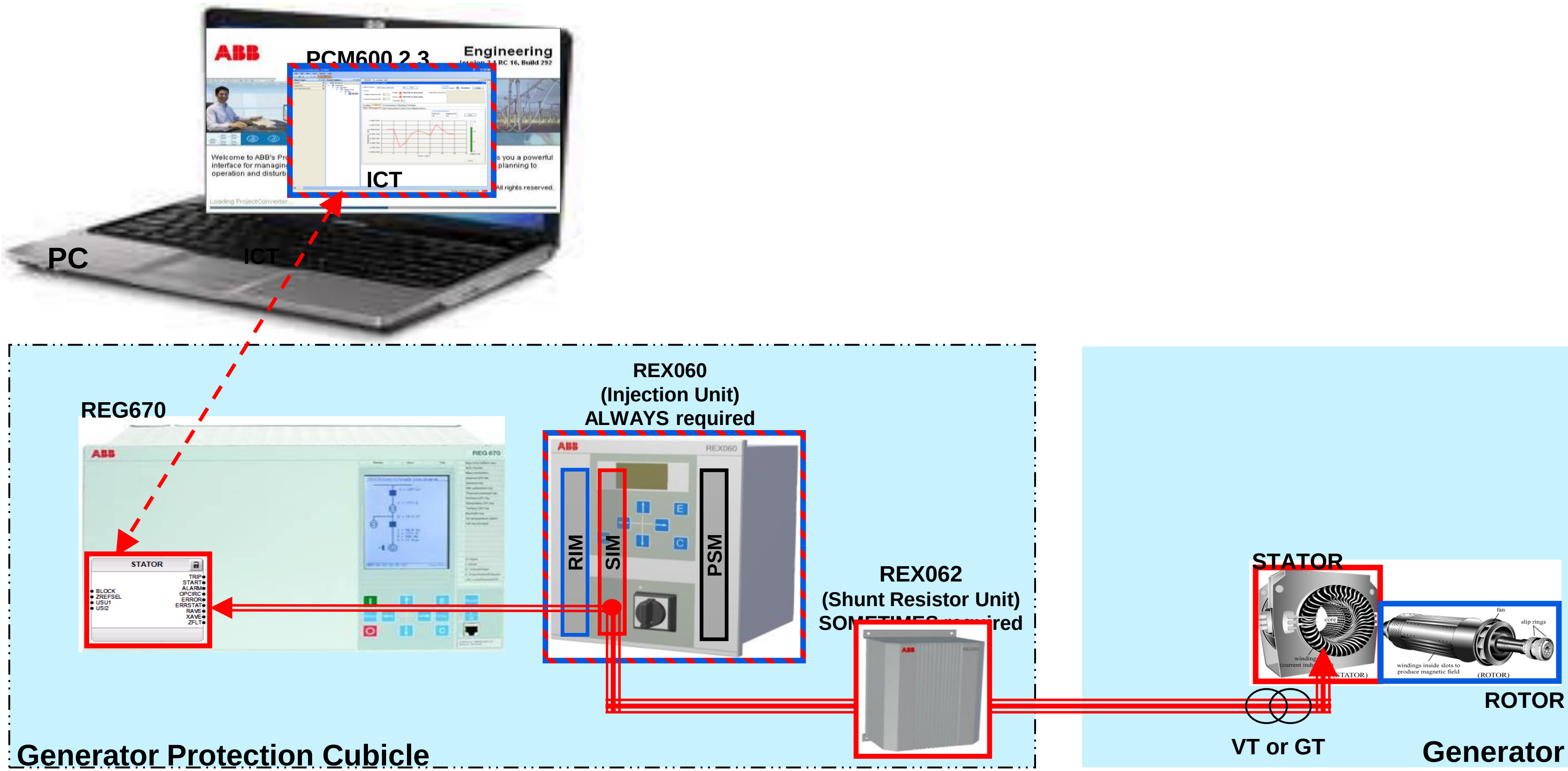
- Simplest approach :
  - 3rd harmonic under-voltage in the neutral (i.e. U_{3N}<)
  - 3rd harmonic over-voltage at generator terminals (i.e. U_{3T}>)
  - Possible problems:
    - Generator start-up
    - Generator shut-down
    - Different generator loading
- 3^{rd} harmonic differential principle

$$\left|U_{N3} + U_{T3}\right| \geq Beta \cdot \left|U_{N3}\right|$$

3rd harmonic based 100% stator earth-fault



Stator injection

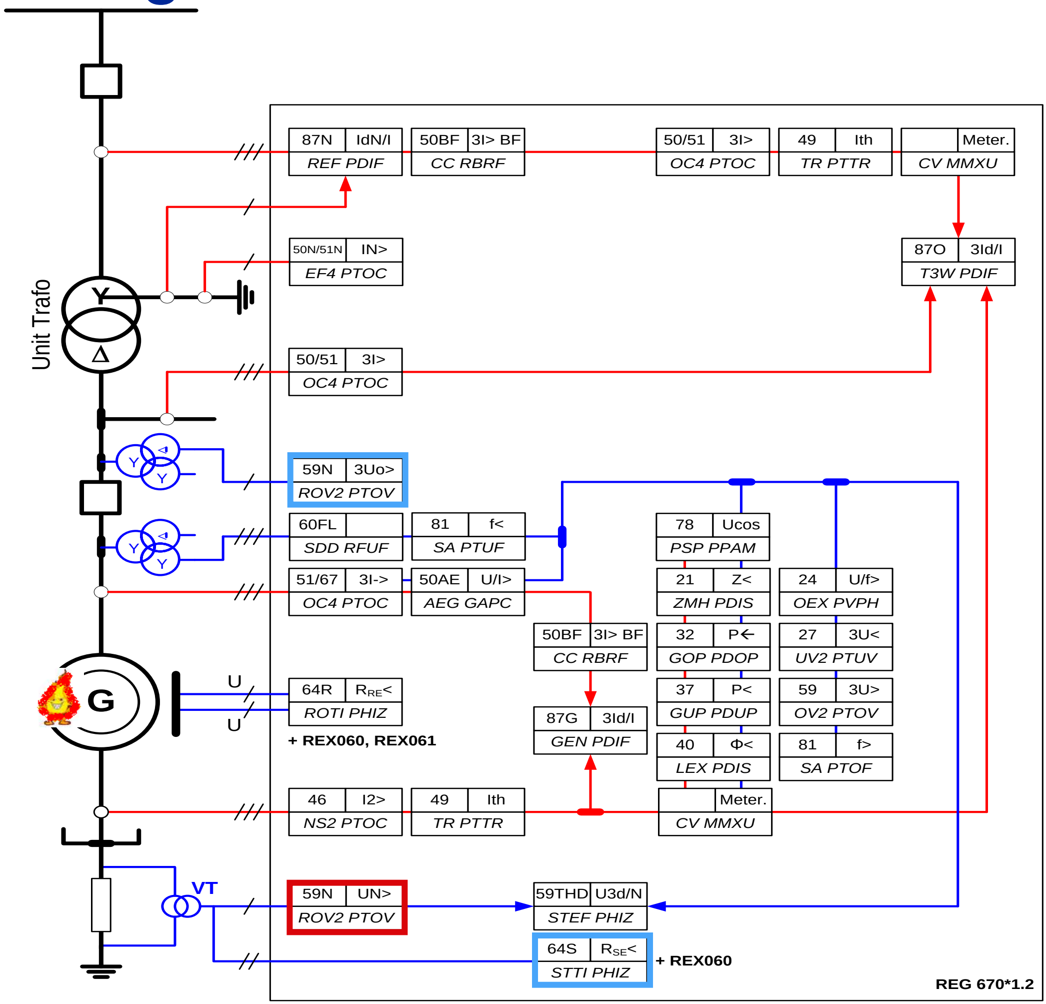


Earth fault in the stator winding

- Endangering condition
  - Overvoltage in two healthy phases
  - Voltage in the star point
  - Relatively small earth fault current
- Protected object
  - Stator winding
- Consequences
  - Damage to the stator core
  - Risk of second earth fault

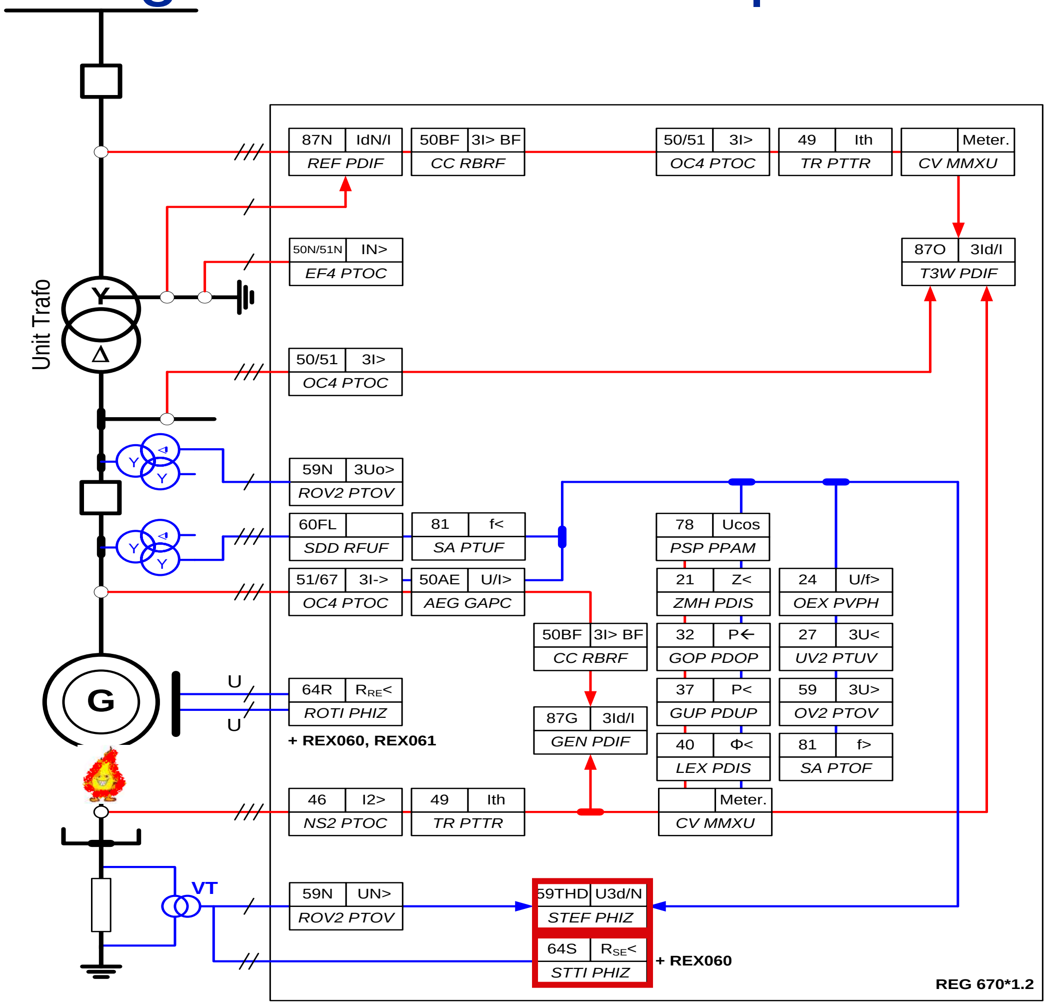
Main Protection Function

Reserve Protection Function



Earth fault in the stator winding close to the star point

- Endangering condition
  - None
- Protected object
  - Stator star point
- Consequences
  - Damage to the stator core
  - Risk of second earth fault



Main Protection Function

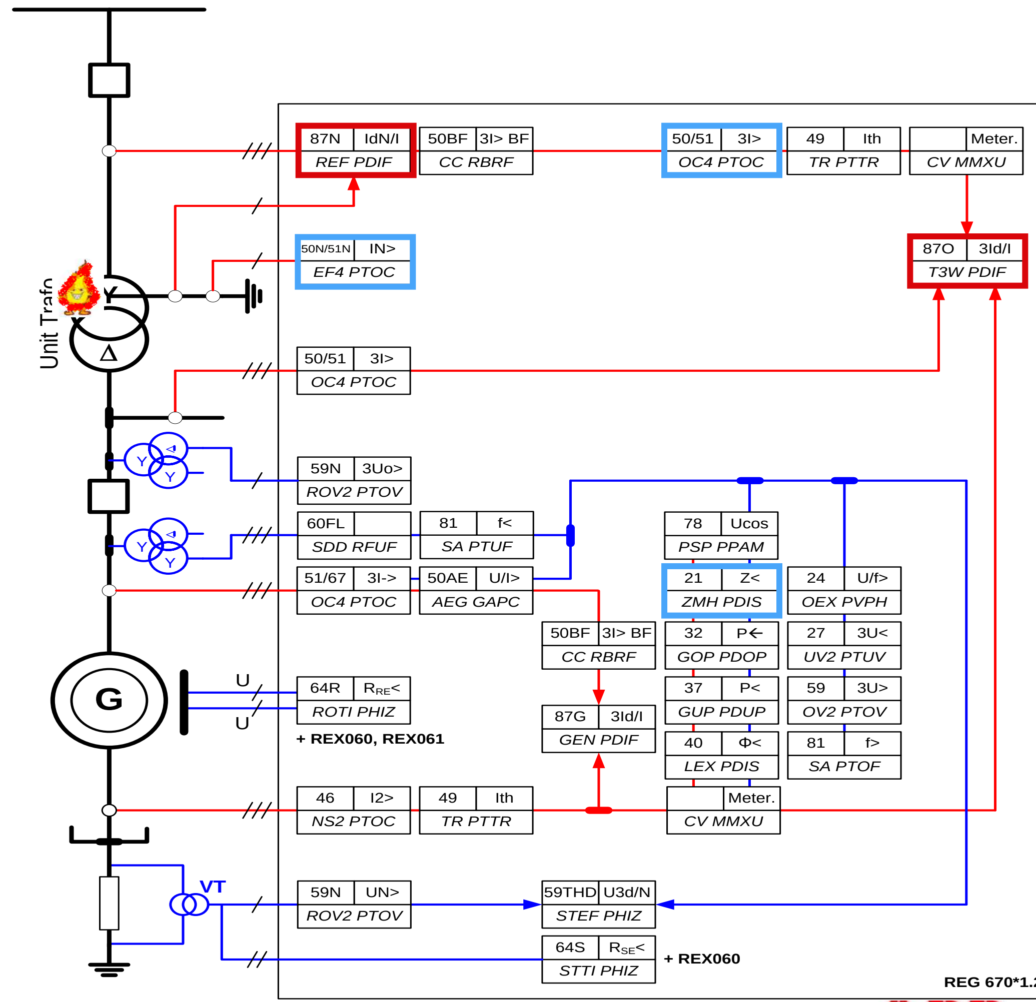
Reserve Protection Function

Earth fault in transformer HV winding

- Endangering condition
  - Overcurrent
- Protected object
  - Transformer windings
- Consequences
  - Heating
  - Forces
  - Smelted trafo core

Main Protection Function

Reserve Protection Function

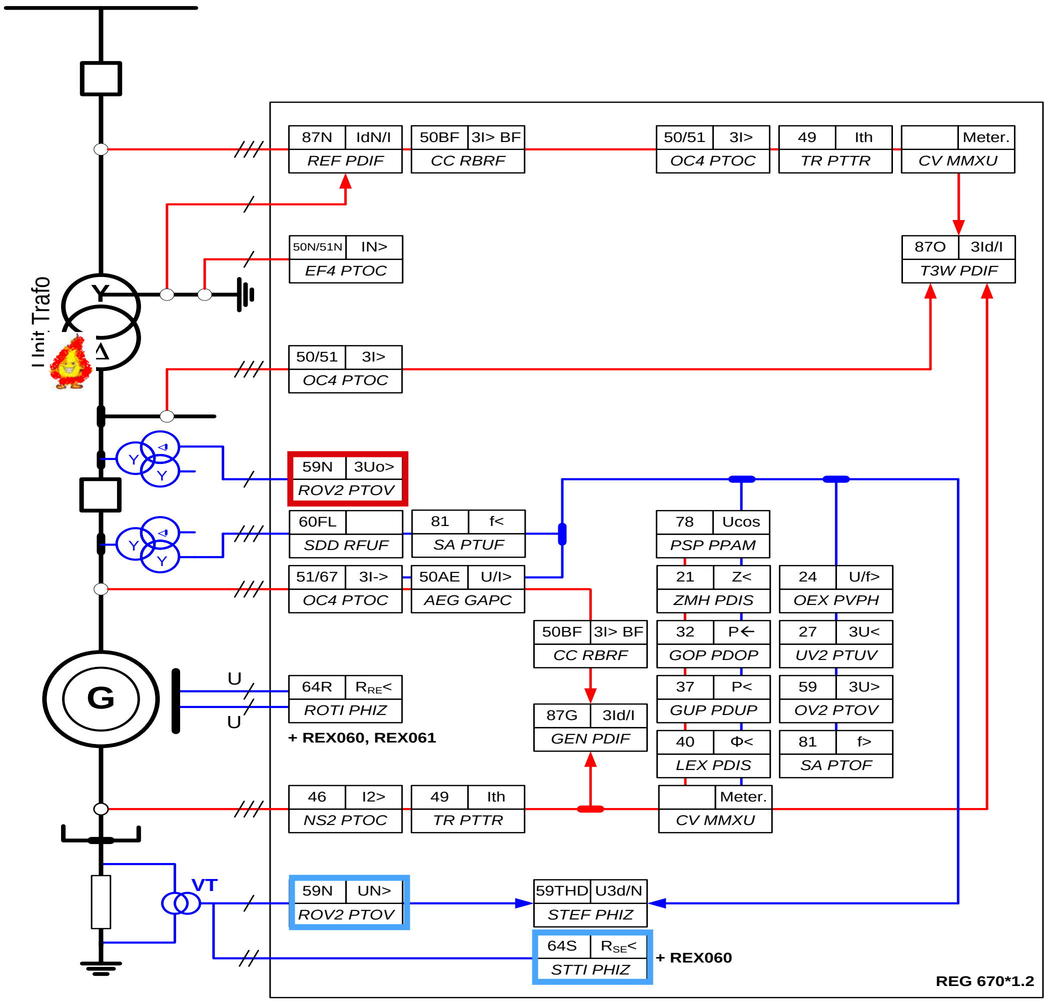


Earth fault in transformer LV winding

- Endangering condition
  - Overvoltage in two healthy phases
  - Voltage in the star point
  - Relatively small earth fault current
- Protected object
  - Transformer winding
- Consequences
  - Small possibility to damage trafo core
  - Risk of second earth fault

Main Protection Function

Reserve Protection Function

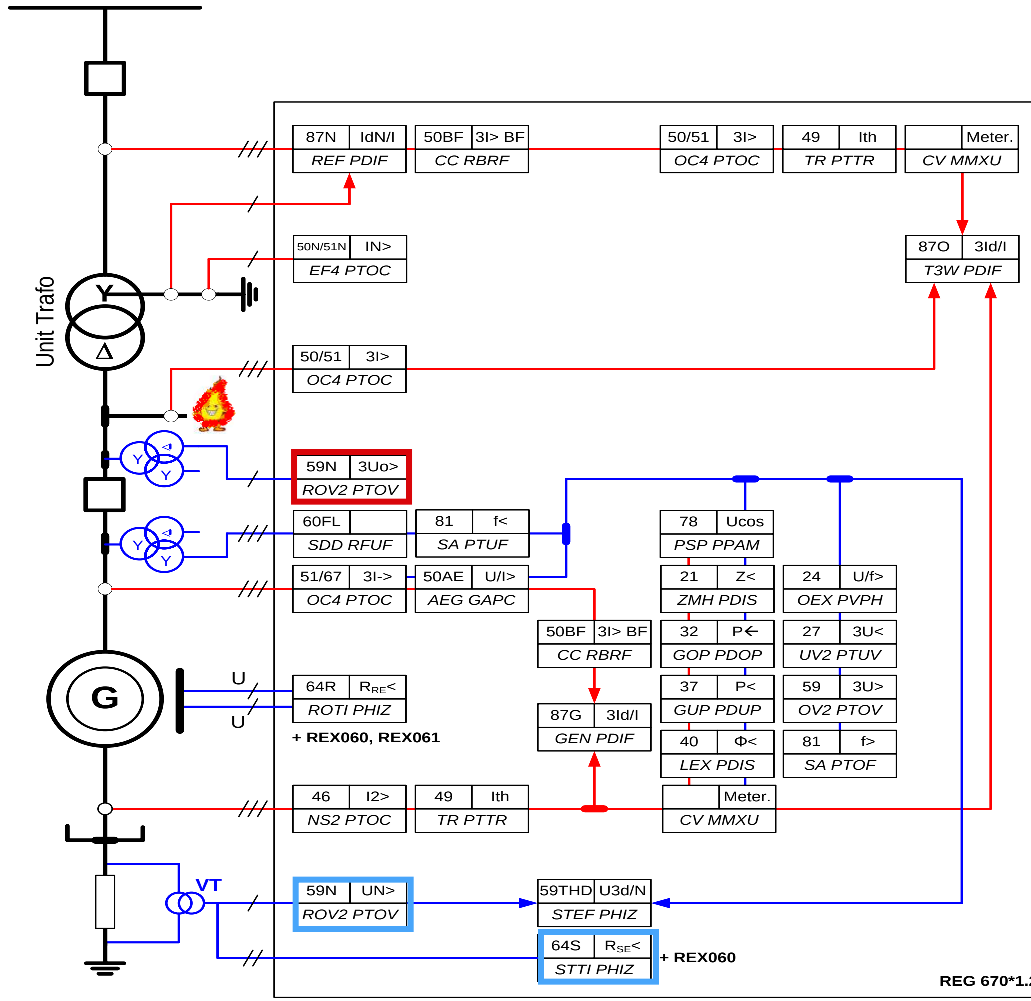


Earth fault at the generator buswork 2

- Endangering condition
  - Overvoltage in two healthy phases
  - Voltage in the star point
  - Relatively small earth fault current
- Protected object
  - Buswork, other equipment
- Consequences
  - Risk of second earth fault

Main Protection Function

Reserve Protection Function



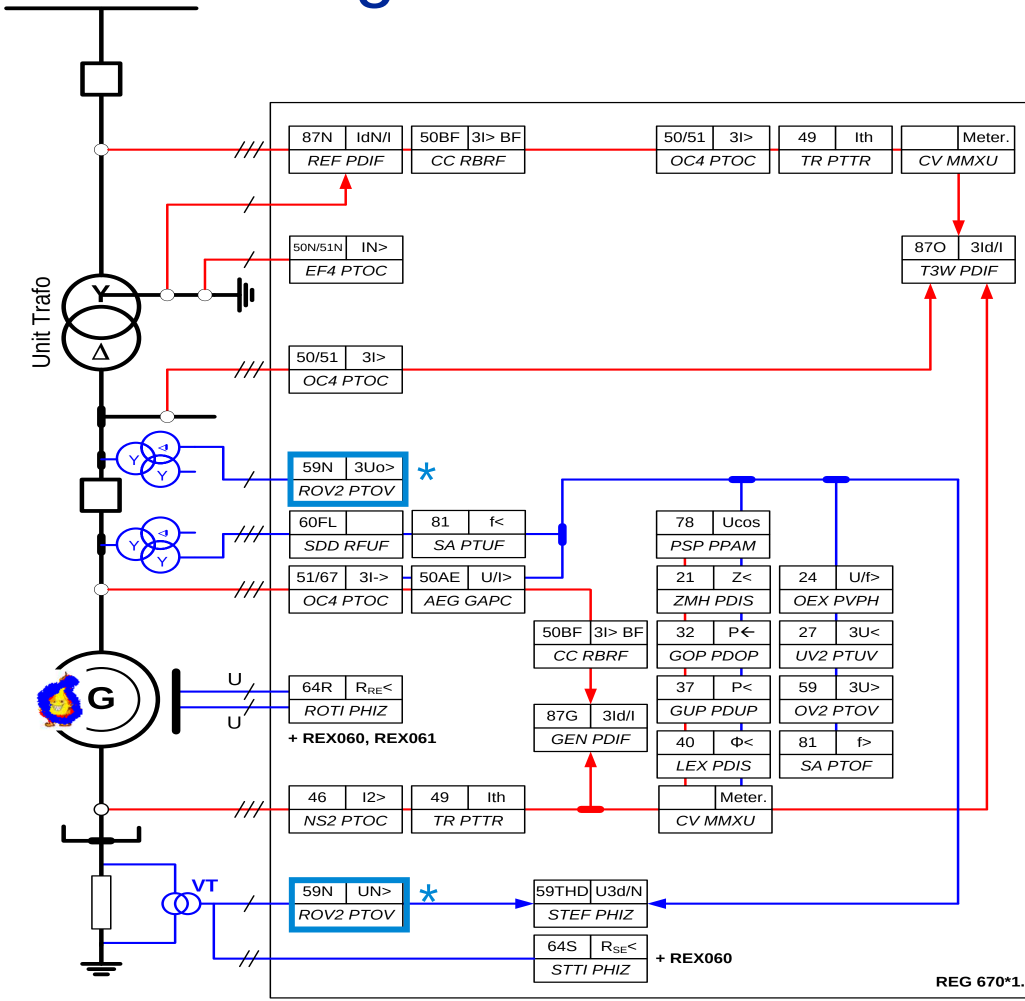
Turn to turn fault in the stator winding

- Endangering condition
  - Circulating currents
  - Asymmetrical phase currents
- Protected object
  - Stator winding
- Consequences
  - Damage to the stator core
  - Risk of evolving into earth fault

*** 59N will detect this fault when develops into an earth fault**

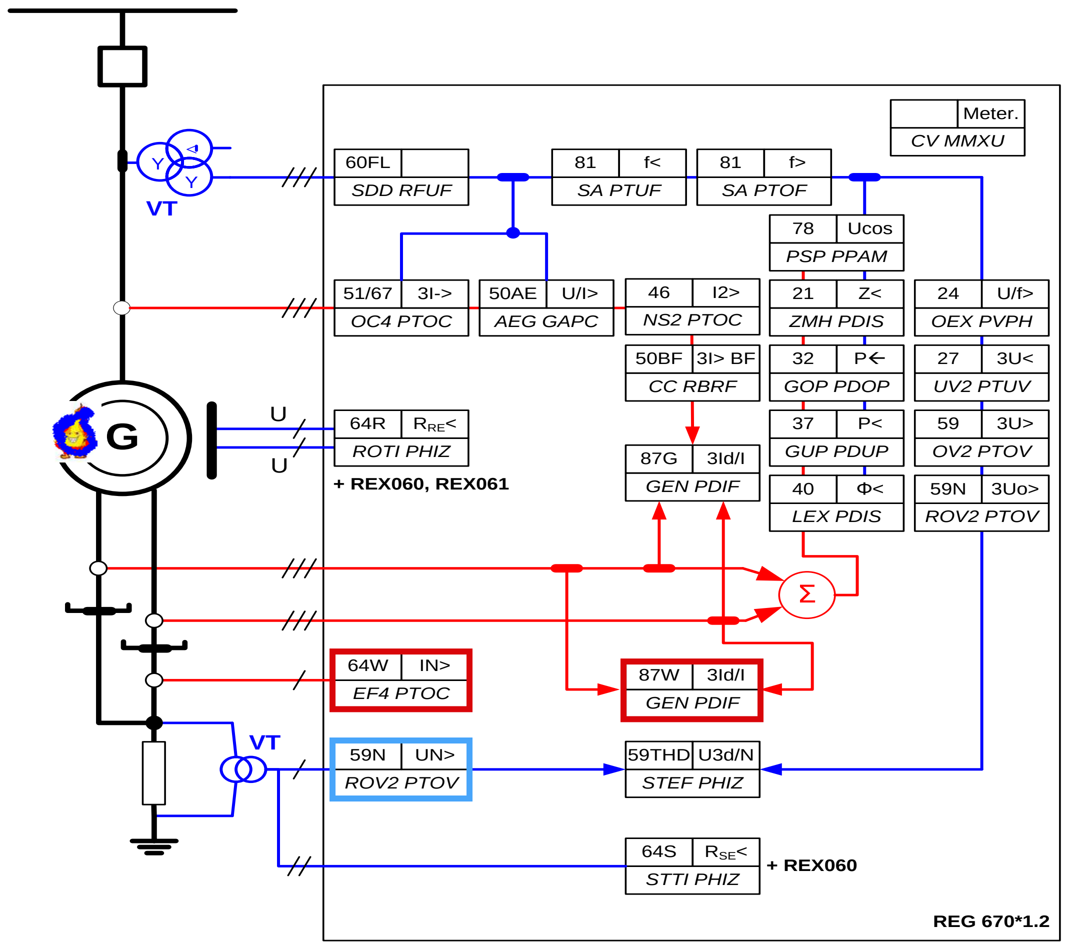
Main Protection Function

Reserve Protection Function



Turn to turn fault in the stator winding

- Generator with split stator phase winding can have dedicated turn-to-turn fault protection as shown in the figure



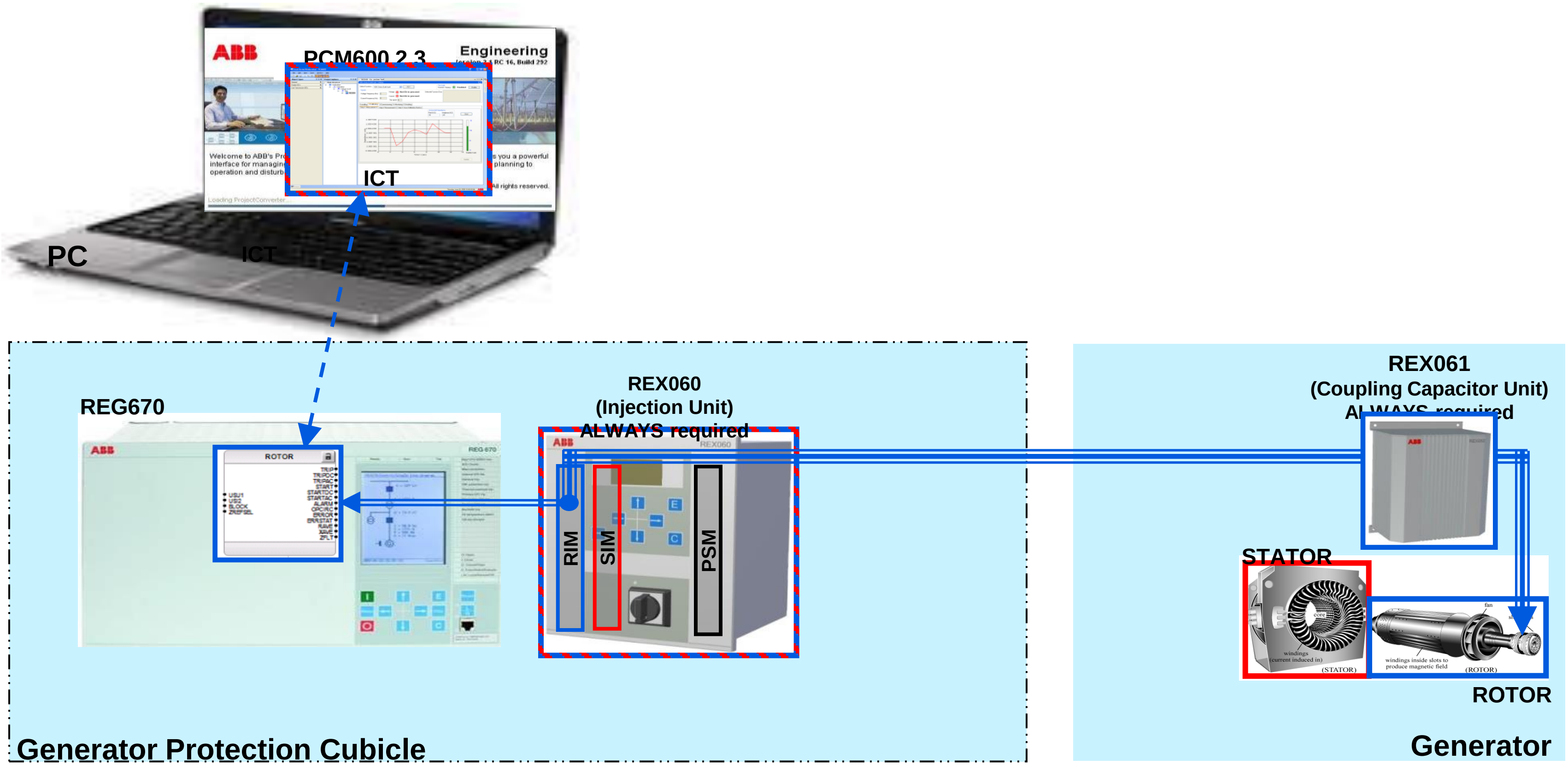
Main Protection Function

Reserve Protection Function

Rotor earth fault

- The field circuit of the generator is normally isolated from earth
- With a single earth fault in the rotor circuit it is possible to have continuous operation without generator damages
- There is however a risk of a second rotor earth fault. In such a case there will be large current and risk of severe damages.
- The requirement of fast fault clearance is moderate

Rotor injection

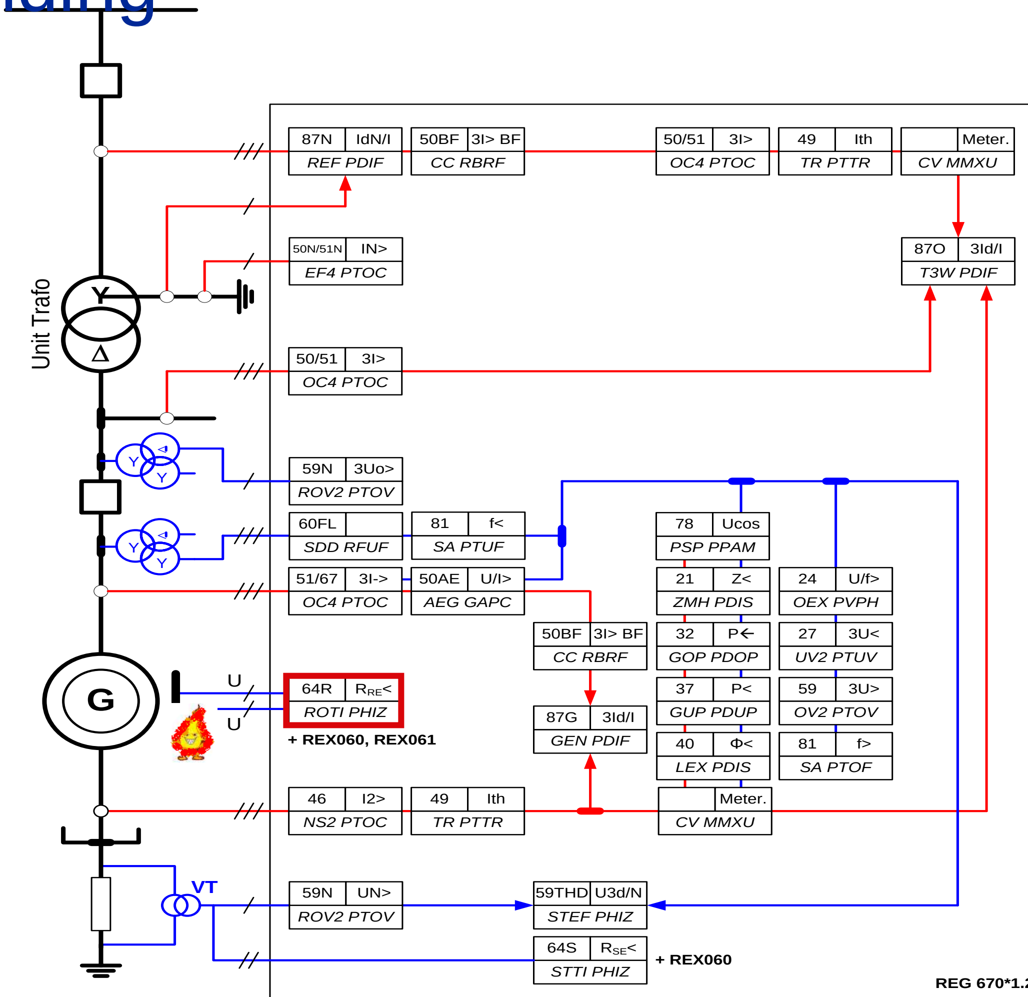


Earth fault in the rotor winding

- Endangering condition
  - None
- Protected object
  - Rotor winding
- Consequences
  - Risk of evolving into double earth fault

Main Protection Function

Reserve Protection Function



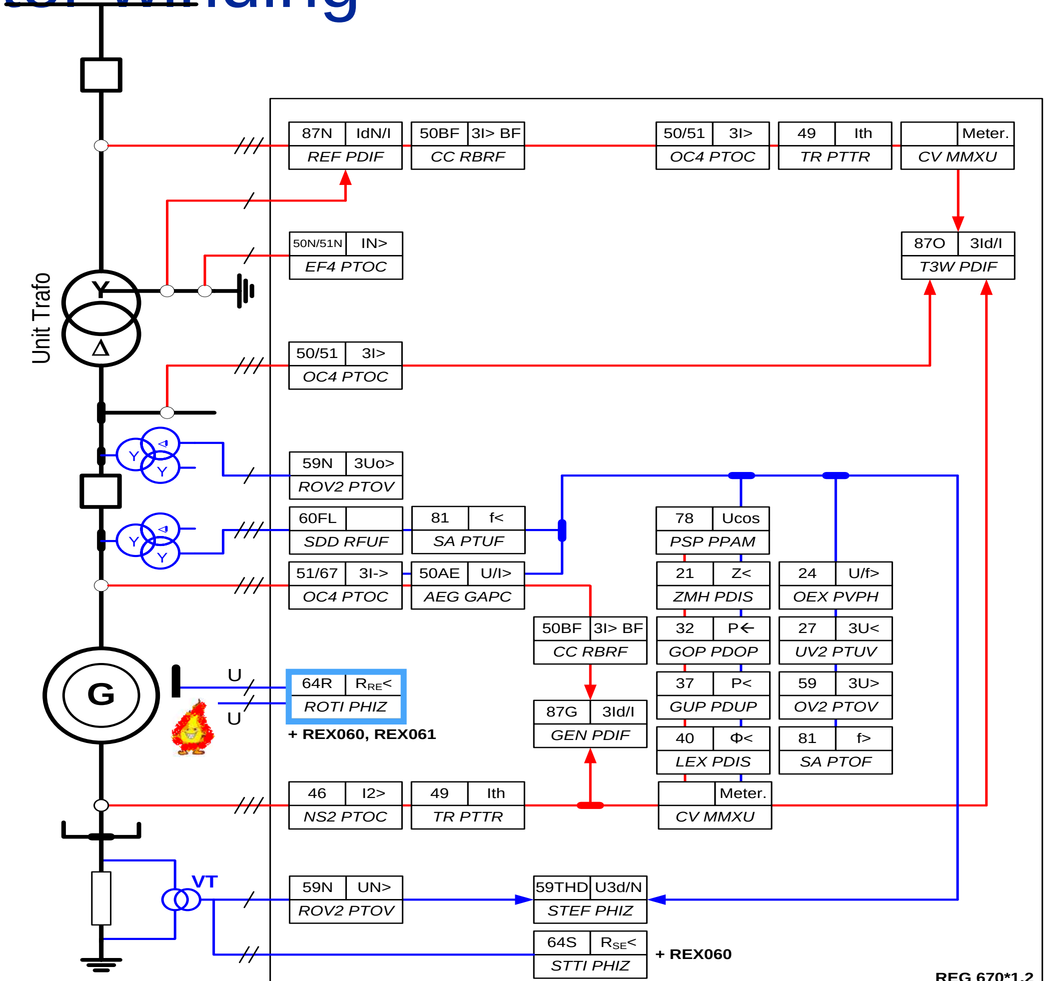
Turn to turn fault in the rotor winding

- Endangering condition
  - None
- Protected object
  - Rotor winding
- Consequences
  - Damage to the rotor core
  - Risk of evolving into earth fault

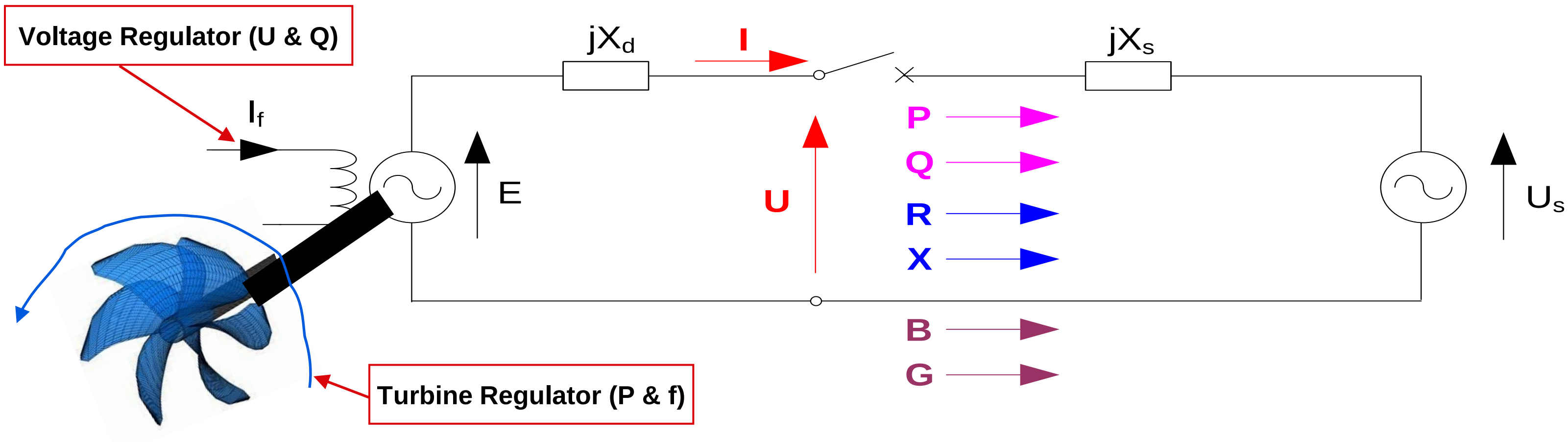
*** 64R will detect this fault when develops into an earth fault**

Main Protection Function

Reserve Protection Function

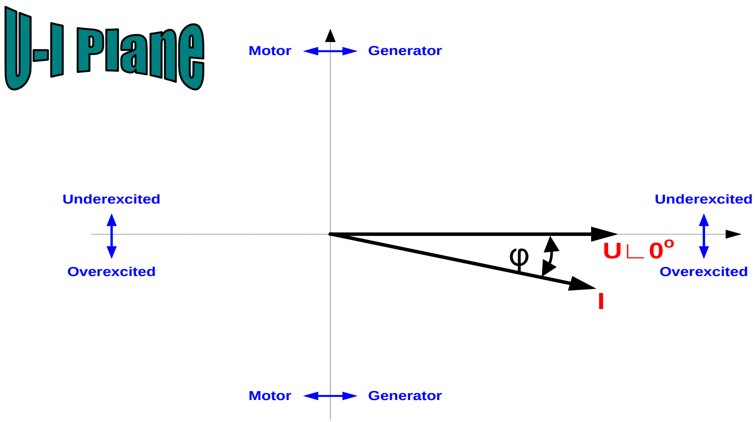


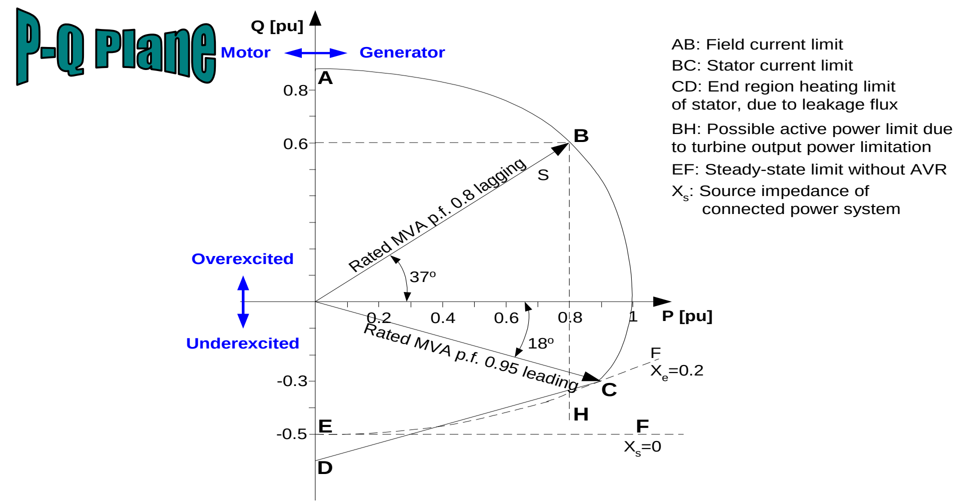
Performance of synchronous machine

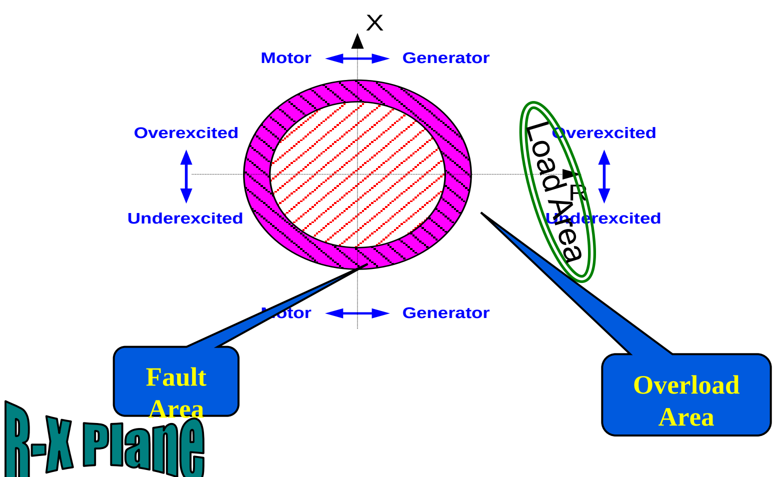


- Synchronous machine operating in a parallel with a large power system can:
  - supply active power to the system (operates as generator)
  - receive active power from the system (operates as motor)
  - supply reactive power to the system (overexcited machine; operates as shunt capacitor)
  - receive reactive power from the system (underexcited machine; operates as shunt reactor)
  - Note: machine shall have fixed rotating speed at all times

Different protection operating planes







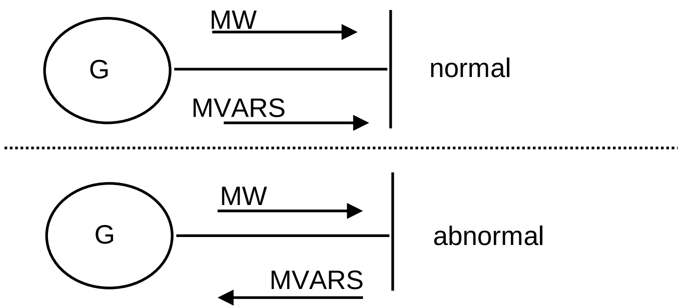
Loss of/under excitation 40

Causes

- open field circuit
- field short circuit
- accidental tripping of the field breaker
- AVR failure
- loss of field at the main exciter

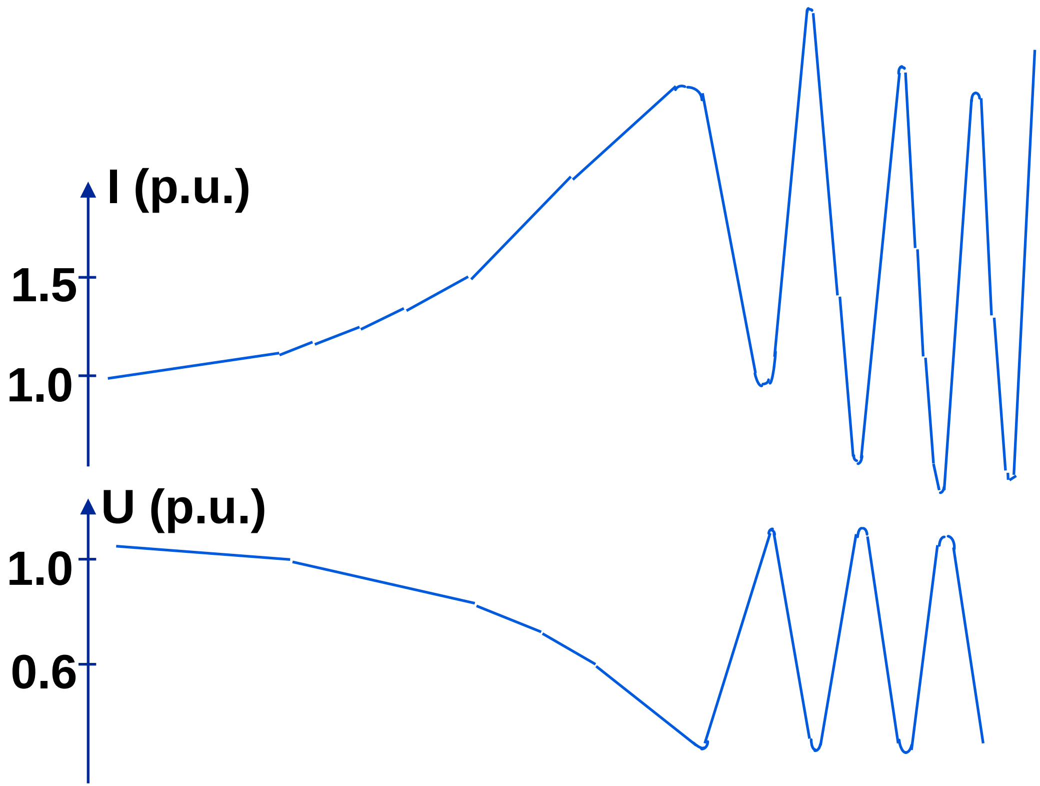
Consequence

- Machine speed higher than synchronous speed
- Asynchronous running of a synchronous machine **without excitation**
- Stator end-core heating
- Induced rotor currents



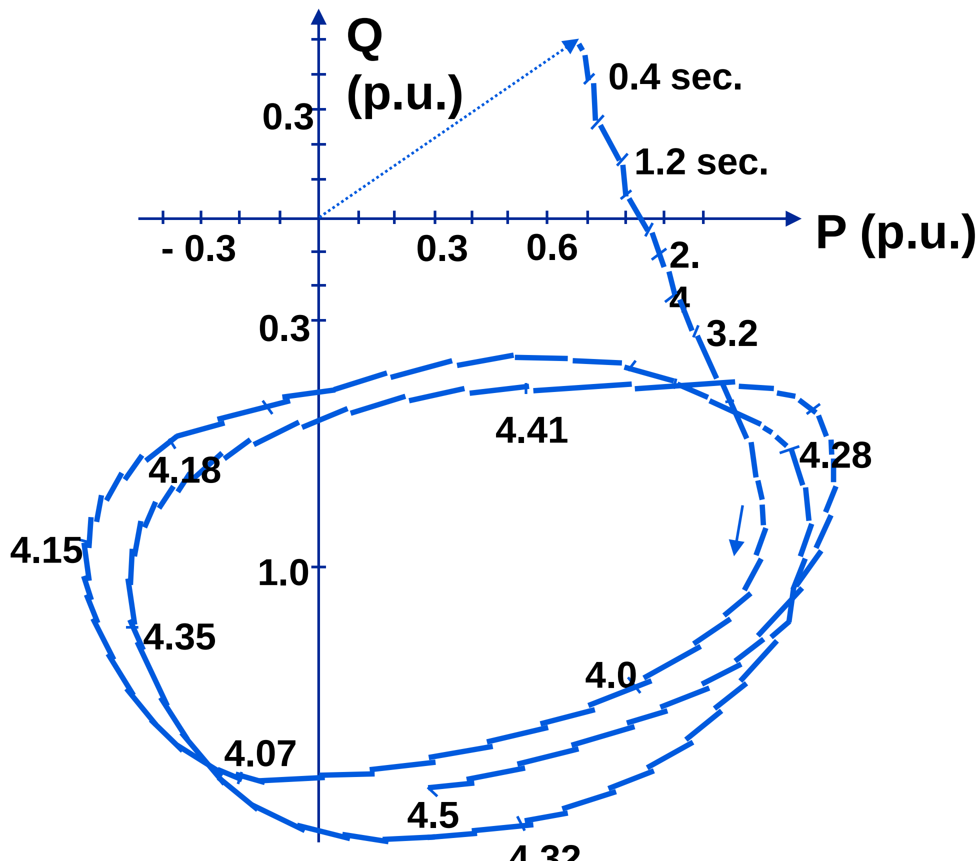
Loss of/under excitation 40

RMS values of U & I during loss of field



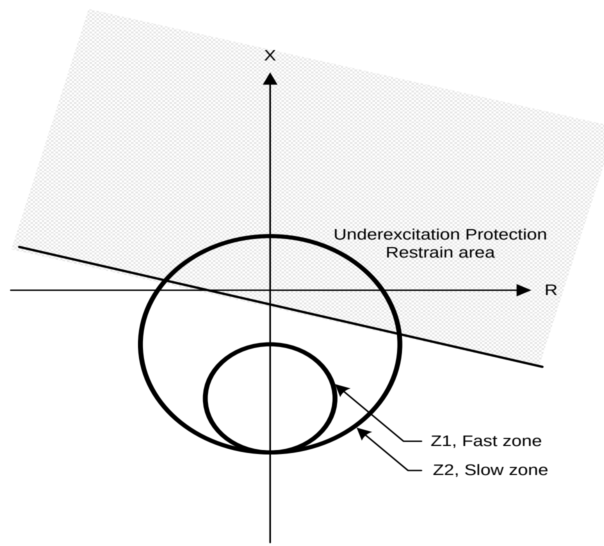
Loss of/under excitation 40

Generator apparent power S during loss of excitation



Loss of/under excitation 40

- Loss of/under excitation is based on under-impedance measurement (offset Mho)
- Main features:
  - Two zones Z1 and Z2, with independent block and trip
  - Directional element for additional zone restriction

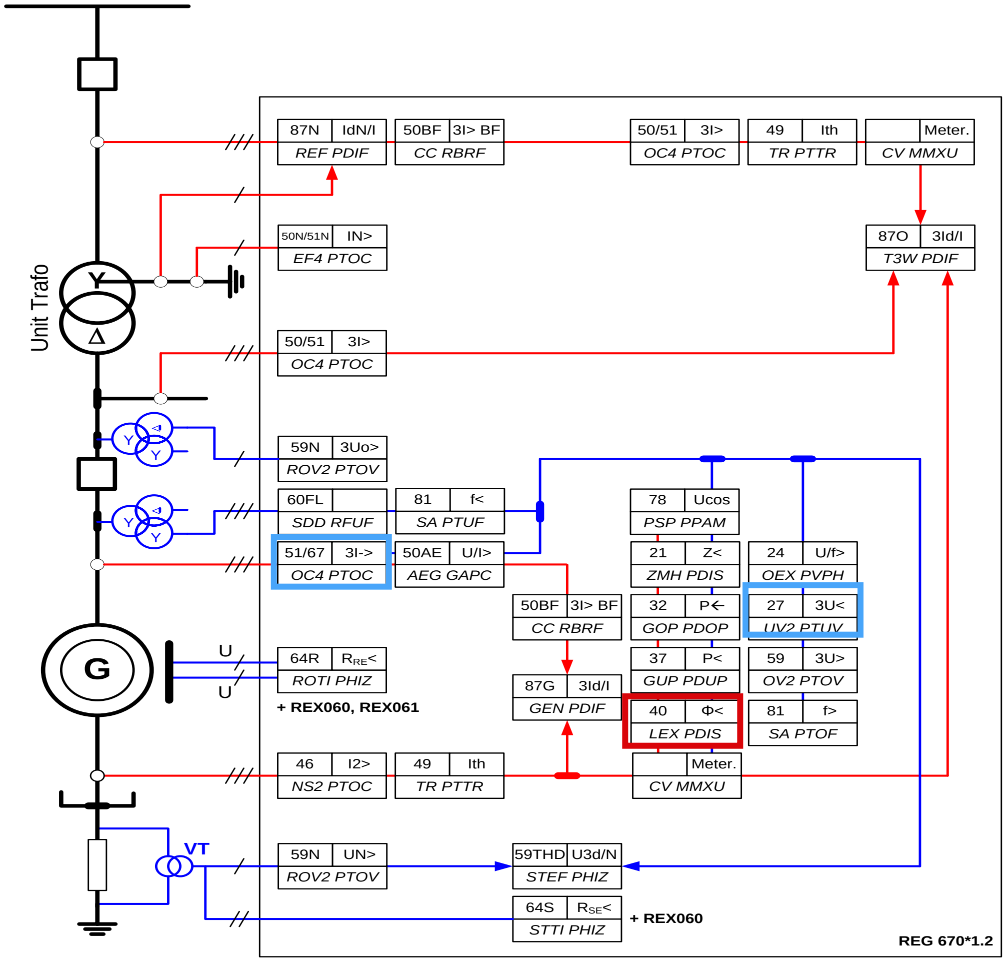


Loss of/Under excitation 40

- Endangering condition
  - Stator reactive current component
- Protected object
  - Rotor and stator winding
- Consequences
  - Thermal damage of rotor and stator end regions
  - Asynchronous machine operation
  - Voltage and current variations

Main Protection Function

Reserve Protection Function



Generator motoring protection 32/37

- Generator shall produce active power (i.e. P>0)
- When it starts to receive the active power it acts as a motor (i.e. P<0)
- Not dangerous operating condition for machine but it may be dangerous for the turbine

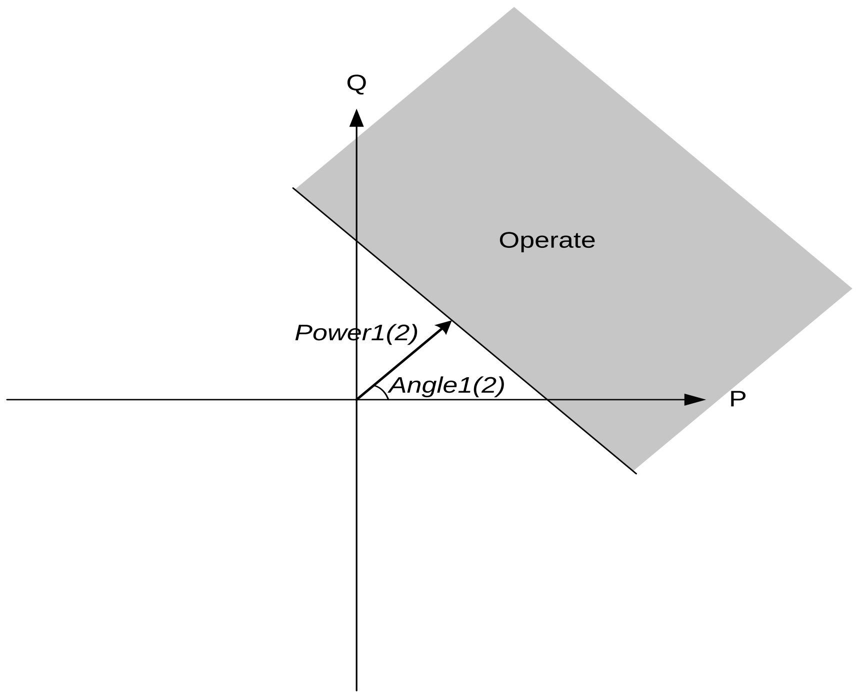
Generator motoring protection 32/37

- Causes
  - loss of prime-mover
  - low water flow (hydro)
  - load variations / problems
- Effects
  - steam units → overheating of turbine and turbine blades
  - hydro units → cavitation of the blades
- Demands
  - accurate active power measurement (i.e. P~0 & Q=30-60%)

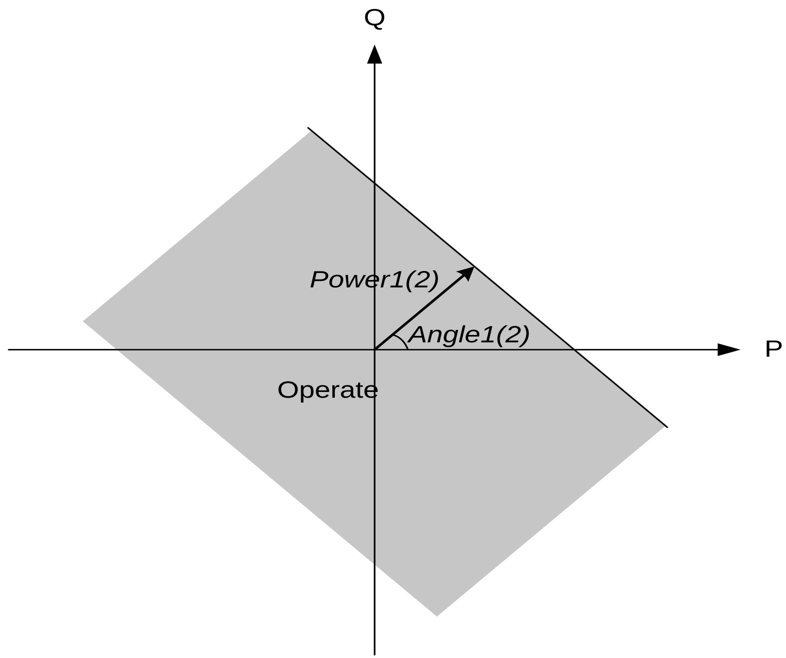
Directional power protection 32/37

- Reverse power, low forward, active and reactive power

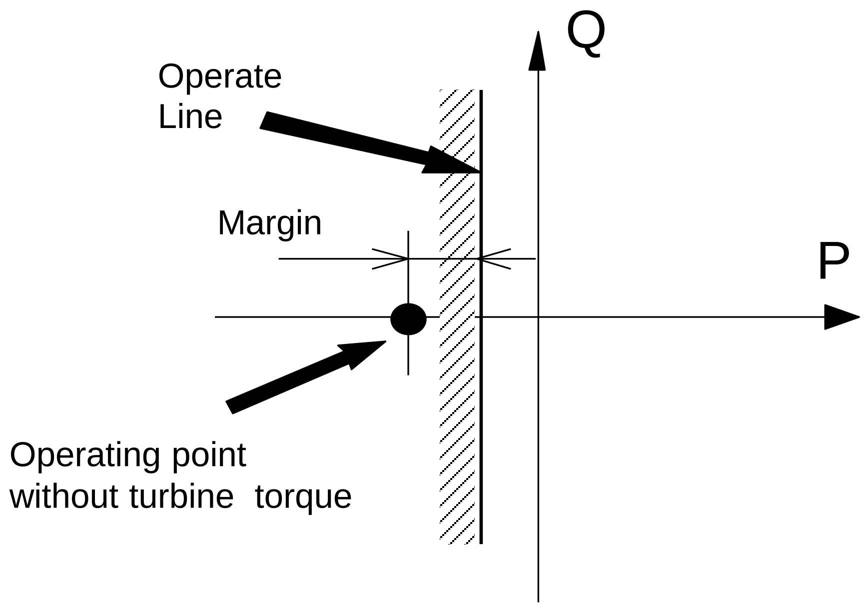
Overpower (e.g. 32)



Underpower (e.g. 37)

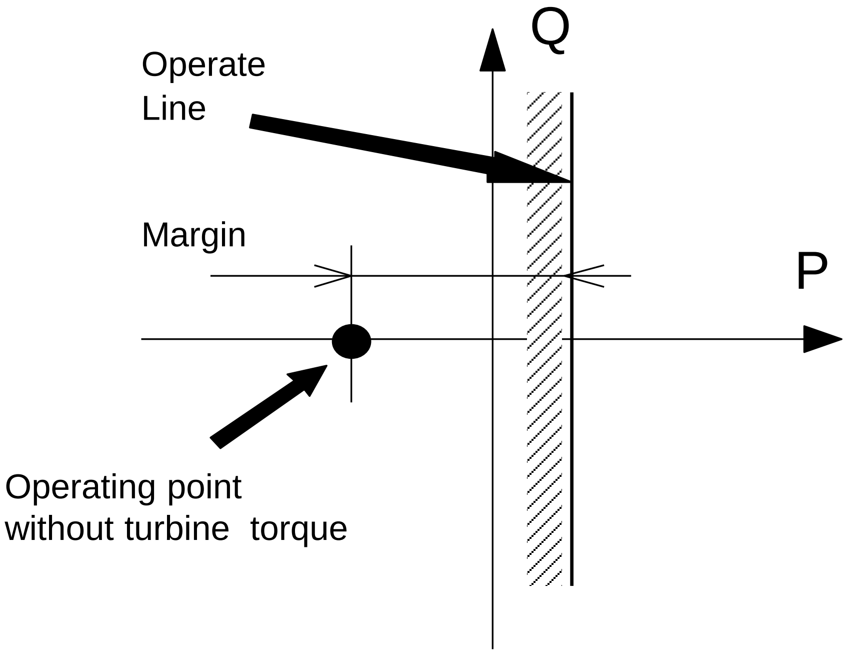


Reverse power protection



- Set desired pickup (0,5 to 3%)
- Set time delay 5-30 s
- Sequential tripping logic

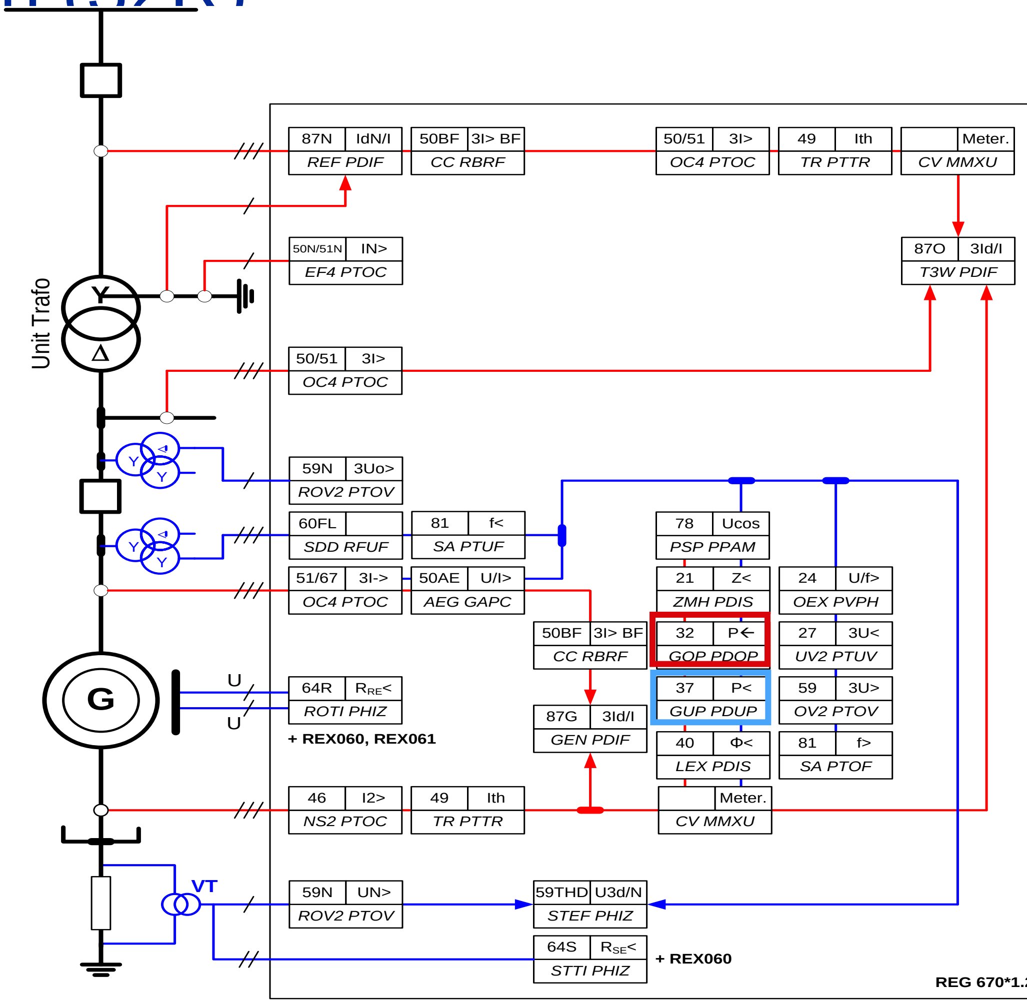
Low forward power protection



- Set desired pickup (1 to 10%)
- Set time delay 5-30 s
- Sequential tripping logic
- Blocked by external signal when generator is not loaded

Reverse Power Protection (32R)

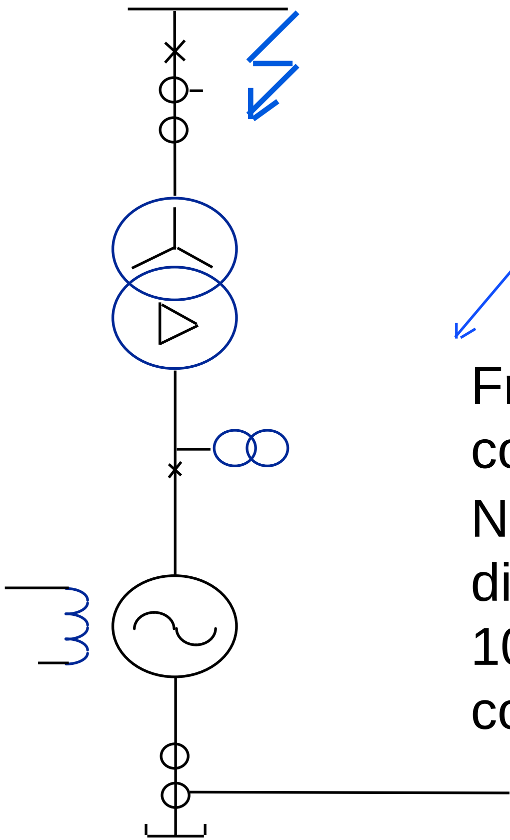
- Endangering condition
  - Motor operation
- Protected object
  - Turbine
- Consequences
  - Excessive heating of turbine blades (steam units)
  - Mechanical damages to thrust bearing (Francis turbines)
  - Explosion risk for diesel units

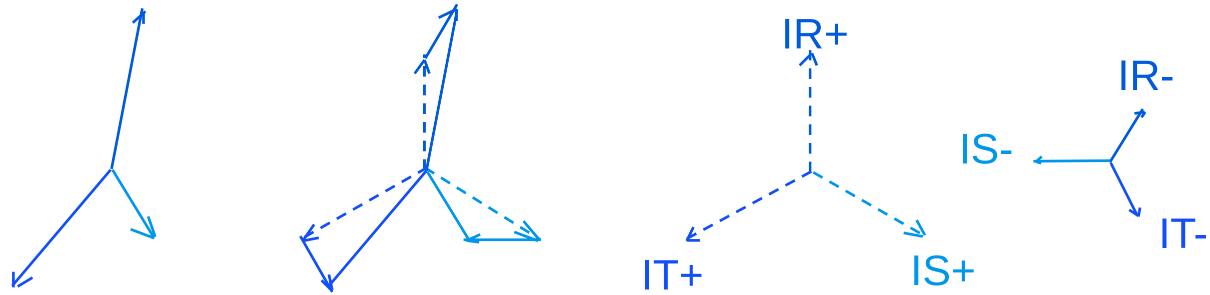


Main Protection Function

Reserve Protection Function

Negative sequence overcurrent (46)





From asymmetric currents, a negative sequence current component I_2, is filtered out.

Negative sequence stator currents rotate in a opposite direction from the rotor and consequently induce a 100Hz current component into the rotor. As a consequence rotor ends can over-heat.

I- , I_{nsc}

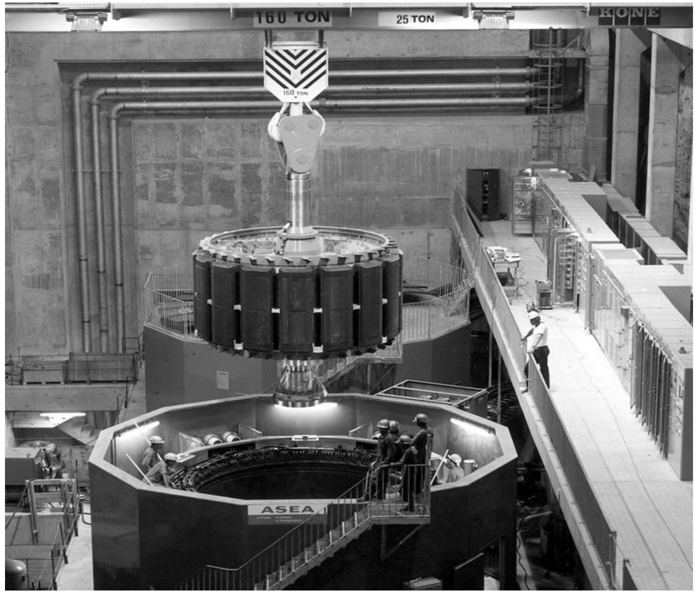
46

$$I_2^2 \times t = k$$

Negative phase sequence (46)

Causes

- unbalanced loads
- untransposed transmission circuits
- unbalanced system faults
- series faults
- CB pole discrepancy
- open circuits



Features

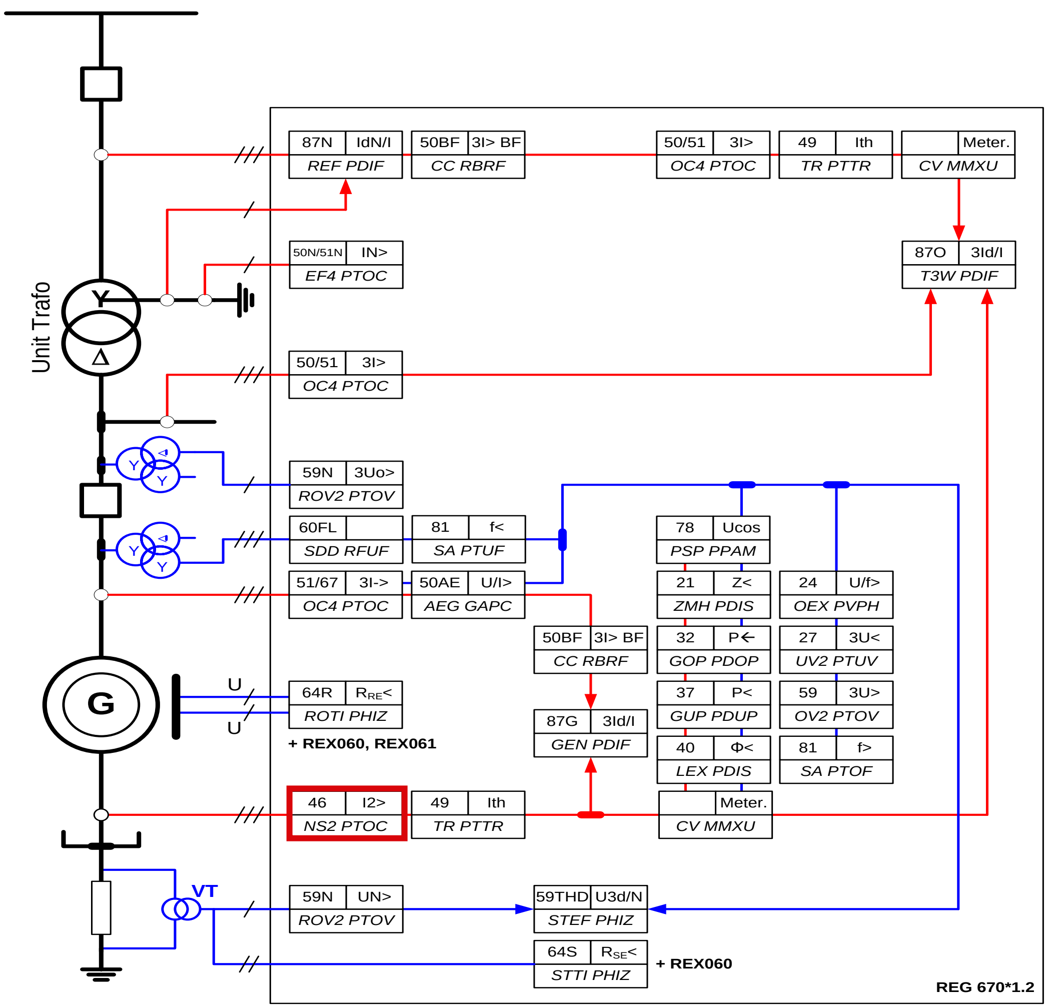
- Characteristic adjustable to $I_2^2 t=k$

Broken stator winding

- Endangering condition
  - Unsymmetrical currents
- Protected object
  - Stator windings
  - Rotor
- Consequences
  - Rotor overheating
  - Vibrations

Main Protection Function

Reserve Protection Function

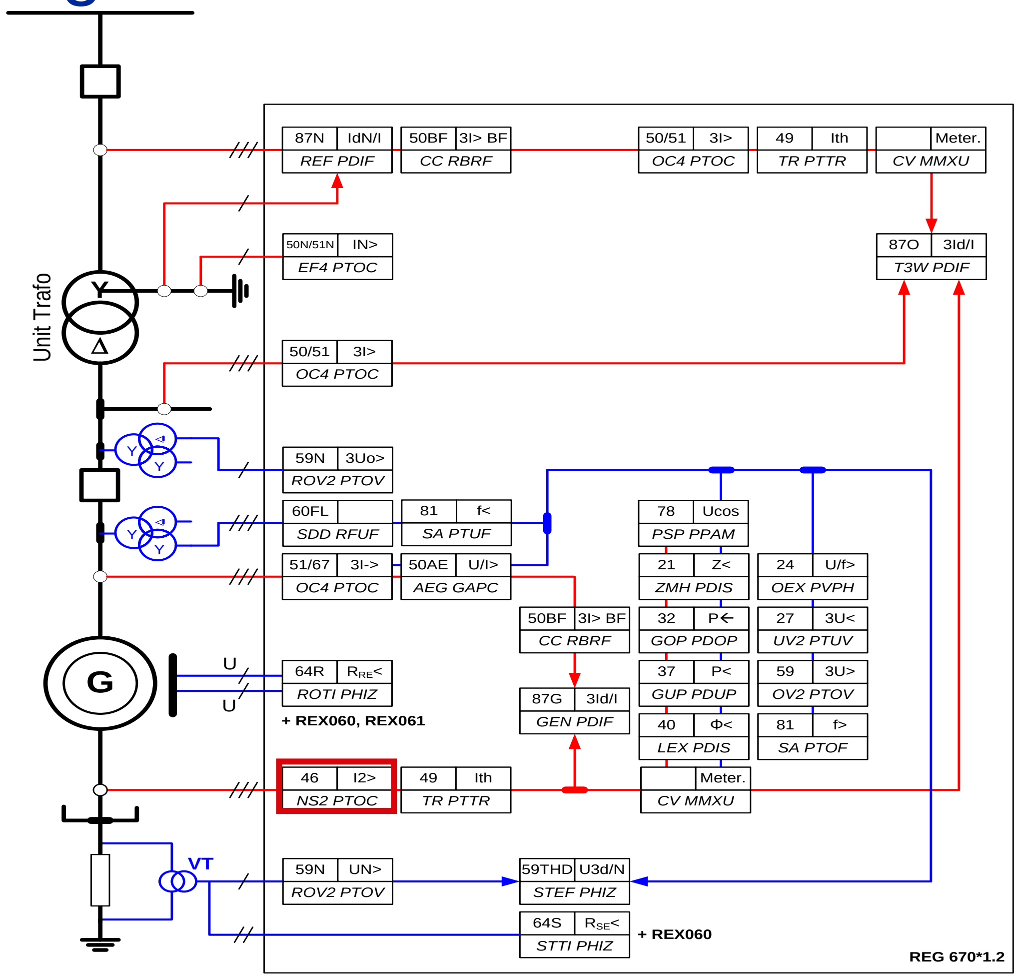


Broken transformer winding

- Endangering condition
  - Unsymmetrical currents
- Protected object
  - Stator windings
  - Rotor
- Consequences
  - Rotor overheating
  - Vibrations

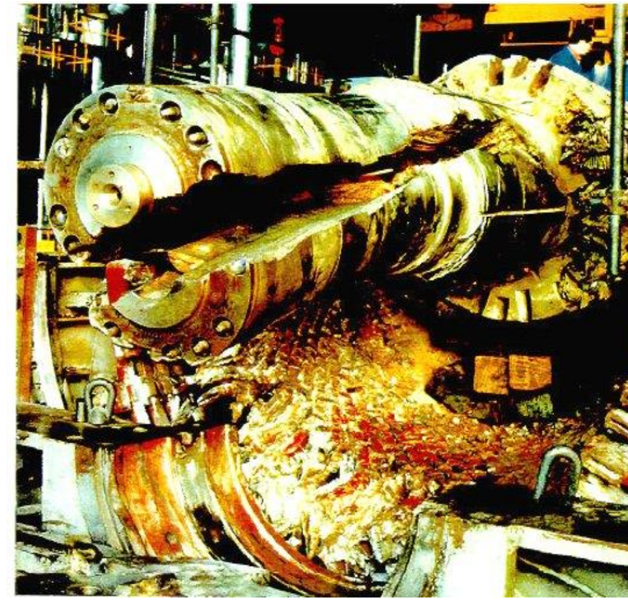
Main Protection Function

Reserve Protection Function



Pole slip / out of step protection (78)

- Asynchronous running of a synchronous machine with the rest of the system but **with excitation intact**
- Characterized by power (P & Q) oscillation
- Manifests as impedance movement in R & X plane
- Big mechanical impact on turbine and shaft
- Pole Slip typically caused by:
  - Long fault clearance time (especially close by 3Ph faults are critical)
  - Inadvertent tripping of a transmission line (increase of transmission impedance between generator and load)
  - Loss of large generator unit

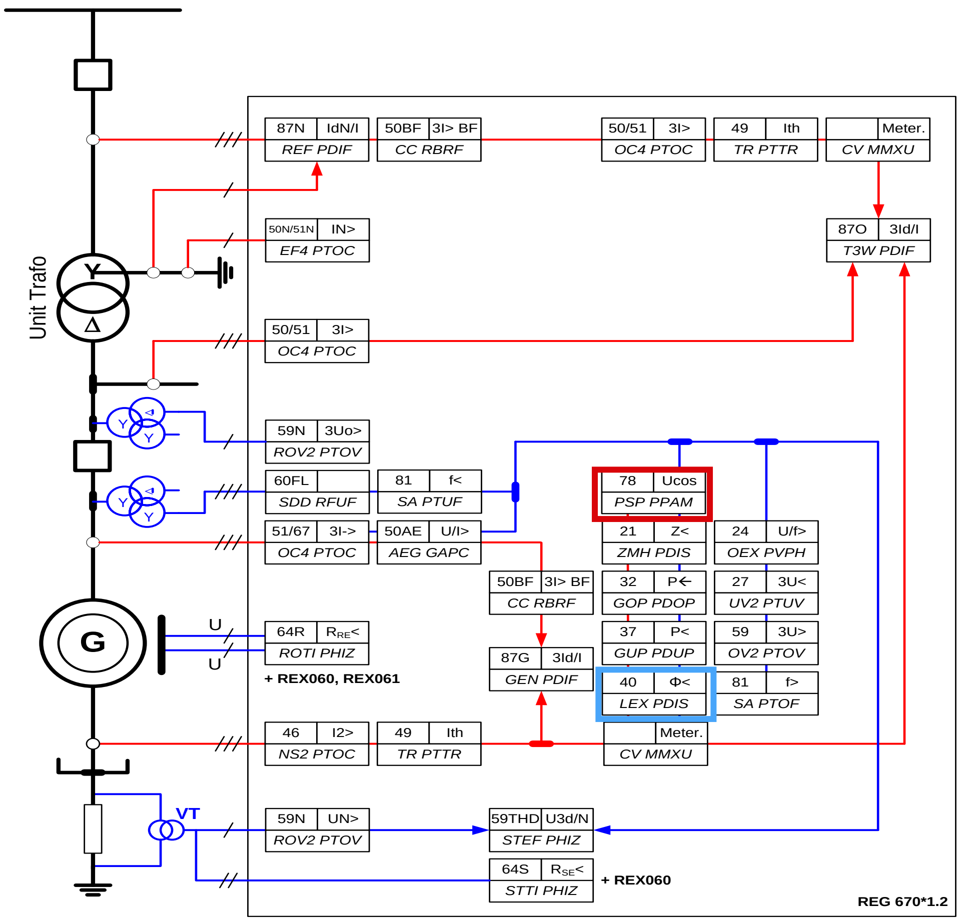


Pole slip / out of step protection (78)

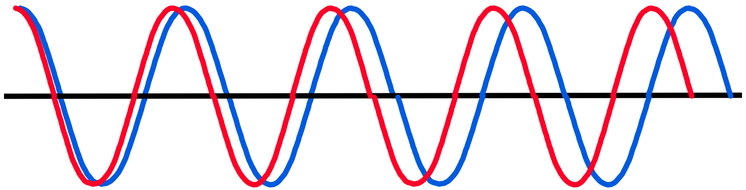
- Endangering condition
  - High stator current
  - Possible system blackout
- Protected object
  - Rotor shaft and stator winding
- Consequences
  - Mechanical damages to shaft
  - Asynchronous machine operation (with field intact)
  - Voltage and current variations

Main Protection Function

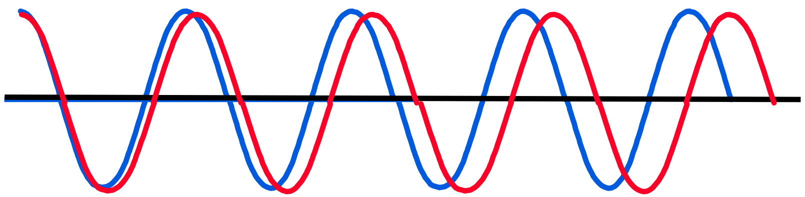
Reserve Protection Function



Frequency protection (81U/O)



- Over-frequency 81O: protects in case of turbine over-speed



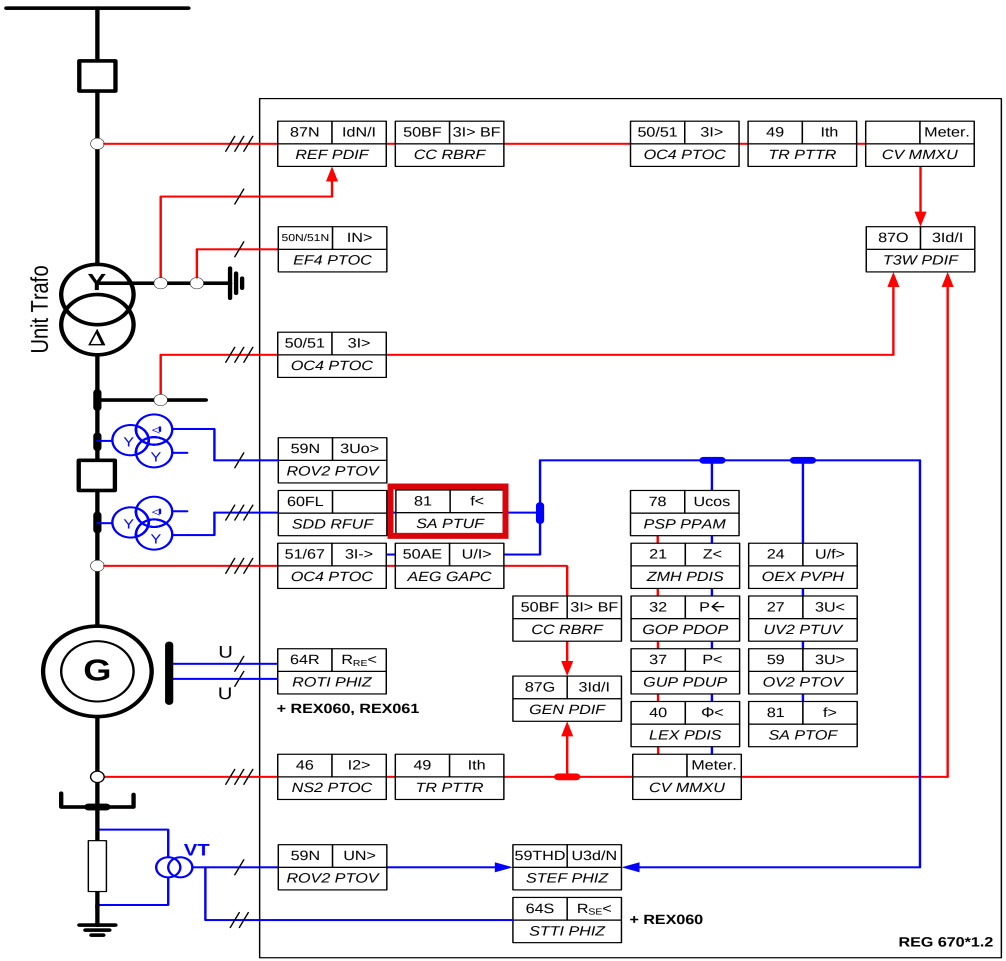
- Under-frequency 81U: protection of the steam turbine at the "critical speed"

Low network frequency (81U)

- Endangering condition
  - Under-frequency
- Protected object
  - Transformer
  - Steam turbine
- Consequences
  - Over-excitation
  - Steam turbine vibrations

Main Protection Function

Reserve Protection Function

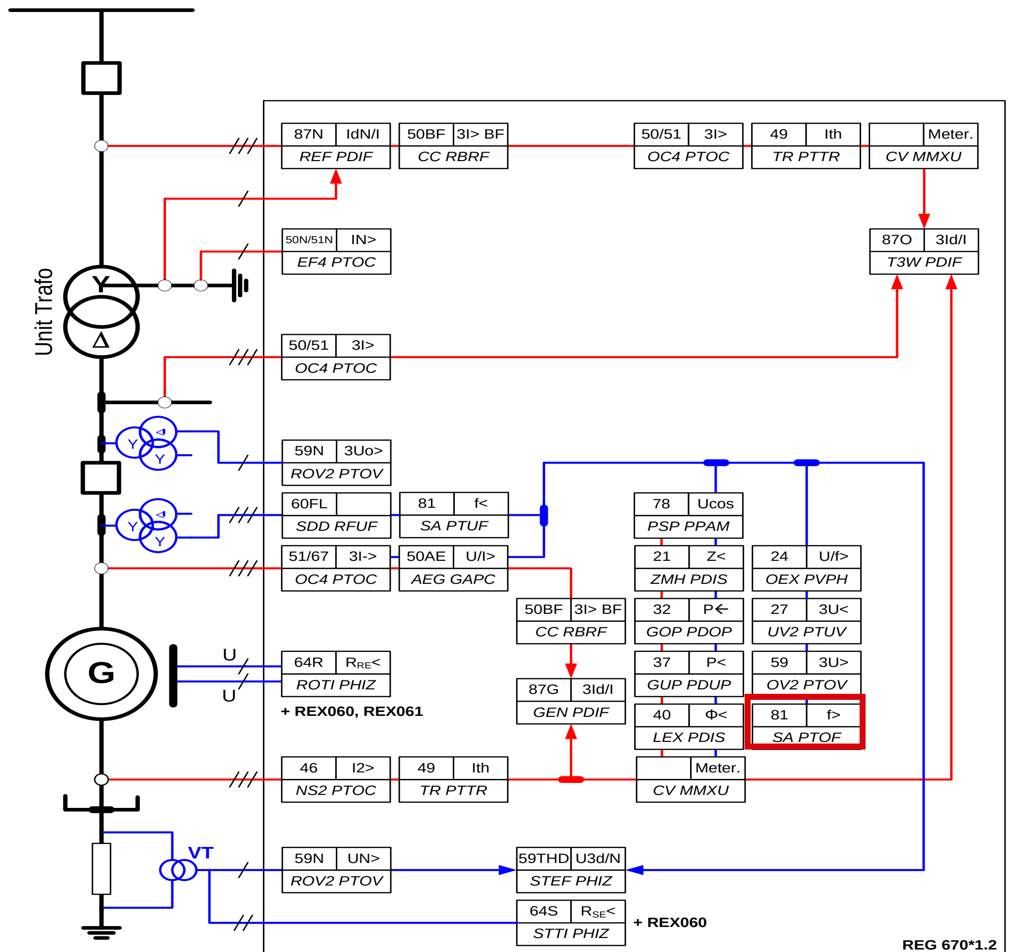


High Network Frequency (81O)

- Endangering condition
  - Over-frequency
- Protected object
  - Turbine
  - Rotor
- Consequences
  - Mechanical stresses
  - Turbine vibrations

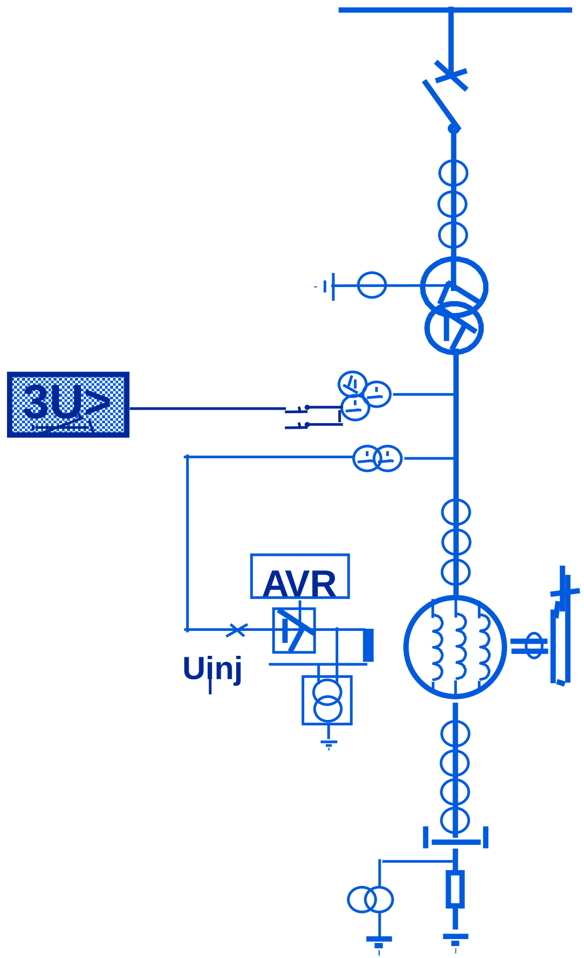
Main Protection Function

Reserve Protection Function



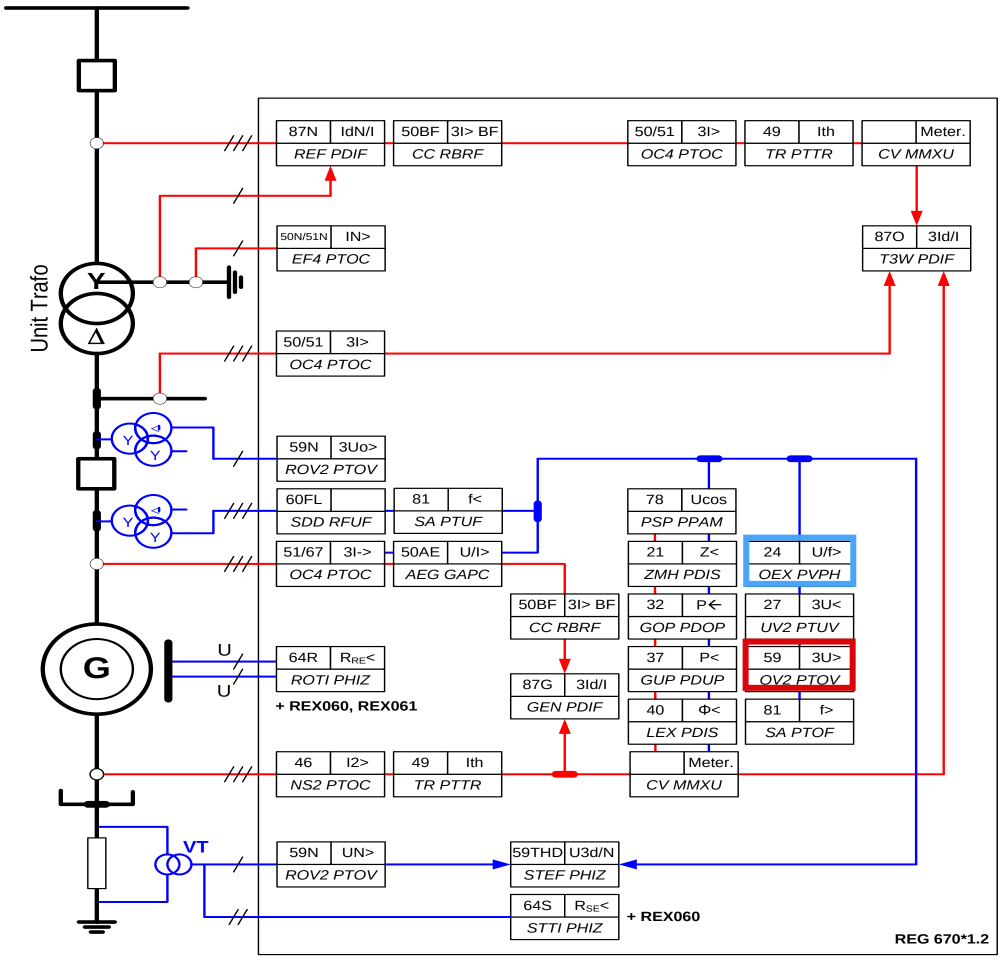
Over-voltage protection, 59

- With faulty AVR overvoltage can cause over excitation of the generator-transformer block
- V can sharply increase after load rejection followed by machine runaway



Over-voltage protection (59)

- Endangering condition
  - Over-voltage
  - Improper voltage regulation
- Protected object
  - Electrical circuits
- Consequences
  - Increased risk for earth-faults
  - Over-excitation



Main Protection Function

Reserve Protection Function

Over-fluxing (excessive V/Hz), 24

$$\Phi \, or B = const \cdot \frac{E}{f} \approx const \cdot \frac{U}{f}$$

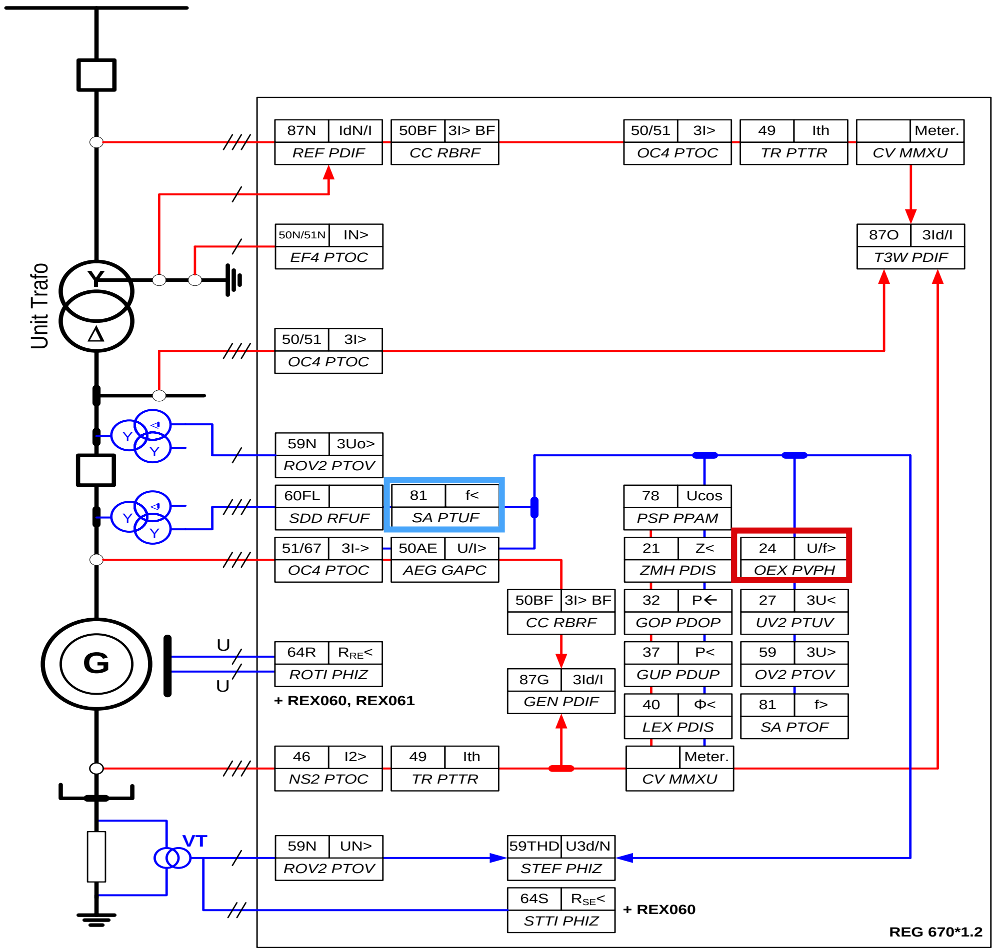
- Overfluxing protects generator and transformer magnetic core against overheating
- Specially critical during start-up and shut-down
- Wide frequency operation of the relay important for generator protection

Incorrect turbine control (24, 81O/U)

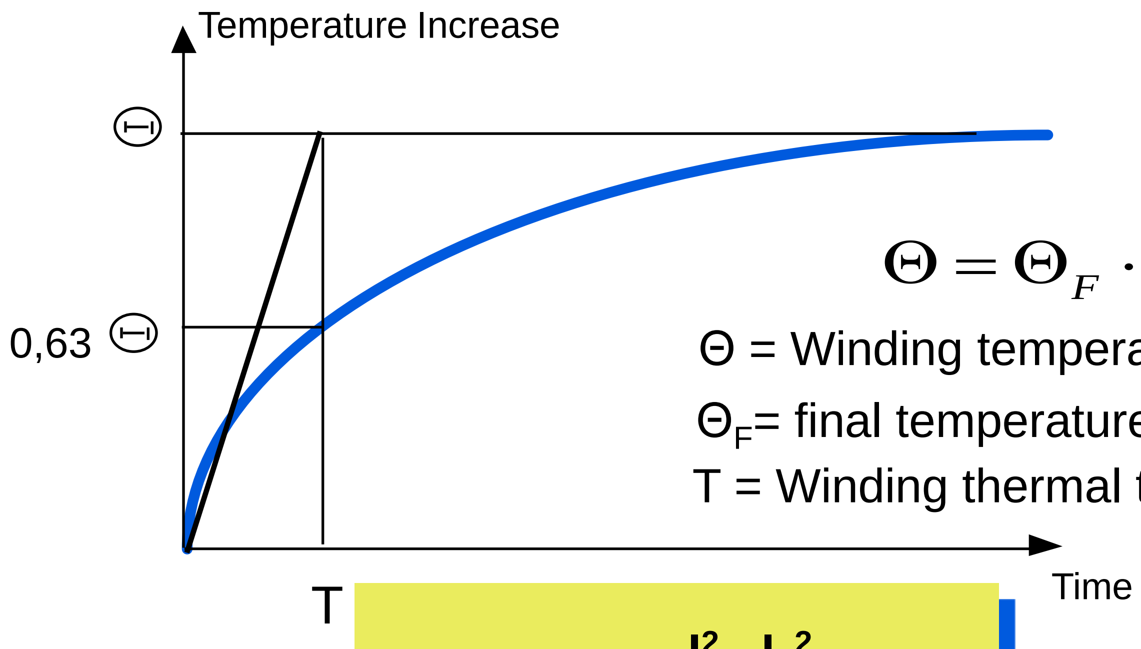
- Endangering condition
  - Under-frequency
- Protected object
  - Transformer
- Consequences
  - Over-excitation

Main Protection Function

Reserve Protection Function



Thermal overload, 49



$$\Theta = \Theta_F \cdot (1 - e^{\frac{t}{T}})$$

Θ = Winding temperature increase

Θ_F= final temperature with present current

T = Winding thermal time constant

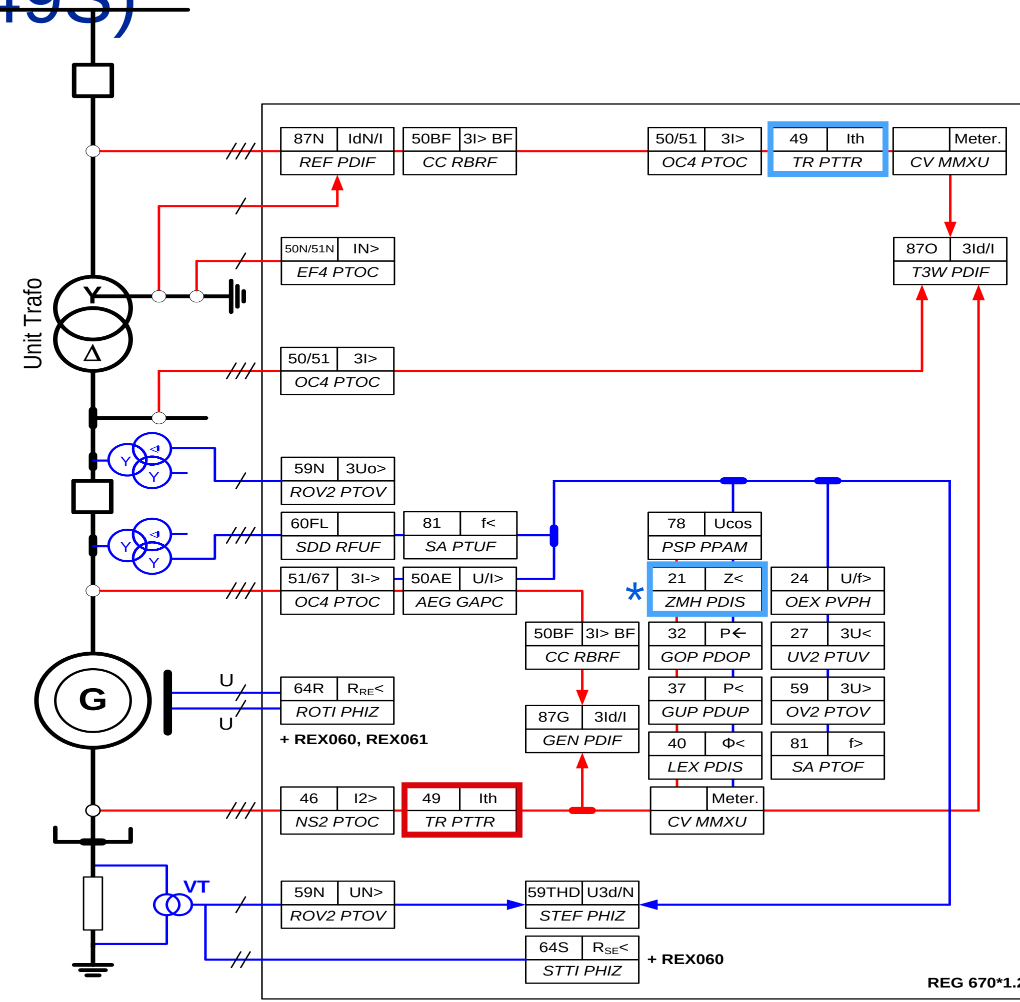
$$t = \tau \times \ln \frac{I^2 - I_p^2}{I^2 - (k \times I_b)^2}$$

Stator thermal overload (49S)

- Endangering condition
  - Stator overcurrent
- Protected object
  - Electrical circuits
- Consequences
  - Stator overheating

Main Protection Function

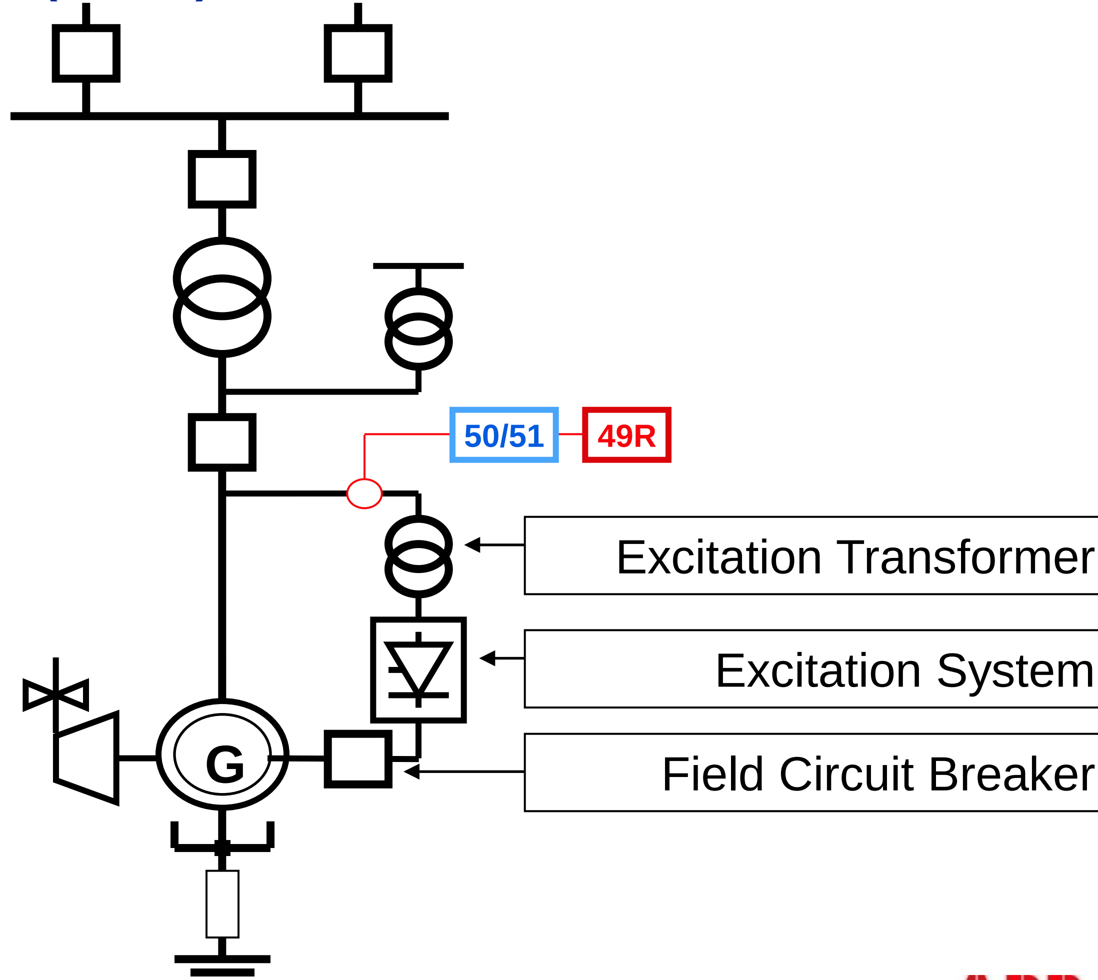
Reserve Protection Function



*** In case of severe overload (setting dependent)**

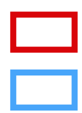
Rotor thermal overload (49R)

- Endangering condition
  - Rotor overcurrent
- Protected object
  - Rotor winding
- Consequences
  - Rotor overheating



Main Protection Function

Reserve Protection Function

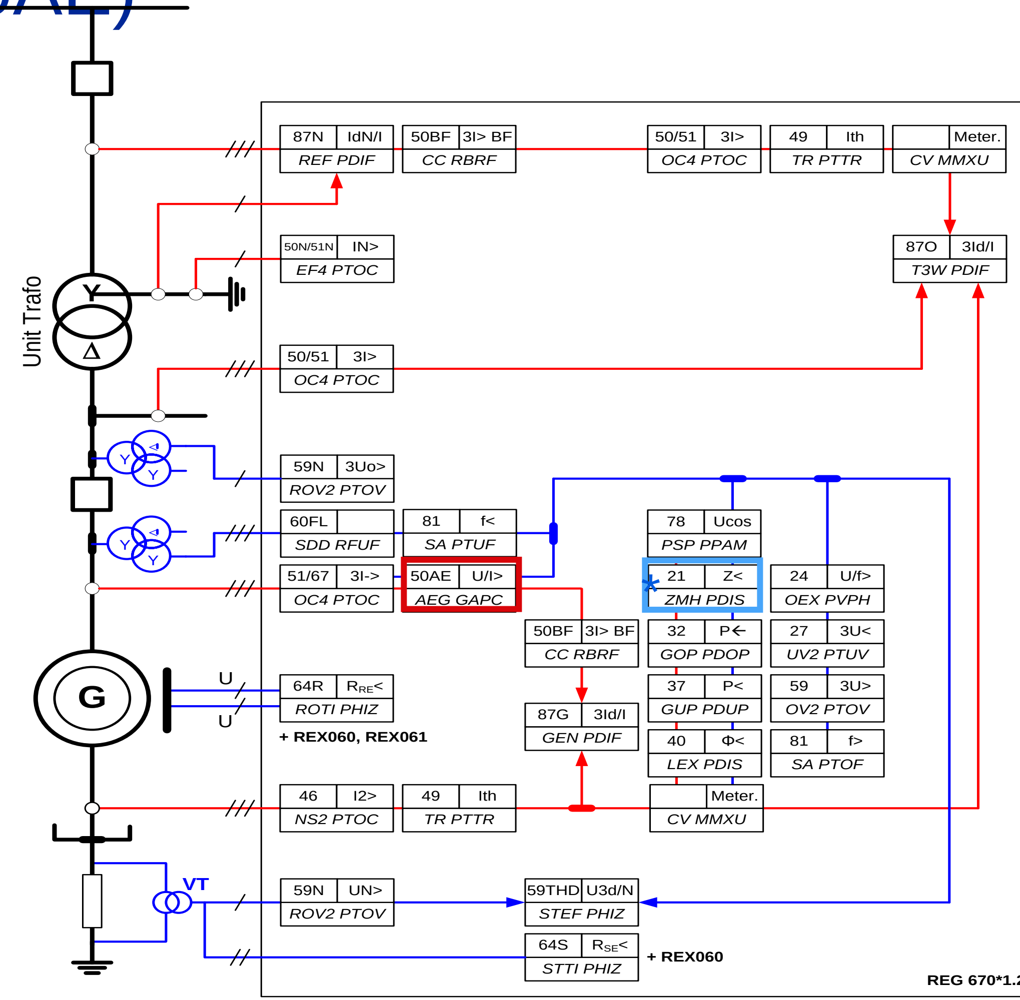


Accidental energizing, 50AE

- Operates when generator is energized by a mistake
- In principle voltage controlled OC function

Accidental energizing (50AE)

- Endangering condition
  - Stator overcurrent or unsymmetrical currents
- Protected object
  - Bearings
  - Rotor
- Consequences
  - Bearing damages due to low oil pressure
  - Rotor overheating
  - Stator overheating



Main Protection Function

Reserve Protection Function

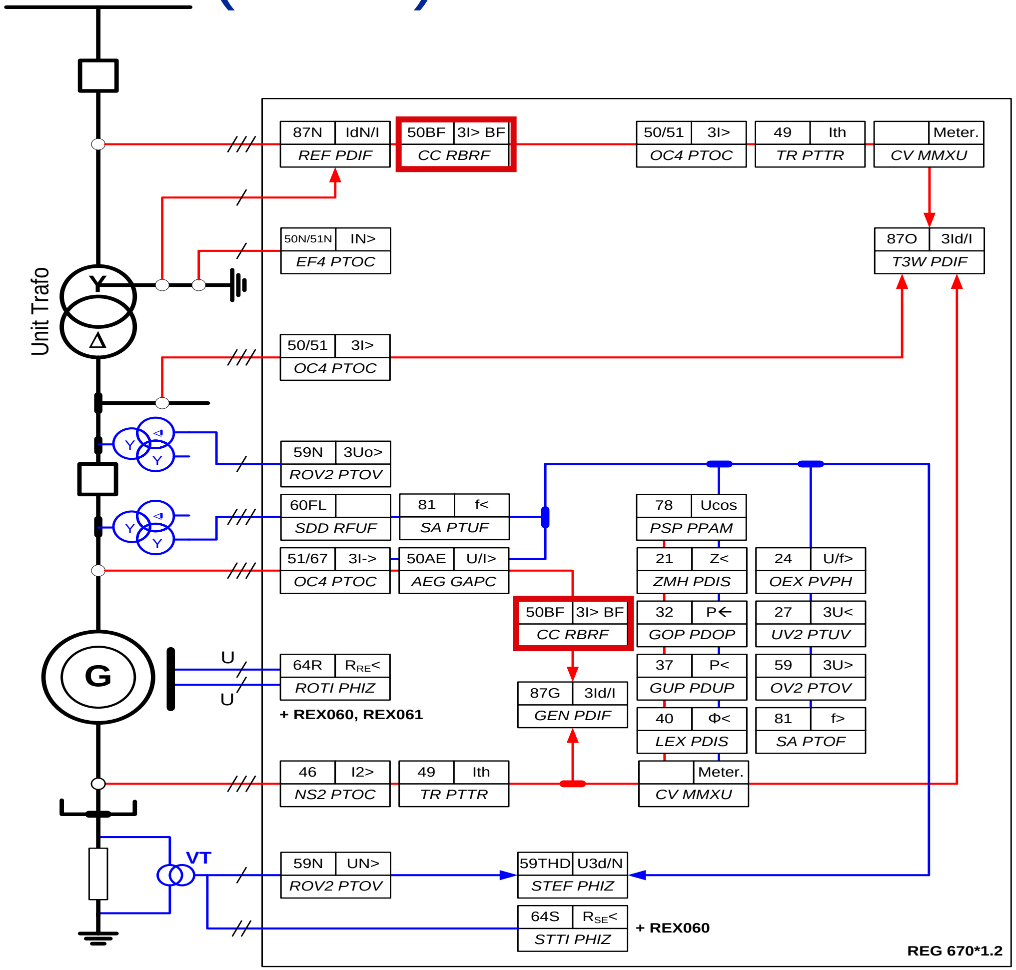
*** 3Z< is a delayed reserve protection**

Breaker-failure protection (50BF)

- Issues a back-up trip of adjacent breaker in case of failure of the circuit breaker of the protected object to open (i.e. to interrupt the primary circuit)
- Its operation in most cases trips only local breakers
- Commonly uses the bus bar protection disconnector replica logic to route its tripping command to adjacent breakers
- Re-trip (t1), Backup trip / bus-strip (t2), Second back-up trip timer (t3)
- Short reset time (15ms)
- Known CB faulty (bypass t2)
- Operating mode
  - Current / Contact / Current & Contact

Breaker fails to open the circuit (50BF)

- Endangering condition
  - Stator overcurrent or unsymmetrical currents
- Protected object
  - Electrical circuits
  - Rotor
- Consequences
  - Rotor overheating
  - Stator overheating
  - Prolonged damages caused by the fault current

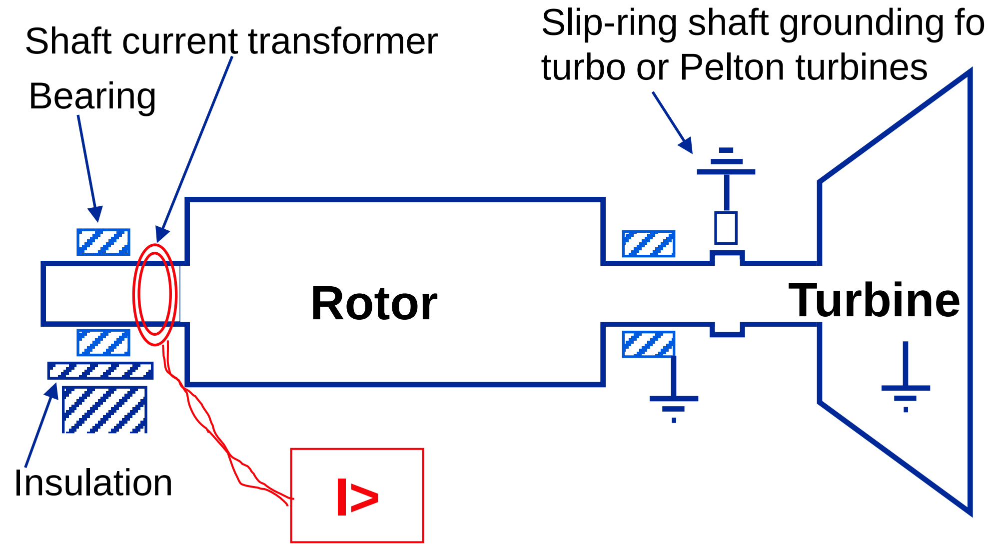


Main Protection Function

Reserve Protection Function

Destroyed bearing insulation (38)

- Endangering condition
  - Shaft (bearing) current
- Protected object
  - Bearing
- Consequences
  - Bearing damages
  - Stator/rotor damages



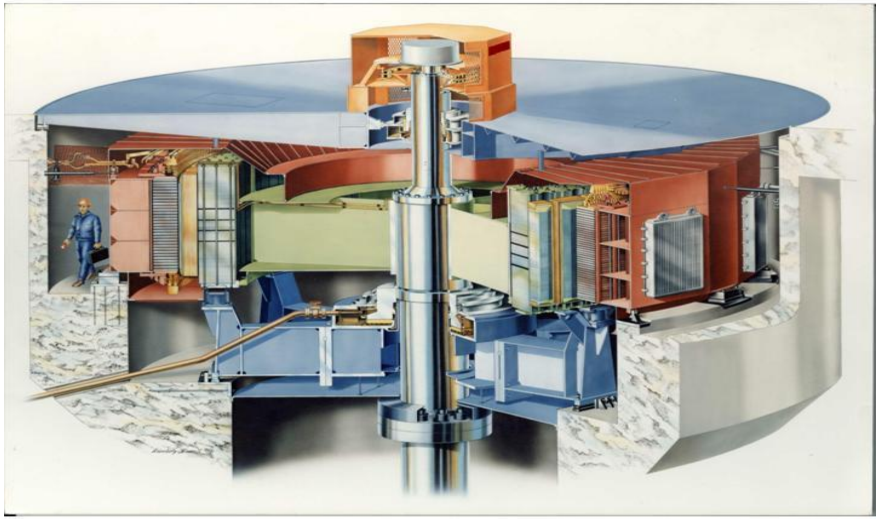
Relay type: RARIC (setting range 0.5-2.0 mA)

Shaft CT type: ILDD

Damage to the bearings occurs if the current through the shaft exceeds 1 A

The induced EMF is about: 0.5 - 1 V for turbo-machines; 10 - 30 V for hydro-machines

Conclusion



- Stator earth faults
- Rotor earth faults
- Stator short circuits
- Stator/rotor interturn faults
- External faults
- Abnormal operation

Thank you for your participation

Shortly, you will receive a link to an archive of this presentation.

To view a schedule of remaining webinars in this series, or for more information on ABB's protection and control solutions, visit:

www.abb.com/relion

ABB Protective Relay School Webinar Series
Disclaimer

ABB is pleased to provide you with technical information regarding protective relays. The material included is not intended to be a complete presentation of all potential problems and solutions related to this topic. The content is generic and may not be applicable for circumstances or equipment at any specific facility. By participating in ABB's web-based Protective Relay School, you agree that ABB is providing this information to you on an informational basis only and makes no warranties, representations or guarantees as to the efficacy or commercial utility of the information for any specific application or purpose, and ABB is not responsible for any action taken in reliance on the information contained herein. ABB consultants and service representatives are available to study specific operations and make recommendations on improving safety, efficiency and profitability. Contact an ABB sales representative for further information.

Power and productivity
for a better world™