Eskom Generation	**STANDARD**	

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REVISION	DESCRIPTION OF REVISIONS	APPROVAL	DATE
0	Original issue and revise over voltage protection	GJ Coetzee	Oct'08
1	Revise back-up impedance figure. Remove alarm and include HV breaker. Revise 4.3.6 (Frequency) and 4.3.11 (LOF). Include "Note" and revise 4.1. General format changes.	D Bhimma	Apr'09
2	Add "Note" to point 4.3.10. Add "Alternative" to point 4.5.2. Revise point 4.13, paragraph six.	M Viljoen	April'10

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Introduction

This standard presents the principles that determine the electrical protection of generating units in Eskom's nuclear fuel power stations. A generating unit consists of the generator, generator transformer, unit transformer and HV yard bus. The standard describes the general tripping principles and the protective relay functions.

1 Scope

1.1 Purpose

This standard describes Eskom's present generator protection and tripping philosophy for nuclear fuel power stations. All power stations that use nuclear fuel with generator circuit-breakers included. It shall be used as a standard when purchasing new generator protection schemes. It shall be used as a guide for modifications to equipment or the revision of settings at existing power stations.

1.2 Applicability

This standard applies to Koeberg and new builds.

2 References

The following document(s) contain(s) provisions that, through reference in the text, constitute requirements of this document. At the time of publication, the edition(s) indicated were (was) valid. These documents are subject to revision and users are responsible to ensure that the most recent edition(s) of the document(s) listed below are used / referenced.

2.1 GGPP 0764:Rev.0, Management of generator protection.

2.2 GGS1012: Rev. 1, Eskom Generator Protection Philosophy for Nuclear Fuel Power Stations with Generator Circuit-Breaker.

3 Definitions and abbreviations

3.1 Definitions

3.1.1 N/A

3.2 Abbreviations

3.2.1 **HV:** High Voltage

3.2.2 **LV:** Low Voltage

3.2.3 **SEF:** Sensitive Earth Fault

3.2.4 **VT:** Voltage Transformer

3.2.5 **ESV:** Emergency Shut down Valve

3.2.6 **DC:** Direct Current

3.2.7 **OEM:** Original Equipment Manufacturer

4 Requirements

4.1 Introduction

If a power station does not comply with this philosophy, then the deviation and the reasons shall be stated in the power station protection setting document and power station specific philosophy

This document describes typical settings and the tripping logic. Setting should however be calculated to protect the plant adequately. Reference should always be made to the plant capability and damage curves. The settings shall be documented as stated in GGPP 0764.

The protection function shall be split into main 1 protection and main 2 protection. Main 1 protection and main 2 protection shall be completely independent of each other and supplied from independent DC systems. Note: No DC change over systems will be allowed in the generator protection schemes.

Redundancy of all protection functions shall be ensured between main 1 and main 2 protection. Although all protection functions will be active at all times, the rotor earth fault and 100% stator earth (injection method) protection functions must be able to be selected to be active on main 1 **or** main 2 when ever these functions can not be included in both protection mains. The voltage and current transformer inputs to main 1 and main 2 must be redundant. See table 1 for protection functions. Separate field input signals must be available for each main protection.

Note: Sufficient relay spares to be kept to enable plant to return to service within 8 hours with both Main 1 and Main 2 in service after first detection of relay failure.

Table 1 — Recommended protection functions

Distribution of protection functions	Main 1	Main 2
(i) Generator protection		
Generator differential	x	x
90 % stator earth fault	x	x
100 % stator earth fault (Active in one main at a time)	x	x
Rotor earth fault (Active in one main at a time)	x	x
Over voltage	x	x
Generator over fluxing	x	x
Frequency	x	x
Reverse power 1	x	x
Reverse power 2	x	x
Pole slipping	x	x
Loss of field	x	x
Negative phase sequence 1	x	x
Negative phase sequence 2	x	x
Back-up impedance	x	x
Generator circuit-breaker fail	x	x
Low forward power 1	x	x
Low forward power 2	x	x
Low forward power 3	x	x
Directional reactive power	x	x
Trip-to-house load	x	x
Switch Onto Standstill	x	x
End Zone protection (If applicable)	x	x
VT Fuse failure	x	x
External protection signals operating via auxiliary inter trip relays		
Turbine trip	x	x
Generator breaker pole disagreement	x	x
Stator cooling	x	x
Emergency push-buttons	x	x
Internal protection signals operating via auxiliary inter trip relays		
Generator breaker cross trip	x	x
HV breaker cross trip	x	x
(ii) Transformer protection		
Gen transformer differential	x	x
Gen transformer restricted earth fault	x	x
Gen transformer over fluxing	x	x
Gen transformer HV back-up earth fault	x	x
Gen transformer tap-changer over current	x	x
Tap-changer mechanism timer	x	x
HV “breaker fail”	x	x
Unit transformer 1 differential	x	x
Unit transformer 1 HV earth fault	x	x
Unit transformer 1 HV over current	x	x
Unit transformer 1 LV sensitive earth fault	x	x
Unit transformer 1 LV earth fault	x	x
Unit transformer 2 differential	x	x
Unit transformer 2 HV earth fault	x	x
Unit transformer 2 HV over current	x	x
Unit transformer 2 LV sensitive earth fault	x	x
Unit transformer 2 LV earth fault	x	x

Table 1 — (concluded)

Distribution of protection functions	Main 1	Main 2
External protection signals operating via auxiliary inter-trip hardware		
Gen transformer Buchholz	x	x
Gen transformer pressure relief device	x	x
Gen transformer winding temperature stage 1	x	x
Gen transformer winding temperature stage 2	x	x
Gen transformer oil temperature stage 1	x	x
Gen transformer oil temperature stage 2	x	x
Gen transformer tap-changer surge relay	x	x
Unit transformer 1 Buchholz	x	x
Unit transformer 1 pressure relief device	x	x
Unit transformer 1 winding temperature stage 1	x	x
Unit transformer 1 winding temperature stage 2	x	x
Unit transformer 1 oil temperature stage 1	x	x
Unit transformer 1 oil temperature stage 2	x	x
Unit transformer 1 LV earthing resistor oil temperature	x	x
	x	x
Unit transformer 2 Buchholz	x	x
Unit transformer 2 pressure relief device	x	x
Unit transformer 2 winding temperature stage 1	x	x
Unit transformer 2 winding temperature stage 2	x	x
Unit transformer 2 oil temperature stage 1	x	x
Unit transformer 2 oil temperature stage 2	x	x
Unit transformer 2 LV earthing resistor oil temperature	x	x
HV yard bus zone 1 or bus zone 2	x	x
HV circuit-breaker pole disagreement		
(iii) External alarm signals		
Stator cooling		
Gen transformer Buchholz		
Gen transformer winding temperature		
Gen transformer oil temperature		
Gen transformer conservator low oil level		
Gen transformer cooler fail		
Gen transformer tap-changer low oil level		
Unit transformer 1 Buchholz		
Unit transformer 1 winding temp		
Unit transformer 1 oil temperature		
Unit transformer 1 earthing resistor oil temperature		
Unit transformer 1 conservator low oil level		
Unit transformer 1 cooler fail		
Unit transformer 2 Buchholz		
Unit transformer 2 winding temp		
Unit transformer 2 oil temperature		
Unit transformer 2 earthing resistor oil temperature		
Unit transformer 2 conservator low oil level		
Unit transformer 2 cooler fail		
HV pantograph pole disagreement		
(iv) Internal alarm signals		
Negative phase sequence	x	x
Over fluxing	x	x
Rotor earth fault (value in ohms)	x	x
Loss of field	x	x
Under frequency	x	x
Stator earth fault (analogue value)	x	x

4.2 Tripping and setting principles

4.2.1 Tripping principles

Tripping principles are determined by several factors. These are, in order of importance:
The safety of personnel.
The safety of the reactor.
The safety of other plant.
Plant availability.

The supply to the reactor auxiliaries is essential for reactor safety. Normally, the supply for the auxiliaries (normal and emergency) of the reactor, turbine etc shall be from the generator via a unit transformer. If this becomes unavailable then the supply for the auxiliaries (normal and emergency) shall be from an alternative secure system. If the alternative supply becomes unavailable then the supply for the emergency auxiliaries only shall be from diesel generators.

The generator protection shall select, according to the type of fault, a suitable combination of the following tripping functions:

A) generator circuit-breaker trip;

B) HV circuit-breaker trip;

C) field suppression

D) unit board 1 incoming circuit-breaker trip (unit transformer 1, LV circuit-breaker);

E) unit board 2 incoming circuit-breaker trip (unit transformer 2, LV circuit-breaker);

F) ESVs close (turbine trip);

G) transformer cooling (pumps and fans);

H) generator stator coolant.

I) bus strip

Firstly, the tripping sequences shall be arranged to safeguard personnel, the reactor, the turbine, the generating equipment.

Secondly, the tripping sequences shall ensure maximum plant availability without comprising safety, following the general principles indicated below.

4.2.1.1 Faults in the generator (upstream of the generator circuit-breaker) require only the generator isolation and a turbine shutdown. The supply to the unit boards will be maintained from the HV system.

Tripping functions: A, C, F and H.

4.2.1.2 Faults between the generator circuit-breaker, the HV circuit-breaker and the unit board circuit-breakers require a unit shutdown.

Tripping functions: A, B, C, D, F and G.

4.2.1.3 Faults in the HV system that affect the machine, only require the HV circuit-breaker to be opened, leaving the unit in an " house load" condition.

Tripping functions: B.

4.2.1.4 Faults that may be in the generating unit or in the HV system, are initially assumed to be in the HV system and the HV circuit-breaker is opened. The unit is left in an islanded condition and if the fault persists after a further time delay, a unit shutdown is initiated.

Tripping functions: B, and if necessary A, B, C, D, E, F and in some cases G.

4.2.1.5 Faults that may be in one of the unit transformers or in its corresponding unit board system, are initially assumed to be in the unit board system and the respective incoming circuit-breaker is opened.

If the fault persists after a specific time delay a unit shut-down is initiated.

(The loss of one unit board requires a load reduction of the machine).

Tripping functions: D or E and if necessary A, B, C, D, E, F and G.

4.2.1.6 The following conditions require closing of the ESVs (turbine shutdown), followed by tripping of the generator circuit-breaker when the machine is unloaded. This is referred to as a soft shutdown.

a) Mechanical faults in the turbine or reactor.

b) Abnormal conditions that do not require immediate isolation of equipment.

c) Operator shutdown.

Tripping functions: F.

A reverse power relay is used to detect when the power < 0 and then to operate A and C.

Tripping functions: A, B, C, D, E, F, G and H.

4.2.1.7 If the generator breaker fails to open when required, the unit is shut down.

Tripping functions: A, B, C, D, E and F.

4.2.1.8 If the HV breaker fails to open when required, the adjacent HV breakers are tripped .

Tripping function: I.

4.2.2 Setting principles

Protection settings shall be such that protection equipment shall not operate spuriously as protection trips impose stress on the reactor shutdown plant as well as loss of revenue. This is to ensure maximum availability of generating units while providing adequate protection against faults and abnormal conditions. This document contains typical settings. Final settings should be calculated using the OEM data for the protected objects (generator and/or transformers).

NOTE — Modern microprocessor based protection equipment does not consist of discrete relays for each protection function. Where the word **relay** is used in this document, it may be substituted with the word **function** for microprocessor based protection equipment.

4.3 Generator protection

4.3.1 Generator differential protection

This is a unit type protection, instantaneous in operation, covering the stator winding for phase-to-phase faults.

The generator differential relay is not sensitive to single-phase earth faults due to the high neutral earthing resistance arrangement.

As this protection operates for generator internal faults, opening the generator circuit-breaker directly eliminates the system in feed to the fault (if the unit is synchronised).

Typical setting:

Spill current = 0,1 to 0,4 × full load current.

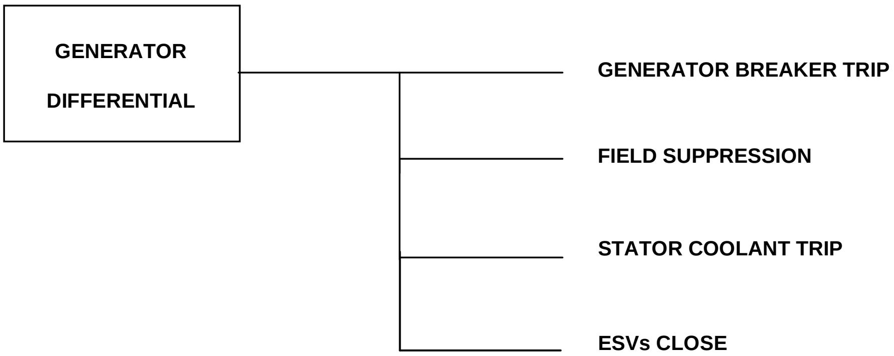


Figure 4.3.1.1 — Generator differential tripping logic

4.3.2 Stator earth fault protection

The high neutral earthing resistance arrangement limits the generator earth fault current to approximately 15 A, thereby minimising damage to the core laminations. Although a single-phase earth fault is not critical, it requires clearance within a short time, due to the following:

a) it may develop into a phase-to-phase fault (presence of ionised air);

b) if a second earth fault occurs, the current is no longer limited by the earthing resistor; and

c) fire may result from the earth fault arc.

Two different types of stator earth fault relays are used at present, both installed in the secondary circuit of the generator earthing transformer.

4.3.2.1 Type 1

Type 1 protects approximately 90 % of the stator winding. This is a voltage relay, monitoring the zero sequence voltage developed across the earthing resistor by the neutral return current.

For faults within 10 % of the generator neutral, the resulting voltage is not enough to operate the relay.

4.3.2.2 Type 2

Type 2 protects the whole stator winding and the generator neutral. The relay operates on the principle of sub harmonic frequency signal injection into the secondary of the earthing transformer, detecting the corresponding current if an earth fault occurs. The relay is set in terms of insulation resistance. The relay has to be calibrated and set on site.

The Delay on Drop Off (DDO) timer effectively latches the protection function to ensure that an intermittent arcing fault is detected.

Typical settings:

Pick-up voltage of the relay = 5 V (Type 1).
Pick-up level of the relay = 500 Ω (Type 2).
Timer t1 = 0,8 s (DDO).
Timer t2 = 1,0 s. (DPU).
Timer t3 = 3,0 s. (DPU).

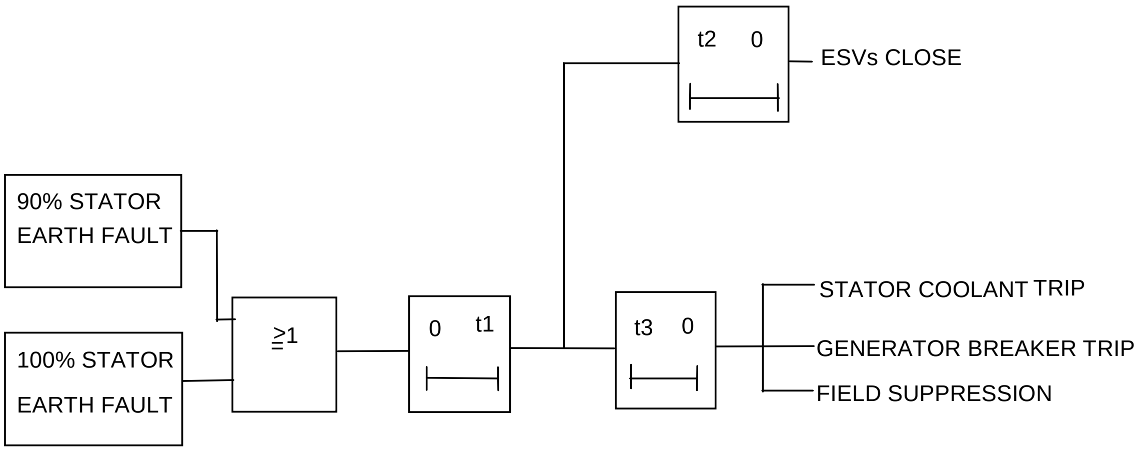


Figure 4.3.2.1 — Stator earth fault tripping logic

4.3.3 Rotor earth fault protection

The relay should operate on the principle of low frequency signal injection into the field winding via capacitors. If an earth fault occurs, the corresponding current is detected. The relay shall be set in terms of insulation resistance. The relay has to be calibrated and set on site.

Application of this protection to brushless machines without main field measuring slip rings may be difficult. In this case the machine supplier shall provide rotor earth fault protection.

An operating procedure shall be in place at power stations. This procedure shall require the operator to shut down the unit immediately if a sustained rotor earth fault occurs.

Typical settings:

Alarm level = 50 kΩ to 80 kΩ.
Pick-up level= 0,5 kΩ to 5,0 kΩ.
Timer t1 = 1 s.
Timer t2 = 5 s.

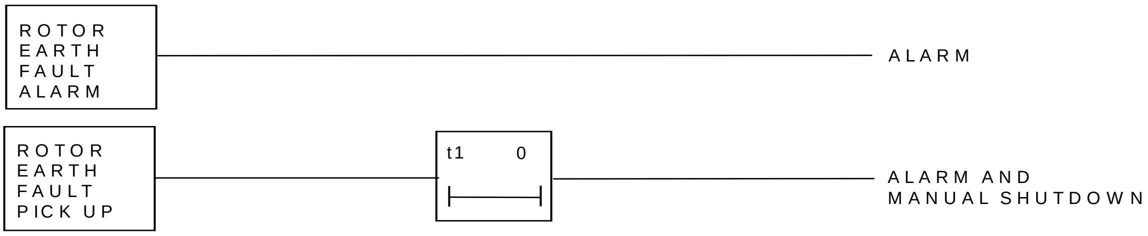


Figure 4.3.3.1 — Rotor earth fault tripping logic

4.3.4 Over voltage protection

An over voltage on the terminals of the generator can damage the insulation of the generator, bus ducting, circuit-breakers, the generator transformer and auxiliary equipment such as voltage transformers, excitation transformers etc..

An over voltage can originate either from the generator or from the HV system. The philosophy is to trip the HV circuit-breaker for over voltages generated by the HV system. A directional reactive power relay is used to determine whether the over voltage originated from the HV network or from the generator. If the over voltage is from the generator, only the generator shall be shutdown.

Note: It is preferred that the Reactive Power measurement should be done on the HV network. If measurement could not be performed on the HV network side, measurement could be done on the Generator Transformer MV side. In this case the influence of the Generator Transformer must be taken into consideration during function setup and setting calculations. The purpose of this is to determine whether the over voltage is due to high network voltages.

Typical settings:

Over voltage relay pick-up	=	1,2 $\times$ V_n.
Over voltage (instantaneous)	=	1,4 $\times$ V_n
Timer t1	=	2,4 s.
Timer t2	=	6 s.
Timer t3	=	1-1,6 s.

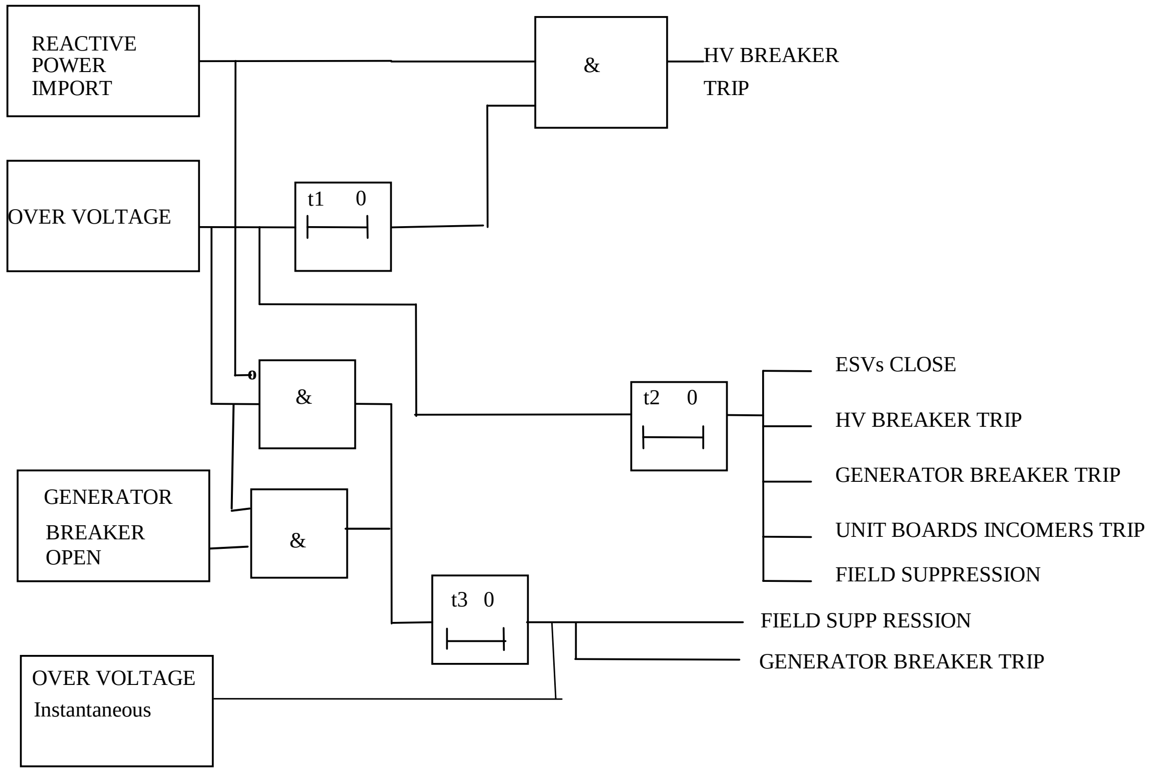


Figure 4.3.4.1 — Over voltage tripping logic

4.3.5 Generator over fluxing protection

Over fluxing protection is provided to safeguard the generator, generator transformer and unit transformers against operation at flux densities which may cause accumulative damage to the core.

From the fundamental equation:

$V = 4{,}44 \times f \times n \times ø$

the level of flux is proportional to the ratio of terminal voltage to frequency (V/f). This ratio is monitored by the protective relay.

An over fluxing condition is more likely to occur while the generator is separated from the system and the speed is allowed to drop, but it can also happen with the machine on load if the tap-changer of the generator transformer (HV side) is on a low tap position and the excitation of the generator is manually increased. In this case the increased generator terminal voltage may cause over fluxing tripping at nominal frequency.

The over fluxing protection operates with a time delay after which the tripping functions are executed.

A short time delayed output signal is also required in order to inhibit "excitation raise" and to give an alarm to the unit operator.

The alarm shall be self-explanatory and well understood so that the operator can react in a short time and reduce the excitation. This will be a small reduction, as "excitation raise" was previously blocked at the over fluxing relay pick-up value.

An inverse time characteristic over fluxing relay is used that greatly enhances the ability of the relay to protect the generator for all levels of over fluxing and ensure maximum operating time at over fluxing levels.

(A separate over fluxing relay may be included in the generator transformer protection on existing units (see 4.4.4 for details).

The over fluxing capability of the machine as well as the protection characteristics shall be shown on a plot in the protection setting document.

Typical settings:

Over fluxing pick-up level (V/f) = 1,1 pu (The over fluxing capability of the transformer shall be checked when selecting this setting).

Timer t1 = 30 s (over fluxing capability of the transformers shall be considered when selecting this setting).
Timer t2 = 1 s.

Timer t3 = 5 s.

If applicable, the settings of the generator over fluxing relay and transformer over fluxing relay in 4.4.4 shall match.

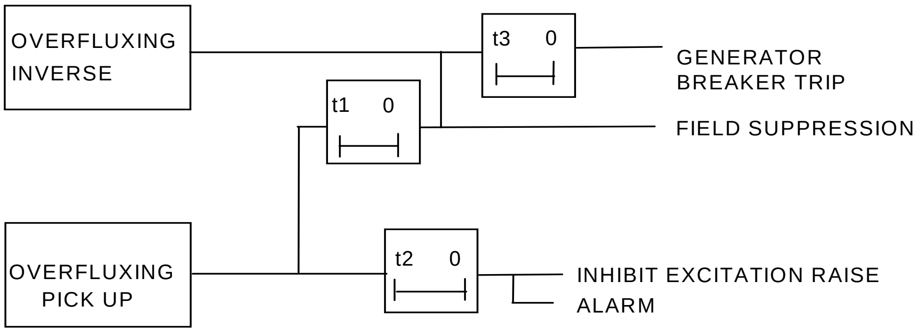


Figure 4.3.5.1 — Generator over fluxing tripping logic

4.3.6 Under frequency and Over frequency protection

NOTE: THIS PROTECTION FUNCTION MUST BE SET ACCORDING TO THE LATEST APPROVED SA GRID CODE DOCUMENT.

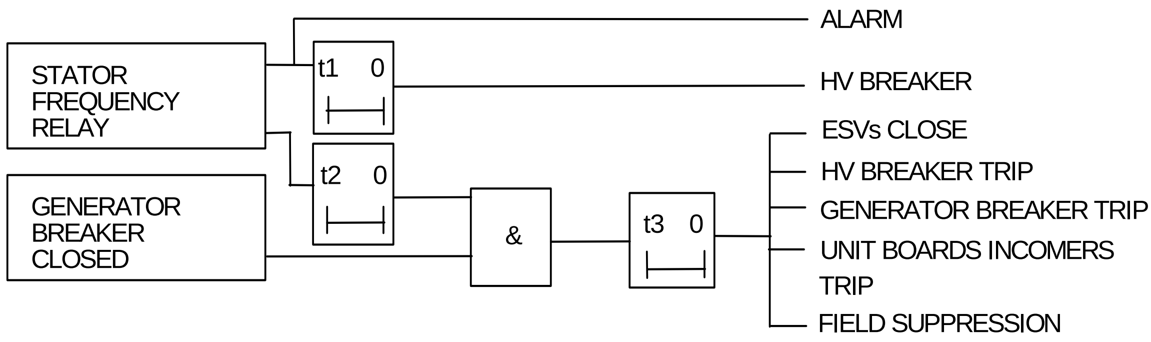


Figure 4.3.6.2 — Frequency tripping logic

4.3.7 Reverse or low forward power protection

When the steam flow through the turbine is interrupted by closing the ESVs or the governor valves, the remaining energy stored in the set is delivered to the system. The machine then enters into a motoring condition, drawing power from the system to supply its losses while keeping the turbo-alternator shaft at synchronous speed. The purpose of the fast reverse power trip is to provide a “soft shutdown” of the generating unit.

The reverse power relay detects that the unit is motoring and should therefore be shutdown.

Sustained reverse power is undesirable due to turbine limitations.

There are two categories of reverse power:

Normal unit shutdown

The operator unloads the turbine by closing the governor valves until the generator enters into the motoring mode. The reverse power relay trips the generator circuit-breaker after a "long" time delay.

Tripping for mechanical faults and abnormal conditions

For faults in the turbine or boiler, the turbine protection closes the ESVs. For abnormal conditions, the generator protection closes the ESVs. When the generator develops reverse power, the relay after a "short" time delay trips the generator circuit-breaker.

A protection field suppression signal may also be required if the AVR does not have a built-in facility to reduce the generator field current as the speed decreases, to avoid over fluxing conditions.

Typical settings:

Reverse power relay pick-up	=	$< 0{,}01 \times P_n$.
Low forward power relay pick-up	=	$< 0{,}05 \times P_n$.
Under frequency relay	=	47 Hz.
Timer t1	=	0.5 s.
Timer t2	=	15 s.

NOTE — Depending on the manufacturer’s requirements, Low Forward Power relays are often used instead of Reverse Power Relays. Sometimes both types are used. When sensitive reverse power settings are necessary, use a measurement CT input for the protection function.

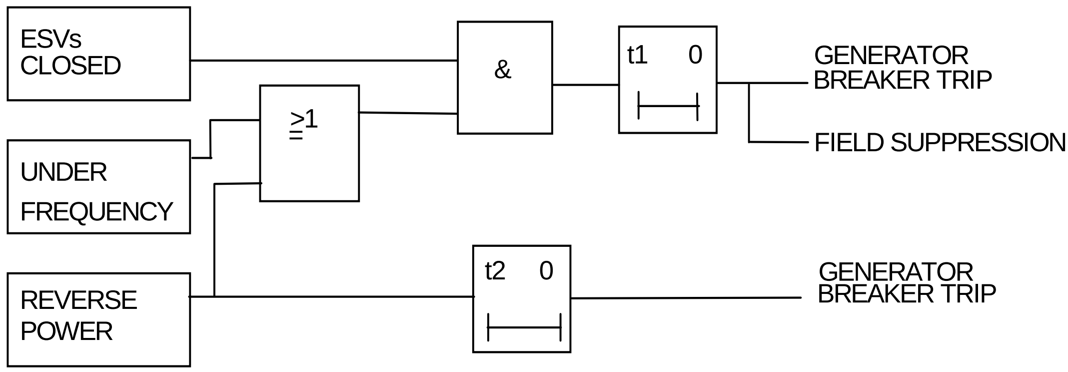


Figure 4.3.7.1 — Reverse power tripping logic

4.3.8 Turbine trip during islanded operation

For an islanded generator, when the turbine protection operates, the closing of the ESVs results in a frequency reduction. The tripping functions will then be done from an under frequency signal instead of a reverse power signal as in the case when the machine is connected to the system. The tripping logic is shown in figure 4.3.7.2.

Typical settings:

Reverse power relay pick-up	=	0,01 p.u. power.
Timer t1	=	1 s.
Under frequency relay pick-up level	=	47 Hz.

4.3.9 Pole slipping protection

Pole slipping of generators, with respect to the system, can be caused by a number of conditions leading to an increase in rotor angular position beyond the generator transient stability limits. Some of the causes of pole slipping are:

a) large network disturbances;

b) faults on the electrical network close to the generator;

c) weak tie between the network and the generator (tripping of transmission lines);

d) loss of generator field (field winding or excitation supply failure); and

e) operating the generator in an excessive under excited mode.

There are different types of pole slipping relays: The relay setting document shall show that the type in use is effective for the configuration of the power station.

4.3.9.1 Type 1

This relay detects the internal angle of the generator by measuring the rotor angle position relative to the stator terminal voltage. This type of relay will detect all the above types of pole slips.

4.3.9.2 Type 2

This relay will measure the operational impedance of the generator after a close-in fault on the network and detect that the generator has gone into a pole slipping condition. This type of relay can only detect type (b) pole slip as listed above.

In a pole slipping situation, the protection shall separate the unit from the system by opening the HV circuit-breaker.

The pole slipping relay shall directly trip the HV circuit-breaker when the "system centre" is inside the unit. For cases where the "system centre" is in the external network, the relay will only trip the HV circuit-breaker after two pole slips.

Pole slipping relays are normally only used on remote stations where there is a high risk of pole slipping.

Typical settings:

For Type 1, the relay shall be set to allow only one pole slip.

For Type 2, a study of the network shall be made to determine the minimum fault impedance allowed before activating the pole slipping relay.

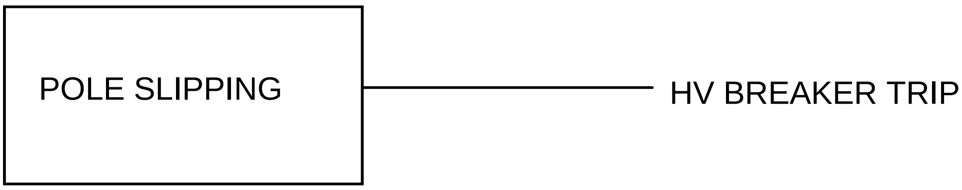


Figure 4.3.9.1 — Pole slipping tripping logic

4.3.10 Negative phase sequence protection

The negative phase sequence (NPS) protection safeguards the generator rotor against overheating caused by the induced double frequency (100 Hz) currents when NPS currents are present in the stator.

Negative phase sequence currents result from asymmetrical faults in the network or unbalanced system conditions. As their origin cannot be directly determined by the relay, the fault is initially assumed to be in the system and the HV circuit-breaker is tripped. If the fault persists after a specific time delay, a general trip and unit shutdown is initiated.

The relays shall be set to the NPS capability of the generator and graded to trip before the MV auxiliaries. Where grading with the MV auxiliaries is not feasible then unit islanding shall be achieved some other means such as blocking of the MV auxiliaries for generator NPS pick up. The NPS capability of the machines varies considerably from station to station and no typical settings are thus given.

Typical settings:

Timer t1 = 2 s.
Timer t2 = 1 s (Note: If the thermal image is used, then t2 time must be sufficient to cater for “reset” of the thermal image before shut down is issued).

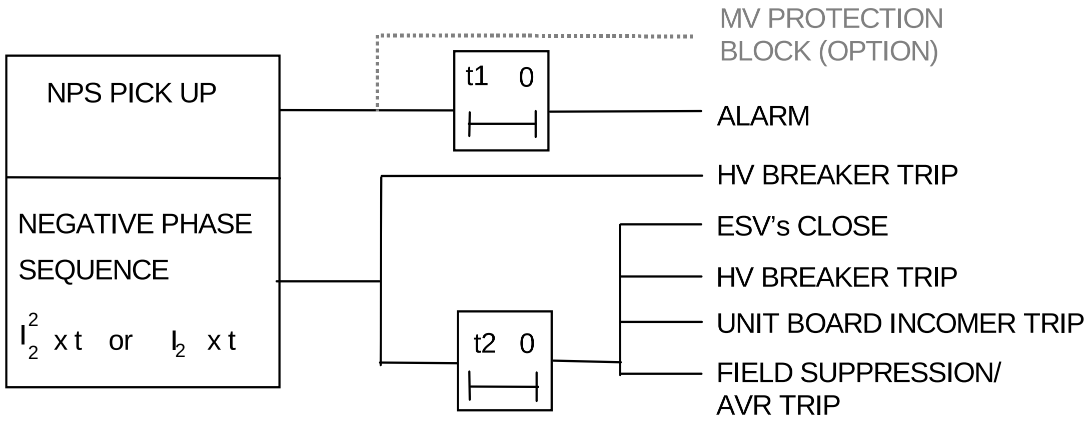


Figure 4.3.10.1 — Negative phase sequence tripping logic

4.3.11 Loss of field protection

The loss of field current protection monitors the generator operating conditions.

Stage 1 provides an alarm for indicating a low field current condition (Admittance method). Stage 2 initiates a trip for a complete loss of field current.

This particular fault requires only generator isolation, by tripping the generator circuit-breaker and the field switch to ensure that the field current will not reinstate when not required.

The ESVs shall not be closed (to keep the unit up to speed for AVR repair work), as the reason for loss of field may have a quick solution. If the problem cannot be solved quickly the operator can shut down the turbine manually. In order to reduce the risk of loss of field condition on the generators, an interlock as shown in figure 4.3.11.2 shall be installed. This interlock will trip the generator circuit-breaker when the field switch has tripped thus preventing the unit from operating with a loss of field. The loss of field relay shall have fuse fail interlocking.

Typical setting:

This protection shall be set to the theoretical stability line excluding the external reactance and co-ordinated with AVR limiter.

Alarm	=	8 % inside theoretical stability line (Note: Alarm to indicate a low excitation condition and a loss of field condition).
AVR limiter	=	10 % inside the theoretical stability line.
Trip	=	10 % outside theoretical stability line. (For impedance method: diameter Xd + Xd'/2 and off set = Xd'/2)
Timer t1	=	1 s.
Timer t2	=	2 s.
Timer t	=	<10s.

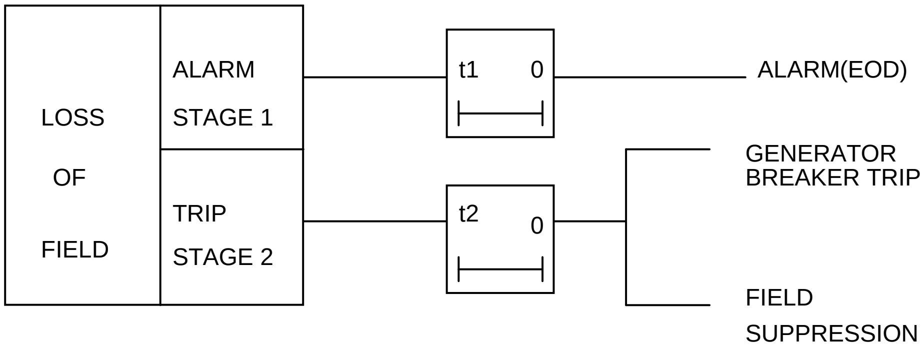


Figure 4.3.11.1 — Loss of field tripping logic

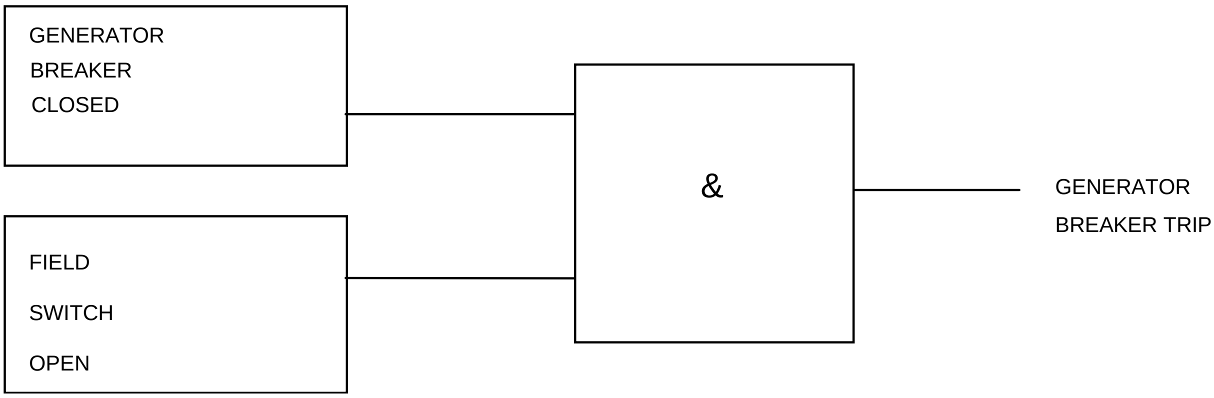


Figure 4.3.11.2 — Generator/field switch trip to prevent loss of field

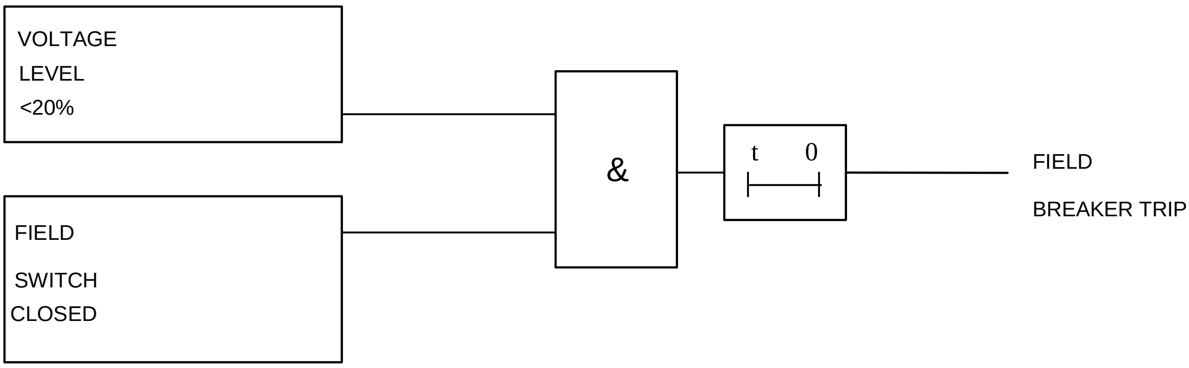


Figure 4.3.11.3 — Initial energization

4.3.12 Back-up impedance protection

An impedance relay with a large reach is used. This operates for phase faults in the unit, in the HV yard or in the adjacent transmission lines, with a suitable delay, for cases when the corresponding main protection fails to operate.

The impedance relay shall have fuse fail interlocking.

The back-up impedance relay trips the HV circuit-breaker first, and if the fault persists after a specific time delay, it initiates a general trip and unit shutdown.

Required settings:

The impedance relay shall be set to marginally exceed a reach up to the HV busbars (110 % of generator transformer impedance).

Timer t1 = 1,5 s (no deviation allowed).
Timer t2 = 2,5 s.

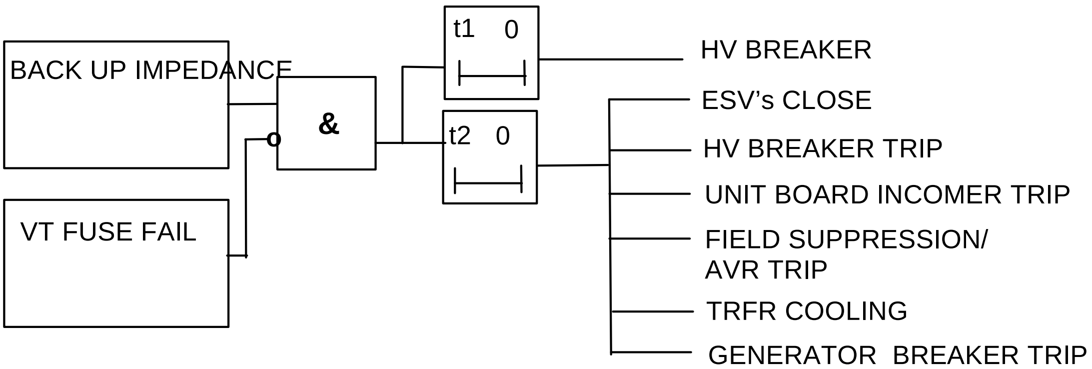


Figure 4.3.12.1 — Back-up impedance tripping logic

4.3.13 Overload relay

This protection function, if provided, shall provide an alarm only.

Figure 4.3.13.1 – Overload protection relay tripping logic

4.3.14 Turbine protection relay (Included in turbine protection equipment)

The turbine protection relay (TPR) monitors the turbine condition and will be operated by any signal which requires a turbine shutdown.

A TPR relay shall be included on the generator protection panel if the relay does not form part of the external turbine protection system.

It provides, at the generator protection panel, a direct distinction between a turbine trip, electrical fault or other tripping sources.

The ESVs shall be closed by the turbine protection and the generator circuit-breaker and field switch shall then be tripped by the reverse power relay (see 4.3.7).

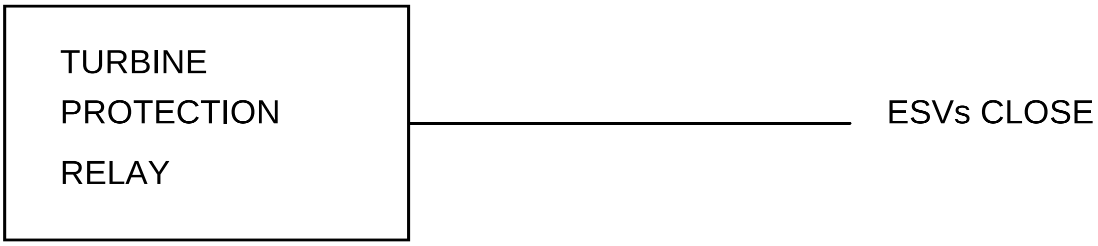


Figure 4.3.14.1 — Turbine protection relay tripping logic

4.3.15 Trip to House Load (TTHL) (unit Islanding)

The Trip to House Load is intended to operate under the following conditions.
More than one unit is exporting power via a common busbar in the HV yard and the station becomes separated from the network. This could occur if the feeder breakers trip.
Upon operation of the TTHL, all generators connected to the common busbar would island and supply their own auxiliaries. This would enable units to be restored faster to the network than if the units had tripped.

The tripping logic is shown in figure 4.3.15.1.

Typical setting:

Undervoltage	=	< 70 %
Under frequency	=	< 47 Hz
Timer t1	=	2 seconds

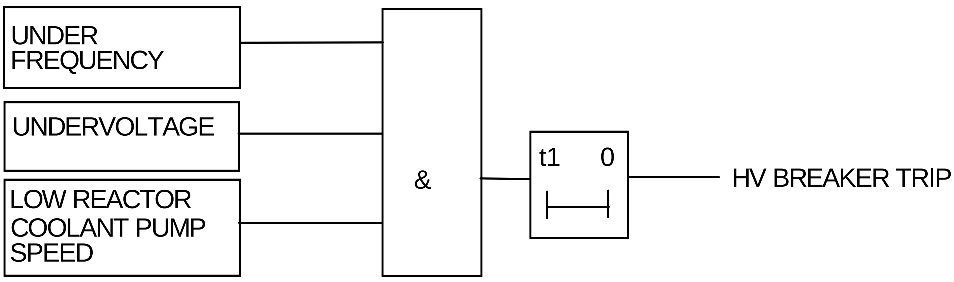


Figure 4.3.15.1 — Trip to house load tripping logic

4.3.16 Undervoltage

This protection is part of the Safeguard Supply Philosophy and needs to be implemented for the sake of Nuclear Safety.

4.3.17 Emergency push-button

4.3.17.1 Turbine trip

For emergency situations, a push-button is provided at the unit operator's desk, for manual tripping of the ESVs. The generator circuit-breaker and field switch shall be tripped by the reverse power relay (see 4.3.7). This push-button is normally used to trip the turbine in the event of a mechanical defect detected by the operator (e.g.: high vibration) and is known as the turbine trip emergency push-button.

4.3.17.2 Electrical trip

At some power stations a second emergency push-button is installed to trip the generator circuit-breaker, field suppression and ESVs close and is known as the generator emergency push-button. This push-button shall only be used in the event of an electrical fault (i.e. excitation or slip rings on fire). It shall never be used for mechanical faults as the turbine will over speed resulting in further stressing of the turbo-alternator shaft line. As the risk exists that the operator might accidentally push the generator emergency push-button instead of the turbine emergency push-button for a mechanical fault, it is recommended that only the turbine push-button is installed. This will mean that when the turbine push-button is pushed for a generator fault, the tripping of the generator will be delayed by 1 s to 2 s (see 4.3.7).

4.3.17.3 HV circuit-breaker trip interlock

Tripping of the HV circuit-breaker shall be interlocked with low forward or reverse power. This will prevent an over speed condition if the turbine control is defective when the HV circuit-breaker is opened.

If the machine is on high load the ESVs shall close and the HV circuit-breaker shall trip when the power drops to the low forward power level.

If the machine is on low load, only the HV circuit-breaker shall trip. The timer t1 shall remain picked-up long enough for the power to drop to the low forward power level.

Typical settings:

Low forward power = 0,1 p.u.
Timer = 2,0 s (DDO).

Figure 4.3.17.1 — Emergency push-button tripping logic

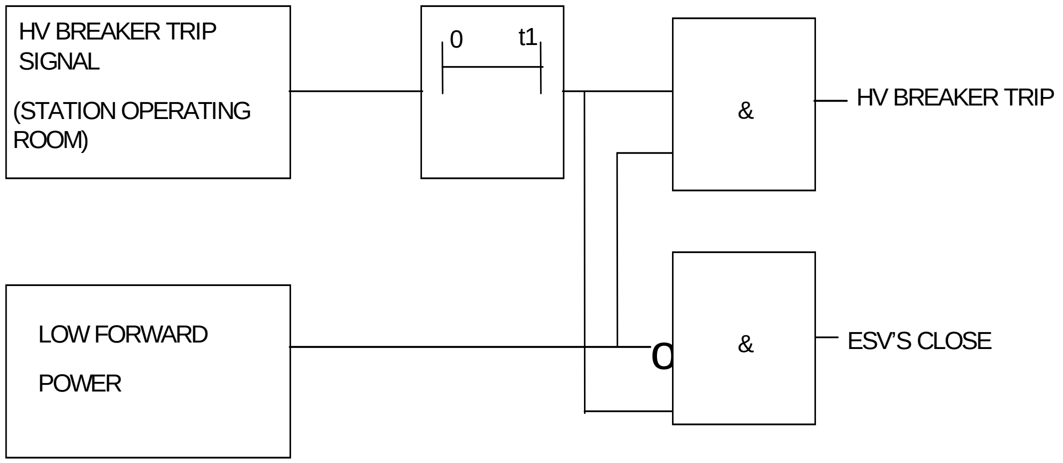


Figure 4.3.17.2 — HV circuit-breaker trip interlock logic

4.4 Generator transformer protection

4.4.1 Generator transformer differential protection

This is a unit type protection, with coverage from the generator terminals up to the HV circuit-breaker and the unit transformer HV terminals.

It shall detect phase faults on both sides of the generator transformer and single-phase-to-earth faults on the HV side only (the earth fault current on the LV side is very small, due to the high neutral earthing resistance).

A fault in the generator transformer differential zone requires a general trip and unit shutdown (see figure 4.4.2.1).

Transformer differential relays have harmonic restraint circuits to prevent incorrect operation when the generator and unit transformers are energized from the system.

The tripping logic is shown in figure 4.4.2.1.

Typical settings:

The setting shall be greater than the tap-change range plus CT errors.
Spill current = 0,2 to 0,5 $\times$ full load current.

4.4.2 Generator transformer HV restricted earth fault protection

This is a unit type protection that operates for earth faults on the generator transformer HV side and also covers a large portion of the HV winding and the HV terminals up to the HV current transformers.

The restricted earth fault relays have harmonic restraint circuits to prevent incorrect operation when the generator and unit transformer are energised from the system.

The restricted earth fault relay initiates a general trip and unit shutdown (see figure 4.4.2.1).

The tripping logic is shown in figure 4.4.2.1.

Typical settings:

The setting shall be greater than the CT errors.
Spill current = 0,1 to 0,4 × full load current.

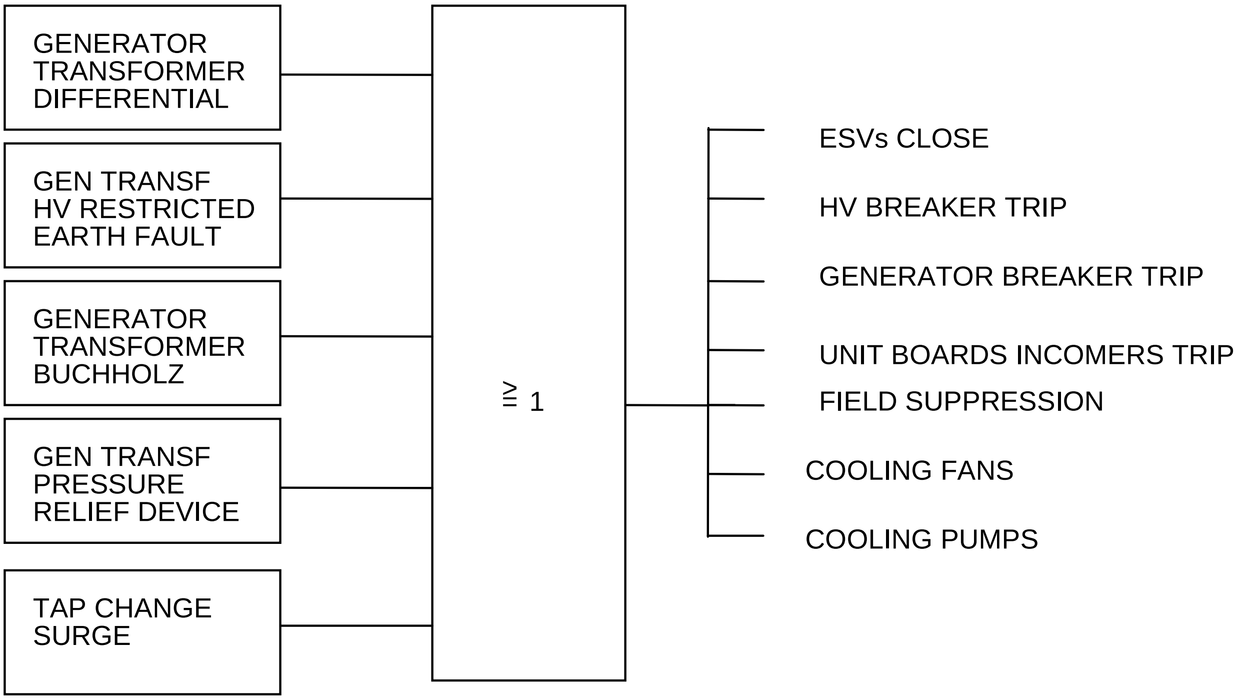


Figure 4.4.2.1 — Part of the generator transformer protection tripping logic

4.4.3 Generator transformer HV back-up earth fault protection

This is an IDMT relay that monitors the current in the generator transformer neutral. It can detect faults in the transformer HV side or in the adjacent network.

The back-up earth fault relay trips the HV circuit-breaker first, and if the fault persists after a specific time delay, it initiates a general trip and unit shutdown.

NOTE — System Operations requested an additional earth fault relay to be installed in the residual circuit of the HV phase CTs to provide fast protection for a fault between the generator transformer and the HV circuit-breaker. However, System Operations would accept that this is not necessary if the generator transformer differential and restricted earth fault relays are supplied by independent DC systems, independent current transformers and trip independent trip coils.

The tripping logic is shown in figure 4.4.3.1.

Required settings:

The IDMT curve shall grade with feeder protection under all conditions.

Timer t1 = 0,5 s grading feeders.

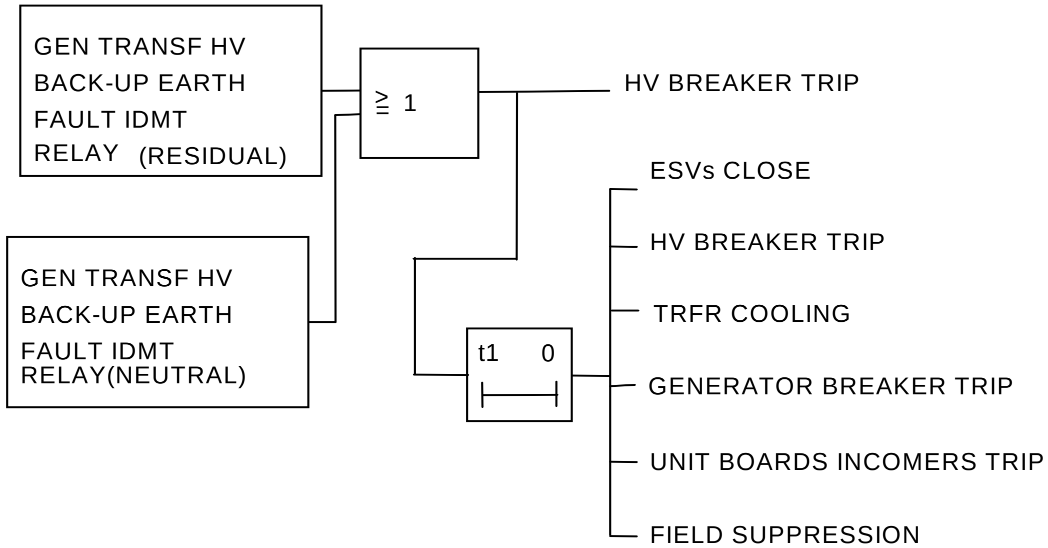


Figure 4.4.3.1 — Generator transformer HV back-up earth fault tripping logic

4.4.4 Generator transformer (and unit transformer) over fluxing protection

This relay shall not be fitted on new installations but if it exists at a station it may remain.

This relay safeguards the generator transformer and the unit transformers against over fluxing, for the following cases:

The generator transformer being "back energized" at a high busbar voltage with the tap-changer on a low tap. This can happen during normal operation or when the power station is islanded, in which case a possible frequency reduction will aggravate the problem. In this case a general trip and unit shutdown is initiated.

During islanded operation of the unit with the transformer supplied from the generator. In this case the generator circuit-breaker and field switch are tripped.

This relay shall preferably be an inverse curve to match the generator transformer capability but a two stage relay is acceptable.

The voltage supply to this relay shall be from the VTs on the transformer side of the generator circuit-breaker.

The tripping logic is shown in figure 4.4.4.1.

Typical settings:

The over fluxing relay shall be set to the capability of the unit transformer or generator transformer, whichever is the lowest.

Over fluxing pick-up *V/f*	=	1,1 p.u.
Timer t1	=	1 s.
Timer t2	=	3s.

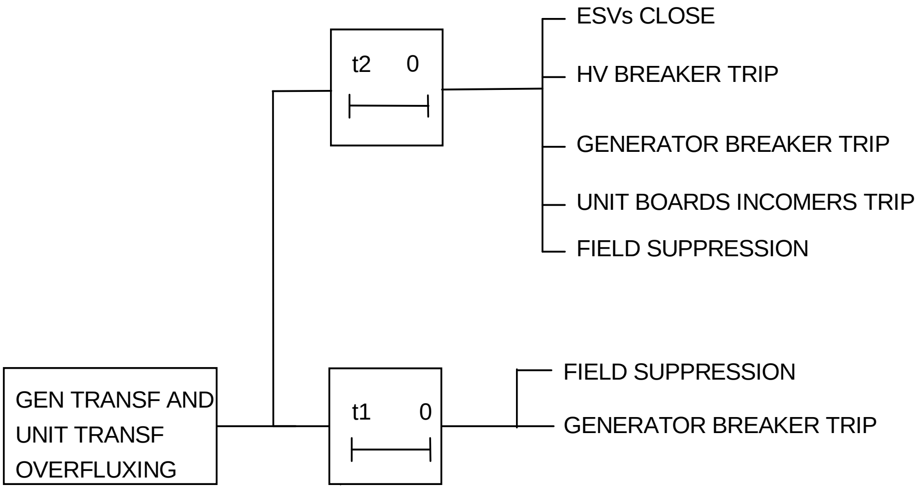


Figure 4.4.4.1 — Generator transformer and unit transformer over fluxing tripping logic

4.4.5 Generator transformer Buchholz protection

The Buchholz relay is a hydraulic device, installed in the pipe line between the transformer tank and the separate oil conservator. It operates on the principle that internal faults in oil immersed transformers are associated with generation of gas and/or a surge of oil.

The relay collects the oil vapour or gas in a vessel, normally full of oil, equipped with a top and bottom float each of which can operate a micro-switch.

A second micro-switch shall be operated by a surge of oil from the transformer tank to the conservator tank.

The sequential displacement of each of the floats, due to the presence of gas, closes suitable contacts leading respectively to an early alarm and/or trip function.

The Buchholz alarm (slow developing fault) initiates an alarm on the usual alarm system.

The Buchholz relay trip initiates a general trip and unit shutdown (see figure 4.4.2.1).

When new transformers are purchased a relay with two independent trip outputs should be specified.

4.4.6 Generator transformer pressure relief device protection

The pressure relief device (PRD) operates on the principle that a severe transformer internal fault gives rise to a sudden over pressure inside the transformer tank, associated with an oil surge.

The PRD is a mechanical device installed on the transformer tank wall, in which a diaphragm is subjected to pressure deformation, operating a trip switch. Special care shall be taken to prevent water ingress which could cause a false trip.

The PRD trip switch initiates a general trip and unit shutdown (see figure 4.4.2.1).

When new transformers are purchased a relay with two independent trip outputs should be specified.

4.4.7 Generator transformer tap-changer over current protection

For on-load tap-change operation, a momentary connection shall be made simultaneously to two adjacent taps during the transition. The short-circuit current between the two taps in the winding is limited by a pair of resistors and the switching operation is done by the tap-change diverter switch.

The over current relay shall be provided to block tap-change operation, during fault conditions. Where the transformer tap change control scheme is equipped with a voltage regulating relay that has this functionality it may be used.

The tripping logic is shown in figure 4.4.7.1.

Typical settings:

Over current pick-up level = 1,5 p.u.

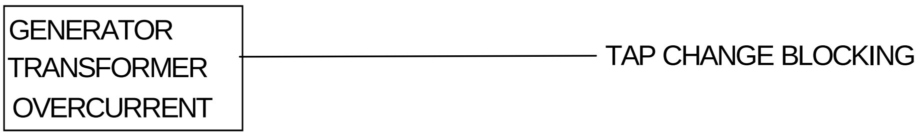


Figure 4.4.7.1 — Generator transformer tap change over current tripping logic

4.4.8 Generator transformer oil and winding temperature protection

Oil temperature and winding temperature monitoring devices are fitted on the generator transformer. Each of these devices is set for three different temperature levels, the lower one for an alarm and the two higher ones for tripping.

High oil or winding temperatures on a transformer can result from an overload condition, exceptional ambient temperatures, core over fluxing or from a failure in the cooling system.

Overloading is not likely to occur in MW loading but may occur in MVAr loading.

For a failure in the cooling system, the time elapsed between the alarm and trip temperatures is sufficient for the operator to take action, typically, reducing load or shutting down to prevent the temperature from reaching a dangerous value and a forced trip.

The desirable tripping functions of the generator transformer oil and winding temperature relays are indicated in figure 4.4.8.1. It is important to note the distinction between:

a) transformers that can operate without forced cooling at reduced load or no-load; and

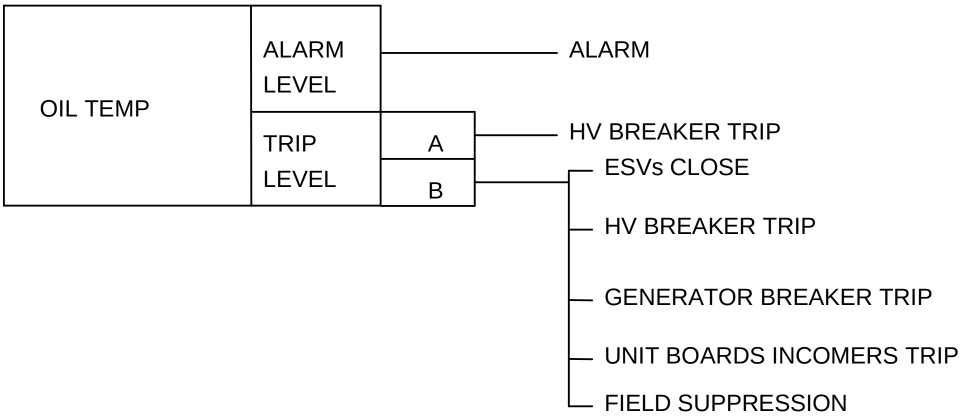
b) transformers that cannot dissipate the core losses without forced cooling.

Typical settings:

Temperature relay settings:

Oil temp alarm level	=	70 to 85 °C.
Oil temp trip A level	=	80 to 95 °C.
Oil temp trip B level	=	100 °C.
Winding temp alarm level	=	95 to 100 °C.
Winding temp trip A level	=	105 to 110 °C.

Winding temp trip B level = 120 ℃.



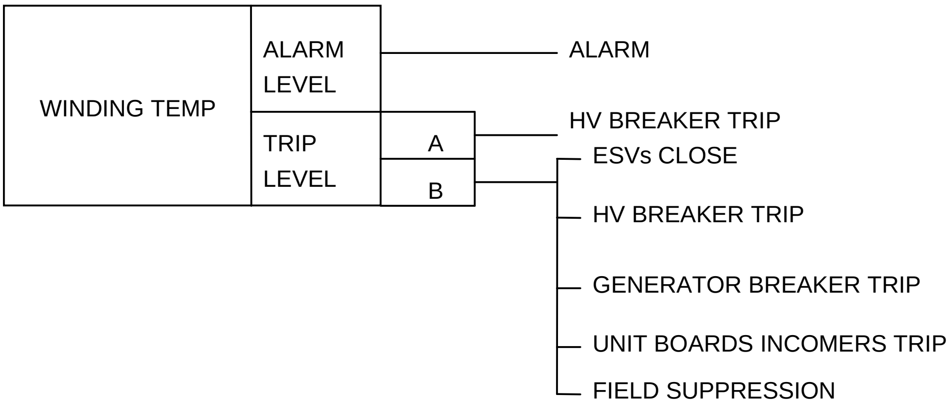


Figure 4.4.8.1 — Generator transformer oil temperature and winding temperature tripping logic

4.4.9 Tap-changer surge protection

The tap-changer is equipped with a pressure device to trip in the event of a high pressure in the tap-change tank. Some tap-changers are not fitted with a Buchholz relay and have pressure relief devices, with similar functions to the device on the generator transformer (see figure 4.4.2.1).

When new transformers are purchased a relay with two independent trip outputs should be used.

4.4.10 Generator transformer cooling supply failure protection

Damage to the transformer core can occur in a very short time if the cooling supply is lost to transformers utilizing the ODAF (Oil direct air forced) cooling method. The OEM's of these transformers supply a de-loading curve indicating the time limits on each loading level for the transformer.

When total cooling supply failure is detected the transformer must be de-loaded to half load, and be removed from service in the OEM specified time if the supply can not be restored.

The desirable tripping functions of the generator transformer cooling supply failure protection are indicated in figure 4.4.10.1.

Typical settings:

Under voltage = <75%.
Under voltage timer (t1)= 3 s.
Timer (t2) = Value set to a value 10% less than the time suggested by the OEM on the de-loading curve.

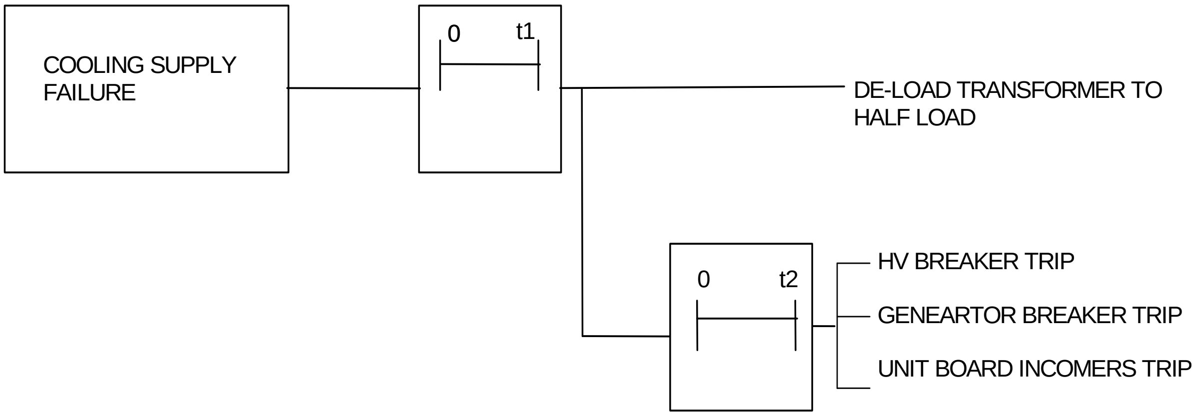


Figure 4.4.10.1 — Generator transformer cooling supply failure

4.4.11 Generator transformer Sergi protection (When applicable)

The so-called "Sergi" protection consists of the following equipment:

i. Conservator shutter valve (sudden flow valve);
ii. Depressurisation set (including rupture disk);
iii. Oil-gasses separation tanks;
iv. Explosion gasses elimination set (nitrogen injection); and
v. Control box.

The main objective of this protection function is to prevent fires, transformer tank rupture, etc. during internal transformer faults.

The principle of operation of this protection function is as follows:

During internal transformer faults high pressure build up takes place in oil immersed transformers. The rupture disk inside the depressurisation sets rupture causing depressurising of the tank. The explosive oil-gas mixture is channelled to the separation tanks. During this time the conservator shutter valve closes, preventing oil flow from the conservator to the transformer. The rupture disk monitoring devices are activated which can be used for tripping of the transformer or automatic nitrogen injection.

The Sergi protection function initiates a general trip and unit shutdown (see figure 4.4.2.1).

The depressurisation sets rupture disk must be equipped with two non-fail safe relays with at least two normally open dry contacts per relay.

4.5 Unit transformer protection

4.5.1 Unit transformer differential protection

This is a unit type protection covering the unit transformer and the cable connection to the unit board.

This protection operates for phase faults, but not for single-phase-to-earth faults as this current is limited by the neutral earthing resistance.

The unit transformer differential relay initiates a general trip and unit shutdown (see figure 4.5.1.1).

Typical settings:

The setting shall be greater than the tap-change range plus CT errors.
Spill current = 0,2 to 0,5 × full load current.

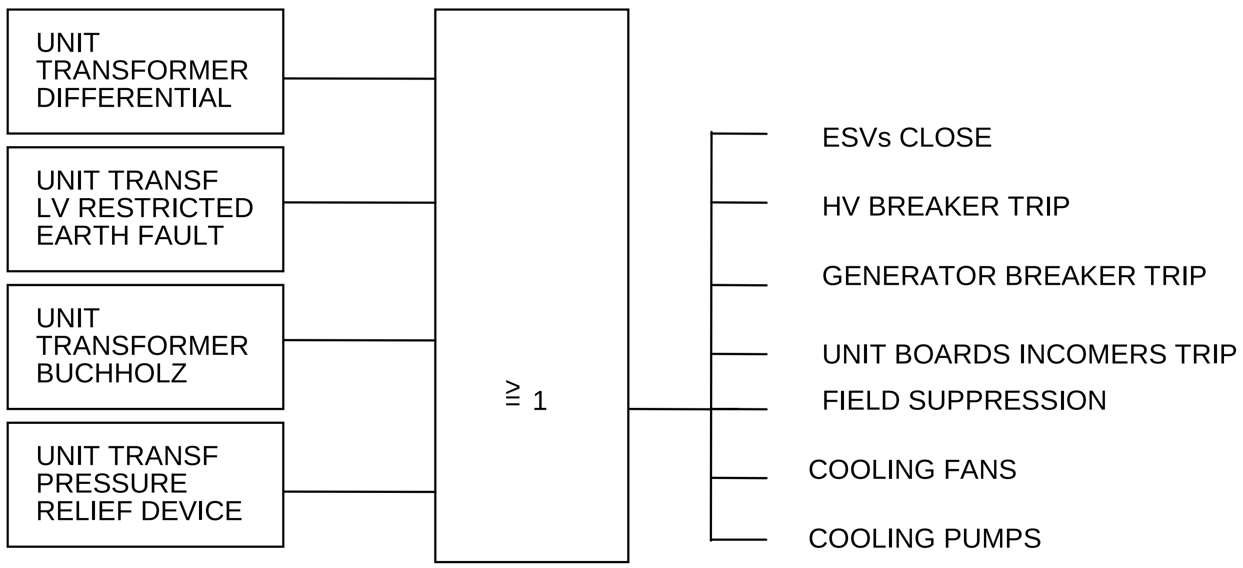


Figure 4.5.1.1 — Part of the unit transformer protection tripping logic

4.5.2 Unit transformer HV earth fault protection

For single-phase-to-earth faults in the generator stator or elsewhere between the generator, the generator transformer and the unit transformers, currents will circulate in the generator earthing transformer and in the unit transformer HV side neutrals.

As earth faults in the generator stator can be isolated by opening the generator circuit-breaker (see 4.3.2), the tripping functions of the earth fault relay in the unit transformer HV neutral shall be time delayed to operate after the generator stator earth fault relay.

Thus, for an earth fault in the transformer area, the stator earth fault protection shall operate first, and amongst other functions, it shall trip the generator circuit-breaker. If the fault persists for a specific time after this, the unit transformer HV earth fault relay shall initiate a general trip and unit shutdown.

This is a voltage relay, monitoring the voltage developed across the earthing resistor by the neutral return current.

Care shall be taken to ensure that the neutral earthing transformer and its associated resistor are adequately rated for the fault current and its clearing time.

Typical settings:

Voltage pick-up level = 2 V to 10 V.
Timer t1 = 5 s.

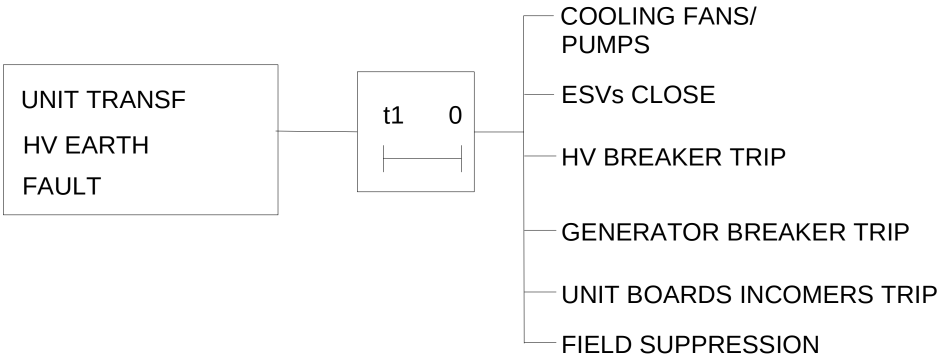


Figure 4.5.2.1 — Unit transformer HV earth fault tripping logic

Alternative protection application:

For instances where the unit transformers HV neutral connections are not available or where an open delta configuration is available on the generator VT (i.e. three single phase or five limb) on the transformer side, a zero sequence voltage measuring relay can be used to detect an earth fault. A resistor needs to be installed across the open delta to minimise the so called "neutral inversion" phenomenon.

Typical settings:

Voltage pick-up level = 20% of phase voltage.
Timer t1 = 5 s.

4.5.3 Unit transformer HV over current protection

This is an IDMT relay that operates for phase faults in the unit transformer or, as a back-up for faults in the unit board system.

The relay tripping logic is indicated in figure 4.5.3.1. The fault is initially assumed to be in the unit board system and the incoming circuit-breaker is tripped. If the over current condition persists after a specific time, a general trip and unit shutdown is initiated.

Typical settings:

The setting of this relay is integrated with the unit board protection.
IDMT pick up = 2 p.u.

Instantaneous = 10 p.u.
Timer = 1 s.

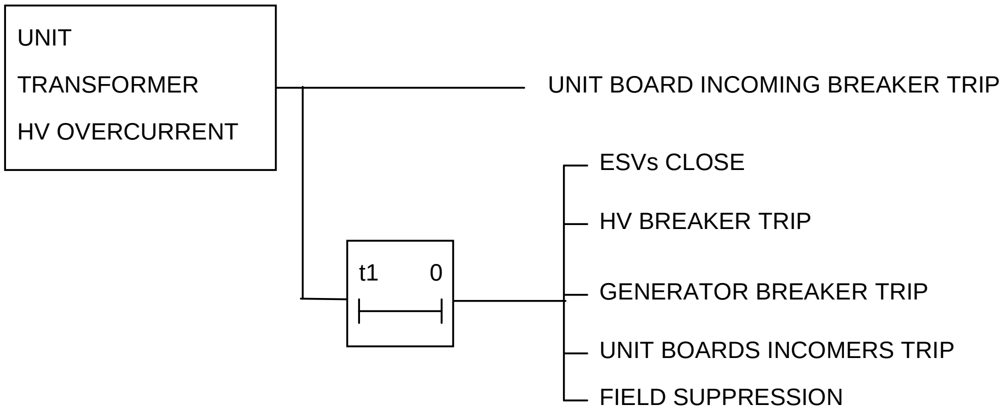


Figure 4.5.3.1 — Unit transformer HV over current tripping logic

4.5.4 Unit transformer restricted earth fault

This is a unit type protection that operates for earth faults on the unit transformer LV side and also covers a large portion of the LV winding and the LV terminals up to the LV current transformers.

The restricted earth fault relay initiates a general trip and unit shutdown. The restricted earth fault relay initiates a general trip and unit shutdown. The tripping logic is shown in figure 4.5.1.1.

Typical settings:

The setting shall be greater than the CT errors.

Spill current = 0,1 to 0,4 × full load current.

4.5.5 Unit transformer LV back-up earth fault protection

This is an instantaneous over current relay, monitoring the unit transformer LV neutral current.

It is the main earth fault protection in the event of a shorted earthing resistor.

The relay tripping logic is indicated in figure 4.5.5.1.

Typical settings:

Over current shall be set between 400 A and 800 A primary.

Figure 8.5.1 —Unit transformer LV back-up earth fault tripping logic

4.5.6 Unit transformer LV sensitive earth fault protection

This is the main earth fault protection for the unit board busbars.

It is graded with the sensitive earth fault protection in the unit board outgoing cables on a time basis and has the tripping functions shown in figure 4.5.6.1.

Typical settings:

This relay is usually set to operate for earth fault currents higher than 80 A.
Timer t1 = 3,5 s.
Timer t2 = 5,0 s.

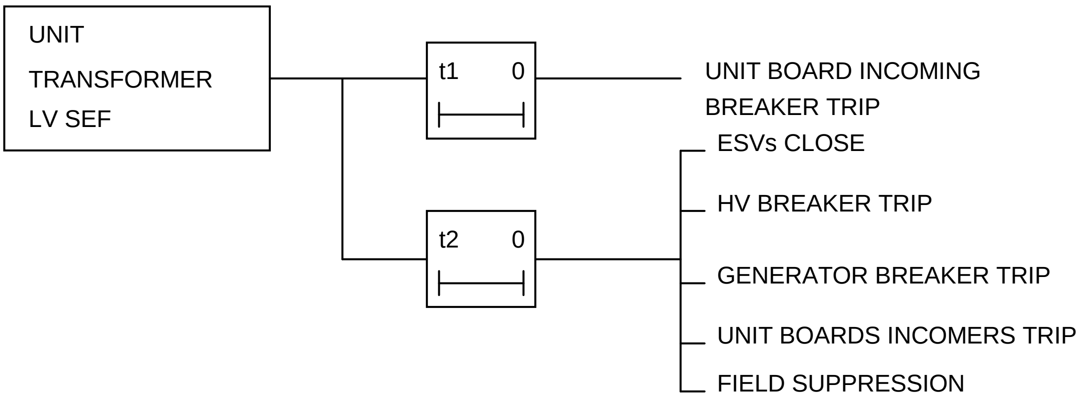


Figure 8.6.1 —Unit transformer SEF tripping logic

4.5.7 Unit transformer Buchholz protection

This protection is similar to the generator transformer Buchholz protection (see figure 4.5.1.1).

4.5.8 Unit transformer pressure relief device protection

This protection is similar to that for the generator transformer PRD (see figure 4.5.1.1).

4.5.9 Unit transformer oil and winding temperature protection

Oil temperature and winding temperature monitoring devices are fitted to the unit transformers. Each of these devices is set for three different temperature levels, the lower one for an alarm and the two higher ones for tripping.

High oil or winding temperatures on a transformer can result from an overload condition, exceptional ambient temperatures, core over fluxing or from a failure in the cooling system.

Overloading is not likely to occur.

For a failure in the cooling system, the time elapsed between the alarm and trip temperatures is sufficient for the operator to take action, typically reducing load to prevent the temperature reaching a dangerous level and a forced trip.

The desirable tripping functions of the unit transformer oil and winding temperature relays are indicated in figure 4.5.9.1. It is important to note the distinction between:

a) transformers that can operate without forced cooling at reduced load or no-load, and

b) transformers which cannot dissipate the core losses without forced cooling.

Typical settings:

Temperature relay settings:

Oil temp alarm level	=	85 °C.
Oil temp trip A level	=	95 °C.
Oil temp trip B level	=	100 °C.
Winding temp alarm level	=	100 °C.
Winding temp trip A level	=	110 °C.
Winding temp trip B level	=	120 °C.

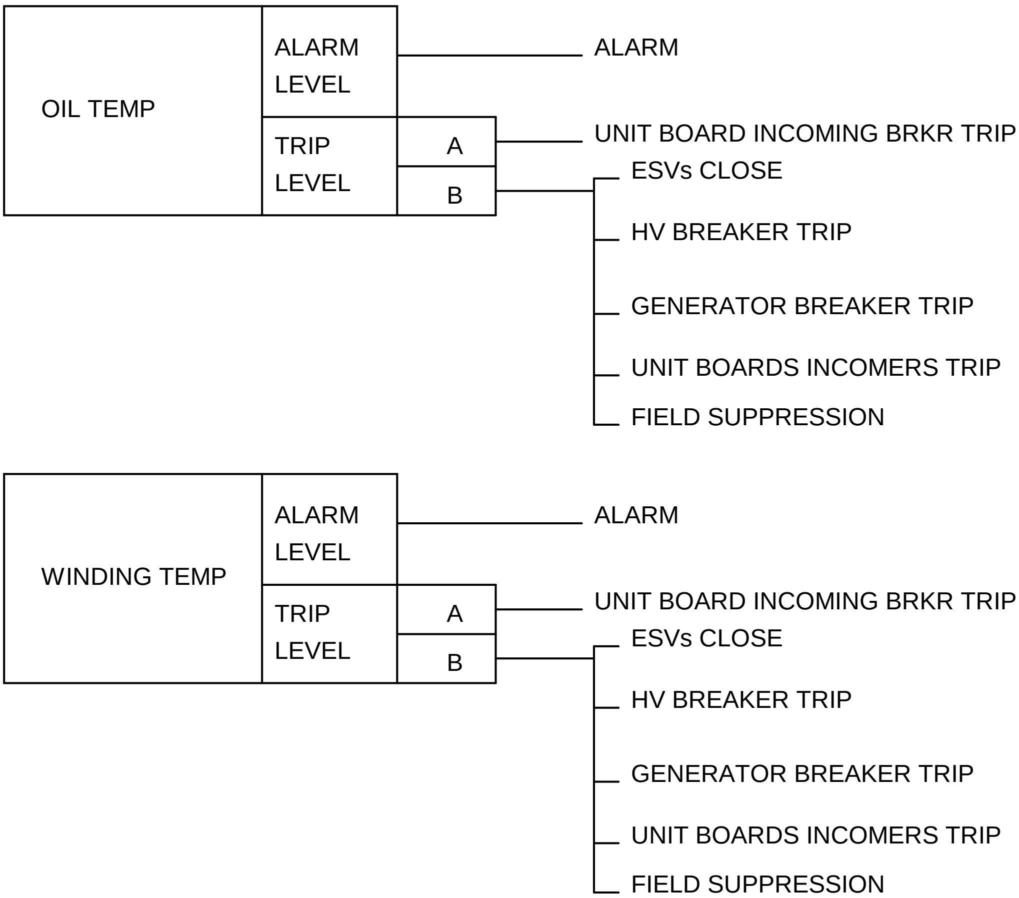


Figure 4.5.9.1 — Unit transformer oil temperature and winding temperature tripping

logic

4.6 HV yard bus zone protection

For the particular case of a fault between the bus zone CT and the HV circuit-breaker, a general trip and unit shutdown is initiated after a specific time delay (120 ms to 200 ms).

As shown in the logic diagram (figure 4.6.1), the fault clearance is monitored by the HV “breaker fail” over current relay.

Typical settings:

Over current relay pick-up level = 0,2 × I_n.
Timer t1 = 0,12 to 0,2 s.

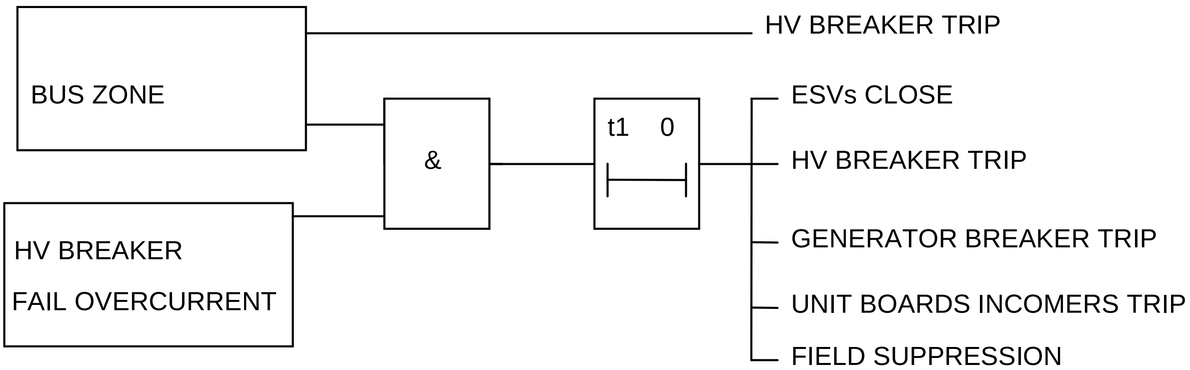


Figure 4.6.1 — HV yard bus zone tripping logic

4.7 “Breaker fail” protection

The “breaker fail” protection monitors the circuit-breaker's operation for protection trip signals, i.e. fault conditions. If a circuit-breaker fails to open and the fault is still present after a specific time delay (120 ms), it trips the necessary adjacent circuit-breakers.

4.7.1 Generator “breaker fail” protection

This protection operates according to the logic shown in figure 4.7.1.1. The generator circuit-breaker state is monitored by a current measurement and from circuit-breaker auxiliary contacts (for fault conditions not associated with significant current).

Typical settings:

Over current relay pick-up level = 0,1 × I_n.
Timer t1 = 0,12 s to 0,25 s.
(The operating time of the circuit-breaker shall be considered when determining these settings)

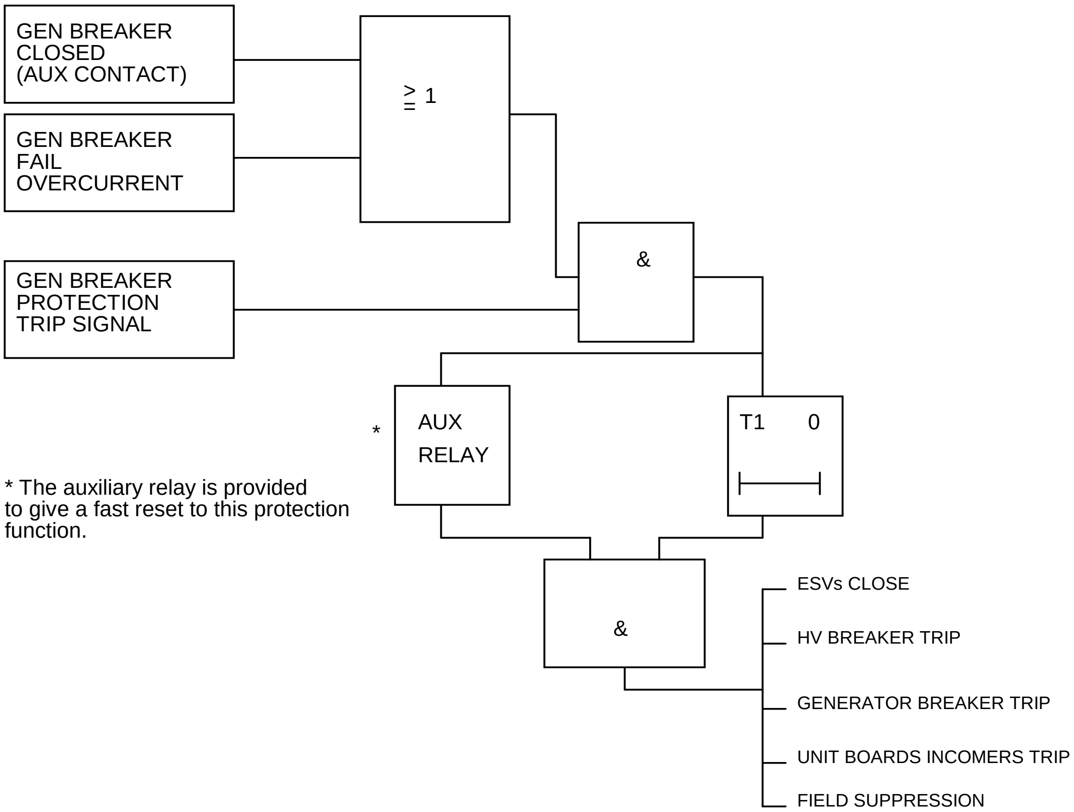


Figure 4.7.1.1 —Generator breaker fail tripping logic

4.7.2 HV “breaker fail” protection

This protection shall follow the logic indicated in figure 4.7.2.1, tripping the adjacent bus sections (or bus section and bus coupler) and the outgoing feeder circuit-breaker, in the HV yard.

The HV circuit-breaker state is monitored by a current measurement, and from circuit-breaker auxiliary contacts (for faults not associated with significant current).

Care should be taken that a breaker fail initiate signal may be require on certain of the HV bus zone schemes employed by Eskom Transmission (fig 4.7.2.1b)

Typical settings:

Over current relay pick-up level = $0,4 \times I_n$.
Timer t1 = 0,12 s to 0,25 s.

(The operating time of the circuit-breaker shall be considered when determining these settings).

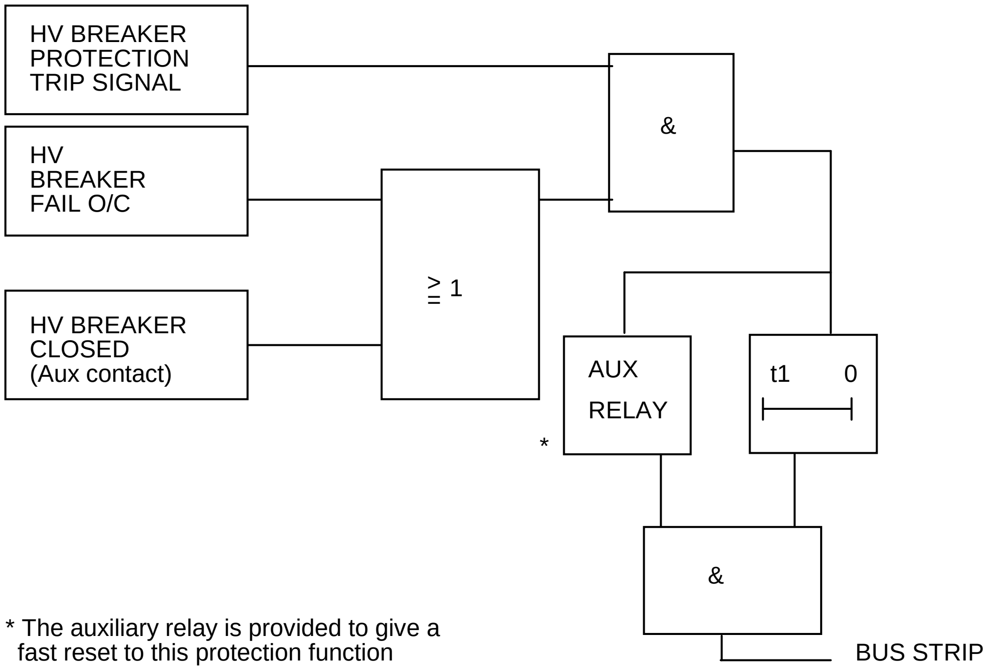
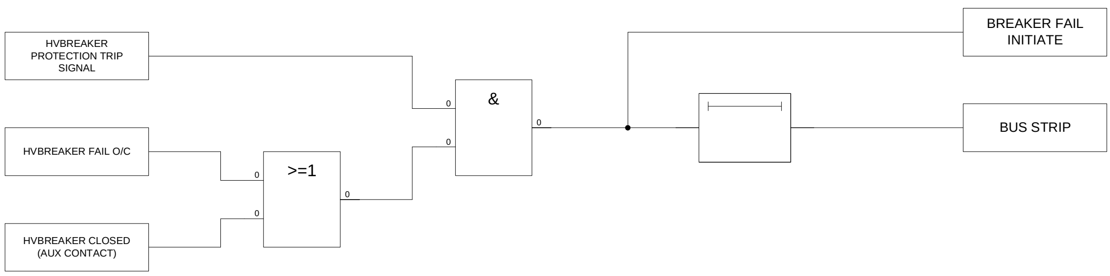


Figure 4.7.2.1a — HV circuit- breaker tripping logic



Where required by the HV bus zone (eg Siemens 7SS50) protection, the breaker fail initiate signal should be provided

Figure 4.7.2.1b — HV circuit- breaker fail initiate tripping logic

4.8 Pole disagreement protection

The pole disagreement protection covers the cases where one or two poles of a circuit-breaker fails to operate after a trip or close signal.

As the pole disagreement could have resulted from a closing operation, the circuit-breaker is tripped first.

If the condition persists, a general trip and unit shutdown is initiated after a specific time.

4.8.1 Generator circuit-breaker pole disagreement protection

This protection follows the logic indicated in figure 4.8.1.1.

Typical settings:

Refer to circuit-breaker operating times to determine these settings.

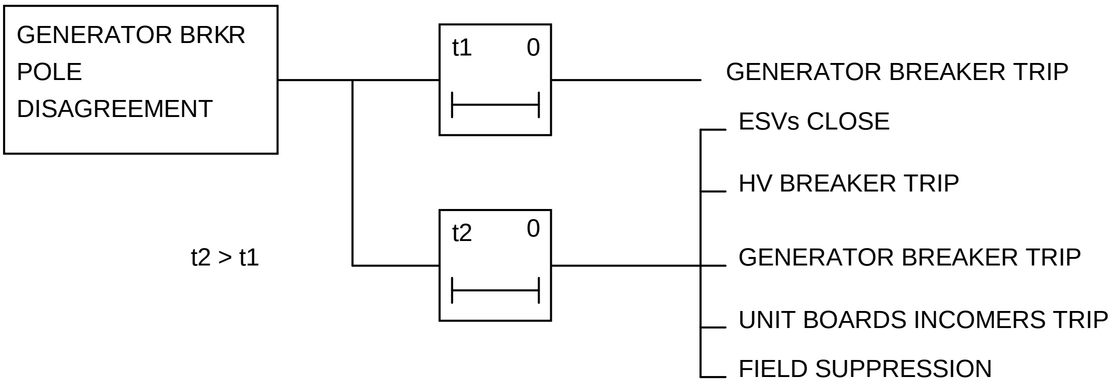


Figure 4.8.1.1 — Generator circuit-breaker pole disagreement tripping logic

4.8.2 HV circuit-breaker pole disagreement protection

This protection follows the logic indicated in figure 4.8.2.1.

Typical settings:

Refer to circuit-breaker operating times to determine these settings.

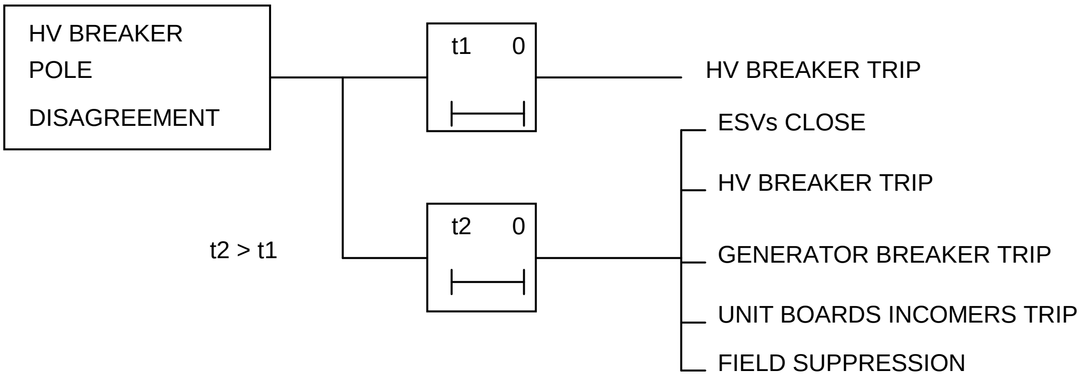


Figure 4.8.2.1 — HV circuit-breaker pole disagreement tripping logic

4.9 Generator Switch onto Standstill protection

This protection shall be installed in the generator protection panels. The DC supply utilised for this protection, must be the same as used for the circuit-breaker closing circuit.

4.9.1 Generator "Switch Onto Standstill" (SOS)

This protection safeguards the generator against an unintended connection to the HV network (back energisation) when at standstill or at low speed.

This Item has been revised significantly as a result of a study done by PTM following a switch onto standstill incident at Majuba power station. For details refer to PTM report 42F3B24i.

This protection consists of current interlocked with voltage. The protection sets (arms) itself when the generator voltage is less than 0.3 p.u. The protection resets (disarms) when the generator voltage is greater than 0.8 p.u.

Fuse fail blocking shall be installed to prevent operation should a fuse rupture when the generator is on load.

The tripping logic is shown in figure 4.9.1.1.

Typical settings:

Current	=	1,2 p.u.
Voltage set	=	0,3 p.u.
Voltage reset	=	0,8 p.u.
Timer t1	=	5.0 s.
Timer t2	=	0,5 s.

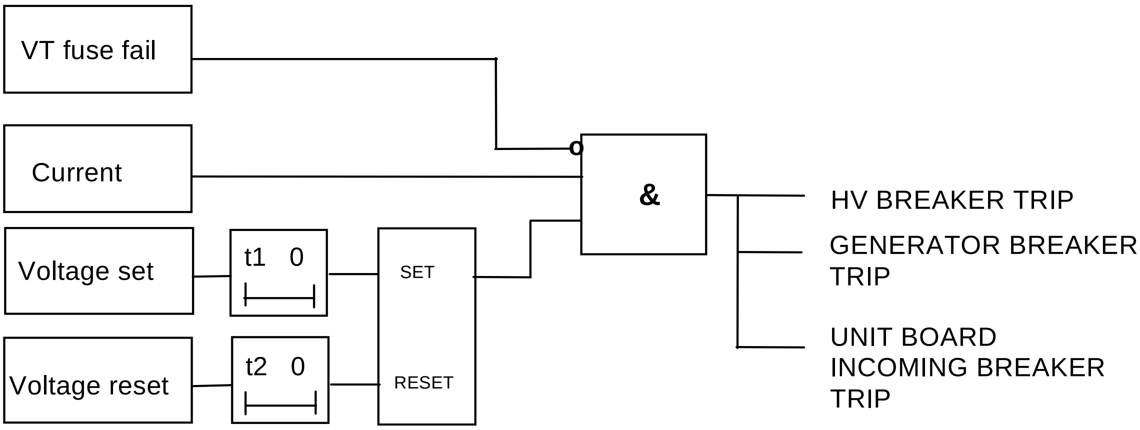


Figure 4.9.1. — SOS tripping logic

4.10 Link/Pantograph pole disagreement

This alarm function covers the case where one or two poles of the link fails to operate after a "close" or "open" command. Settings shall be derived from the link operating speed.

Typical settings:

Refer to link operating time to determine these settings.

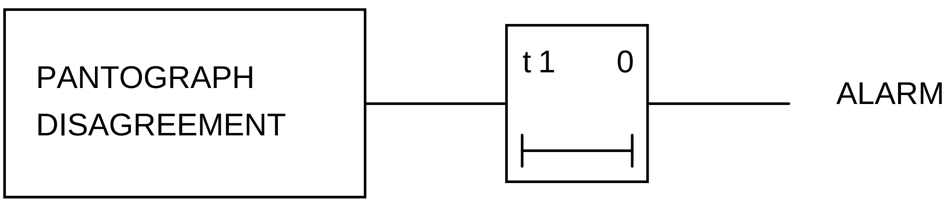


Figure 4.10.1 — Pantograph pole disagreement tripping logic

4.11 Earthing transformer and resistor protection

Earthing transformer and earthing resistor oil temperature monitoring devices are fitted to the earthing transformers and resistors if applicable.

Each device is set for two different temperature levels, the lower level for an alarm and the higher level for tripping.

The desirable tripping functions of the earthing transformer and earthing resistor oil temperature devices are shown in figure 4.11.1.

Typical settings:

Temperature settings:

Oil temperature alarm level	=	85 ℃.
Oil temperature trip level	=	95 ℃.
Oil temperature 2 trip level	=	100 ℃.

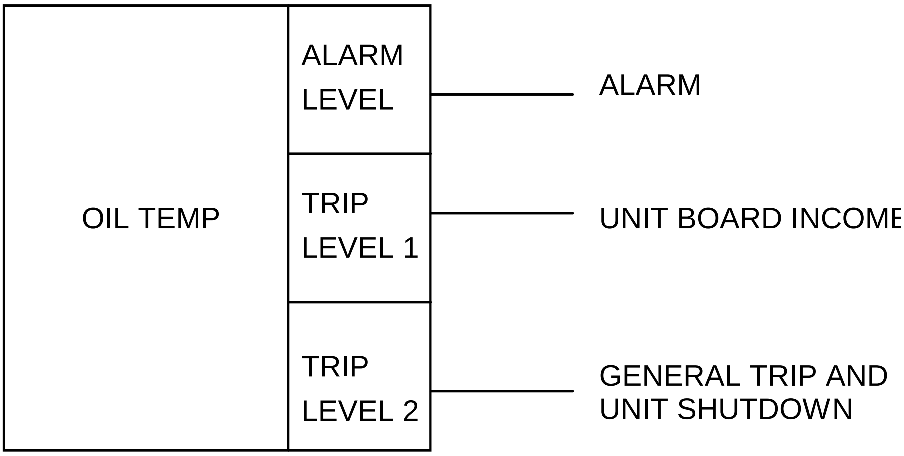


Figure 4.11.1 — Earthing transformer and earthing resistor oil temperature tripping logic

4.12 Remote Back-up protection

This protection shall be installed in the HV Yard substation. **Note:** This protection panel shall only be active when both Main 1 and 2 of the generator protection panels are disabled/switch-off. The DC supplies in the HV Yard shall be used for these protection functions and tripping of breakers. This panel should be the asset of Eskom Generation or Eskom Generation should maintain this panel.

4.12.1 Generator "Switch Onto Standstill" (SOS)

This protection safeguards the generator against an unintended connection to the HV network (back energisation) when at standstill or at low speed.

This protection consists of current interlocked with DLD ("Dead line detection" – dead transformer detection). The protection sets (arms) itself when the generator voltage is less than 0.2 p.u and the current less than 0.05 p.u. The protection resets (disarms) when the generator voltage is greater than 0.2 p.u.

Fuse fail blocking shall be installed to prevent operation should a fuse rupture when the generator is on load.

The tripping logic is shown in figure 4.12.1.1.

Typical settings:

Current = 1,5 p.u.
Voltage (DLD) = <0,2 pu
Current (DLD) = <0,05 p.u.

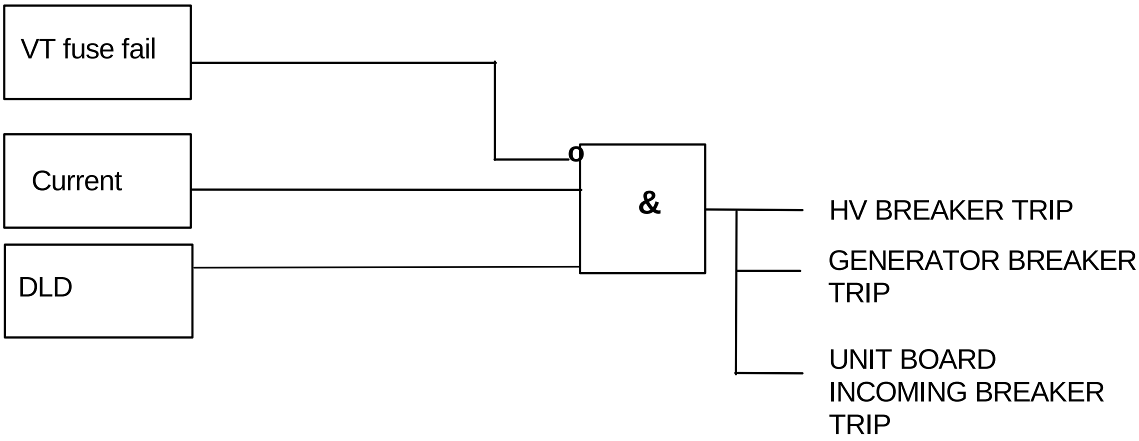


Figure 4.12.1.1 — SOS tripping logic

4.12.2 Impedance protection

This protection function is used during safe rundown of the specific unit in question during failure of all other generator protection functions whilst in service.

The impedance measurement will be done from the voltage and current transformers situated at the generator terminals. VT fuse fail protection must be used for this function.

Typical settings:

The impedance relay shall be set with a forward reach equal to the generator impedance and a reverse reach equal to the generator transformer impedance if the generator VT is at the center of the impedance locus.

Timer t1 = 0,5 s

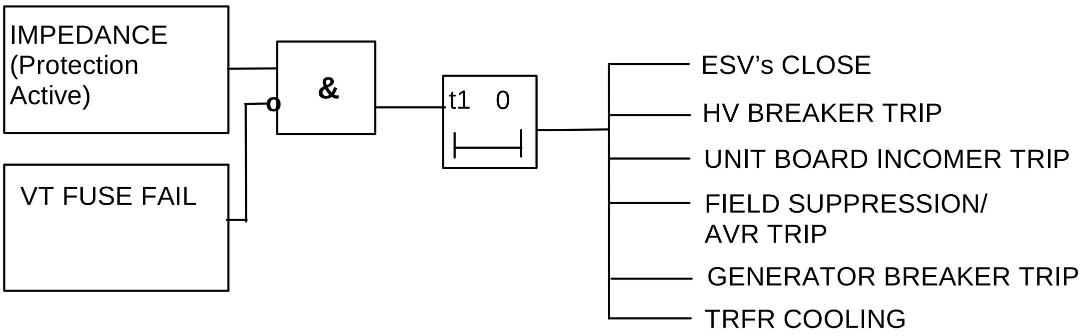


Figure 15.2.1 — Impedance (Remote) tripping logic

4.12.3 HV "breaker fail" protection

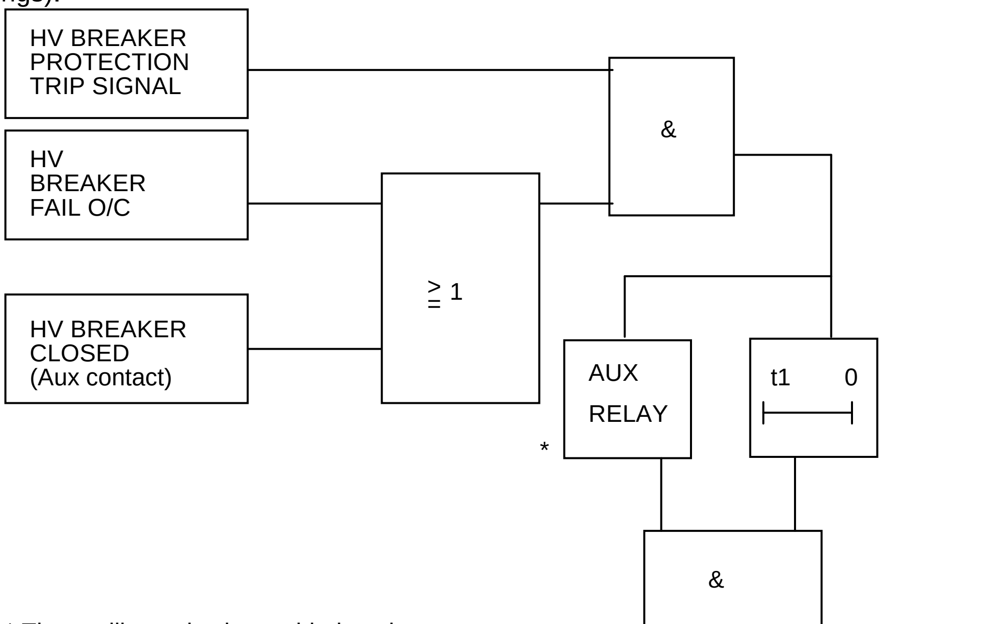
This protection shall follow the logic indicated in figure 4.12.3.1, tripping the adjacent bus sections (or bus section and bus coupler) and the outgoing feeder circuit breaker, in the HV yard.

The HV circuit-breaker state is monitored by a current measurement, and/or from circuit-breaker auxiliary contacts (for faults not associated with significant current).

Typical settings:

Over current relay pick-up level = $0,4 \times I_n$.
Timer t1 = 0,12 s to 0,25 s.

(The operating time of the circuit breaker shall be considered when determining these settings).



* The auxiliary relay is provided to give a fast reset to this protection function

Figure 4.12.2.1 — HV circuit- breaker tripping logic

4.13 Synchronising

The method of connecting a generator to live bus bars is called synchronising. The following conditions must be met before the generator breaker can be closed:

- The voltage frequency of the incoming generator to equal the running system frequency.
- The voltage magnitude of the incoming generator to equal that of the running system.
- The angular difference between the voltage vector of the incoming generator and the running system to be smaller than 5˚.
- The phase rotation of incoming generator and the running system to be in the same direction.

The process of obtaining the above conditions is performed automatically by a synchroniser relay. The synchroniser relay not only senses when the correct conditions have been met but also produce correction signals to operate devices in the speed and voltage regulating systems of the generator.

The close pulse from the synchroniser relay to the breaker is send in advance when compared with ideal synchronising conditions. The synchroniser relay will calculate the time before ideal synchronising requirements are going to be fulfilled. The breaker closing time is then used to determine how long in advance the closing pulse should be initiated.

The synchroniser relay must be designed as a two-channel circuit with monitoring functions between the two channels. A close signal, to the breaker selected for synchronisation, is only issued by the relay if both channels give permission for synchronisation. The monitoring function between the two channels will block the output functions of the relay when it detects a fault in any one of the channels.

The installed synchroniser relay must be equipped with a recording function, which shall be activated with every synchronisation. The recording function will include all three phase analogueue voltage values and closing pulse activation.

Two synchroniser relays shall be installed per unit utilising three phases or with equal functionality as a three phase synchroniser.

TYPICAL SETTINGS

- ∆ f/Hz (Slip) = 0,1Hz
- Maximum difference in voltage magnitude = <5% of nominal (Preferable =<2V)
- Maximum difference in voltage phase angle = ±5˚ (Preferable < ±2,5˚)

5 Records

N/A

6 Annexes

N/A