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Develop Protection System for Stem Turbines Generators using Multifunction Relays in Zawia Oil Refining Company (ARC)

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Abstract

Digital technology has evolved, giving rise to the development of multifunction relays that provide several protection functions simultaneously, in addition to performing control, measurement, and communications functions. For these reasons, multifunction relay applications go beyond traditional protection and solve specific protection and control problems. These devices can be used extensively in Generators which, in general, lack bus differential protection, breaker-failure backup, and automatic transformer restoration systems as well as for loss-of-coordination conditions caused by simultaneous faults. These limitations of traditional protection and control schemes impact power system restoration time and deteriorate primary equipment lifetime. The purpose of this paper is to describe problems found in Generator's systems that lack the schemes mentioned above, and to recommend solutions based on the application of multifunction relays and protection logic processors.

INTRODUCTION

Electric power supply reliability in a distribution system is measured as the availability of electric power to the customers. To improve this availability, it is important to take the following factors into account:

1. Normal operation of the distribution system: service interruptions must be minimized.
2. Fault prevention: distribution systems must be designed to minimize faults. This requires an adequate tradeoff between cost and reliability.
3. Reduction of the negative consequences of faults: protection must be adequate to minimize equipment damage and the number of circuits that lose service as a result of faults.

In designing Generator's protection, control, and metering systems, we need to deal with conflicts between the reliability requirements mentioned above. A limiting factor is technology: old relay designs had limited control and communications capabilities; often, modern multifunction relays are applied following traditional philosophies, which results in not using the relays to their full potential. For example, it is still common today to find operation and control philosophies that prioritize service continuity over primary equipment wear.

The application of multifunction relays in distribution protection, control, and metering systems provides better Protective Relays Protection relay is a device which by means of measuring power system quantities (currents and voltages) and processing them through its internal logic, has the capacity to control the operation of a circuit breaker. The internal logic allows the relay to initiate a tripping sequence when anomalous conditions arise within the power system.

With regard to their construction three types of relays can be distinguished: electromechanical, static and digital. In electromechanical relays, the actuating force is created by electromagnetic interaction. Static relays are based on analogue electronic components such as diodes, transistors, capacitors, etc. whereas numerical relays have their logic implemented in software and microprocessor technology. Some relay designs combine the static and digital technology. This paper concentrates on the analysis of digital relay

A. Digital Relays

A digital relay consists of the following main parts: processor, analogue input system, digital output system and independent power supply [1]. Figure 1 presents a simplified block diagram of a digital relay.

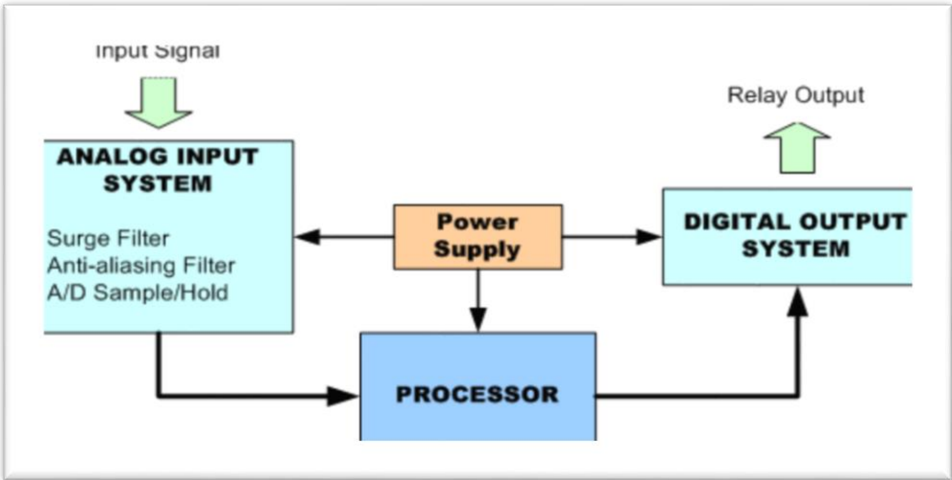


Fig. 1. Block diagram of a digital relay

The generators start withdraw reactive power from the system in the event of loss of filed. The event will be detected by the revers power relay which trip the Circuit Breaker. This event is designed using ETAP transient stability analysis by loss of excitation event.

• In reverse power event the direction of the active power reverses. The reverse power relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating loss of excitation for transient stability analysis

• The generator frequency drops when the system is overloaded. Relay measures the frequency of voltage signal given through VT. Under frequency relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating Under Frequency for transient stability analysis.

• Over Frequency event appears when the load is lost or when the generation excessed the load. Relay measures the frequency of voltage signal given through VT, over frequency relay trip the Circuit Breaker when the frequency of the system rises above the set value. This event was implemented using ETAP by activating Over Frequency for transient stability analysis.

• Over fluxing event appears when disconnecting a high load. If the percentage V/F increased above the set value, the over fluxing relay trips the Circuit Breaker. This event was implemented using ETAP by activating Over Fluxing event for transient stability analysis.

• Overvoltage event appears when the load is suddenly lost. Relay measures the voltages through VT, over voltage relay trip the Circuit Breaker when the voltage of the system rises above the set value. This event was implemented using ETAP by activating over voltage for transient stability analysis.

• Under voltage event occurs when the system is overloaded, so, the generator delivers larger current and the voltage of the system drops. Under voltage relay operates when the voltage of the system goes below the set value. This event is designed using ETAP transient stability analysis by adding a high load.

METHODOLOGY

It is imperative need to install some protective system to protect the expensive elements of modern power system such as generators, transformers, station bus-bar, and transmission lines etc. from different types of faults witch are likely to occur sooner or later. In generating station as a continuous operation of generators is much more necessary so the fault part has to be cleared very quickly for uninterruptable power supply. Unlike other apparatus, opening a breaker to isolate the faulty generator is not sufficient to prevent further damage. The basic electrical quantities those are likely to change during abnormal fault conditions are current, voltage, phase angle and frequency. Protective elements utilize one or more of these quantities to detect abnormal conditions in a power system for taking further essential steps to isolate the faulty equipment to keep the healthy part in normal working condition.

A modern generating unit is a complex system comprising the generator stator winding, associated transformer and unit transformer that shown in figure 10 (if present), the rotor with its field winding and excitation system, and the prime mover with its associated auxiliaries. Faults of many kinds can occur within this system for which diverse forms of electrical and mechanical protection are required. The amount of protection applied will be governed by economic considerations, taking into account the value of the machine, and the value of its output to the plant owner.

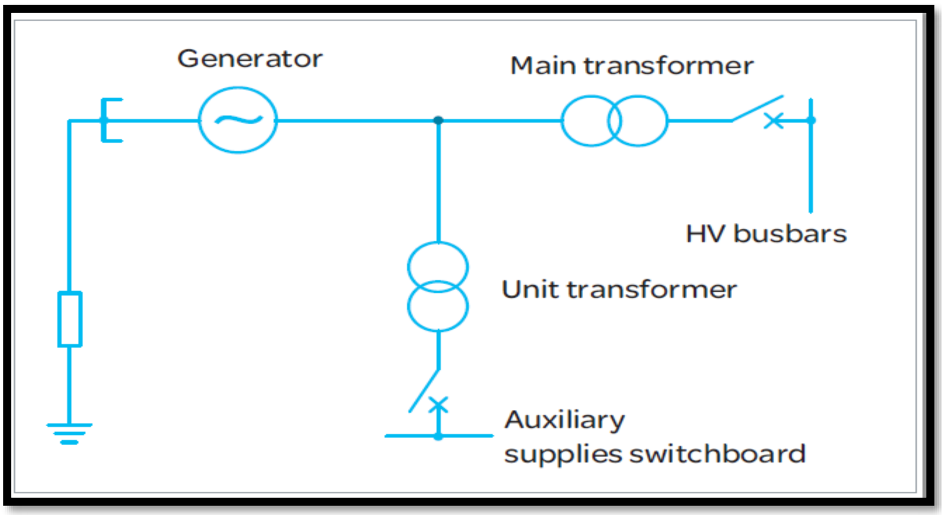


Figure.1. Generator-Transformer Unit

Introduction of Zawia Oil Refining Company (ARC) **Power Plant**

(ARC) power plant adopts QF-60-2 type turbo-generator manufactured by Shanghai Turbo-Generator Co., Ltd. With the rated voltage of 11kV, the generator is driven by direct-coupled steam turbine, and is cooled by the enclosed circulating cooling air. The generator is of brushless excitation (by coaxial brushless exciter and permanent magnetism pilot exciter). The voltage of generator is adjusted by WLZ-4DW micro-computer type automatic exciting regulator produced by the Hebei Industry University Electrical Factory in China. From the view of steam turbine, the rotating direction of the QF-60-2, 60MW synchronous generator is in clockwise rotation.

Specifications of QF-60-2 Type Turbo-Generator for (ARC) **Power Plant**

Generator rating: 60MW, 50HZ, 70.6MVA, 11KV, 370A, 0.85 PF, X′d =18%, Xd=166%, Xe=10.7%, CT (5000/1 A) , VT(11/0.11 KV) Type of generator (QF-60-2)

Generator protection scheme

In the following sections, we consider some prominent abnormal operating conditions shown in figure 11 that need to be carefully considered while providing protection to the generator.

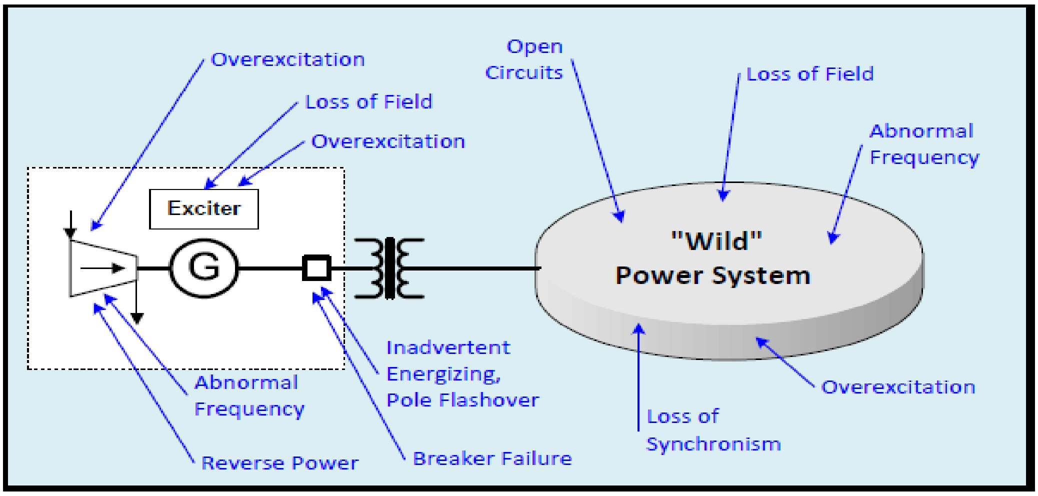


Figure.2. Abnormal operation condition

Overvoltage

Over voltage event occurs when the power system loses the load or when the generator is feeding a very small load.

With health voltage regulator (AVR), over voltage should not happened, but it may be caused by the following contingencies:

• Defective operation of the automatic voltage regulator when the machine is in isolated operation.

• Operation under manual control with the voltage regulator out of service. A sudden variation of the load, in particular the reactive power component, will give rise to a substantial change in voltage because of the large voltage regulation inherent in a typical alternator.

- Sudden loss of load (due to tripping of outgoing feeders, leaving the set isolated or feeding a very small load) may cause a sudden rise in terminal voltage due to the trapped field flux and/or over speed.

For these reasons, it is prudent to provide power frequency overvoltage protection, in the form of a time-delayed element, either IDMT or definite time. The time delay should be long enough to prevent operation during normal regulator action, and therefore should take account of the type of AVR fitted and its transient response.

Setting calculation:

V>1 Voltage Set = 1.15 x 110 = 126.5 V ∴126 V
V>1 TMS = (1.2 –1) x 2 = 0.4 ∴0.4 (IDMT)
V>2 Voltage Set = 1.5 x 110 = 165 V
V>2 Time delay = 0.1s ∴0.1 s

Under voltage Protection

Under voltage protection is rarely fitted to generators. It is sometimes used as an interlock element for another protection function or scheme, such as field failure protection or inadvertent energization protection, where the abnormality to be detected leads directly or indirectly to an under voltage condition. However, it should be addressed by the deployment of 'system protection' schemes. The generation should not be tripped. The greatest case for under voltage protection being required would be for a generator supplying an isolated power system or to meet Utility demands for connection of embedded generation In the case of generators feeding an isolated system, under voltage may occur for several reasons, typically overloading or failure of the AVR. In some cases, the performance of generator auxiliary plant fed via a unit transformer from the generator terminals could be adversely affected by prolonged under voltage.

Where under voltage protection is required, it should comprise an under voltage element and an associated time delay.

Setting calculation:

V<1 Voltage Set = 0.8 x 110 = 88 ∴ 88
V<1 TMS = 3 s ∴ 3 s (for alarm)
V<2 Voltage Set = 0.7 x 110 = 77 V ∴ 77 V
V< 2 Time delay = 2 s ∴ 2 s

Reverse Power Protection

Protection against revers power is provided for some generators to protect the prime mover Parts which may not be designed to experience reverse torque or they may become damaged through continued rotation after the prime mover has suffered some form of failure. The reverse power protection should be provided with a definite time delay on operation to prevent spurious operation with transient power swings that may arise following synchronization or in the event of a power transmission system disturbance.

Prime Mover	Prime Mover	Prime Mover	Prime Mover
Diesel Engine	5 - 25	Fire/explosion due to unburned fuel	
		Mechanical damage to gearbox/shafts	
Gas Turbine	10-15 (split shaft)	gearbox damage	
	> 50% (single shaft)		
Hydro	0.2-2 (blades out of water)	blade and runner cavitation	
	> 2 (blades in water)		
Steam Turbine	0.5 - 6	turbine blade damage	
		gearbox damage on geared sets	50% of motoring power

Table.1: Generator reverse power problems

Setting calculation

Max motoring power for prime mover (IEEE std 242):

For steam turbine 3%

P_{1st} = Generator rating = 60 MW

P_{2nd} = Generator rating / (CT Ratio x VT Ratio)

= (60 x 10^6) / (5000 x 100) = 120 W

$P>1 = 50\% \times 30\% \times P_{2nd}$

= 0.5 x 0.3 x 120 = 1.8 W

Time Delay = 8 Sec

Unbalanced Loading

A three-phase balanced load produces a reaction field that, to a first approximation, is constant and rotates synchronously with the rotor field system. Any unbalanced condition

can be resolved into positive, negative and zero sequence components. The positive sequence component is similar to the normal balanced load. The zero sequence components produce no main armature reaction.

Effect of Negative Sequence Current

The resulting reaction field of the negative sequence rotates in the opposite direction to the D.Sc. field system. Hence, a flux is produced which cuts the rotor at twice the rotational velocity, thereby inducing double frequency currents in the field system and in the rotor body. The resulting eddy-currents are very large and cause severe heating of the rotor.

Setting calculation:

FLC = 60 x 1000 / (√3 x 11 x 0.85) = 3704 .92 A

I2therm>1 Set = 0.6 x 0.1 x 3704.92 x (1/5000) = 0.0444 A

I2therm>1 Delay = 2s ∴2 s (for alarm)

I2therm>2 Set = 0.7 x 0.1 x 3704.92 x (1/5000) = 0.051 A

I2therm>2 K = 15 ∴15

I2therm>t_{max} =15 / 0.1^2 = 1500s

I2therm>t_{min} = 5s

Under/Over frequency and Over Fluxing Protection

These conditions are grouped together because these problems often occur due to a departure from synchronous speed.

Under frequency

Under frequency may occur as a result of overload of generators operating on an isolated system, or a serious fault on the power system that results in a deficit of generation compared to load. This may occur if a grid system suffers a major fault on transmission lines linking two parts of the system, and the system then splits into two. Prime movers may have to be protected against excessively low frequency by tripping of the generators concerned. An under frequency condition, at nominal voltage, may result in some over fluxing of a generator and its associated electrical plant. The more critical considerations would be in relation to blade stresses being incurred with high-speed turbine generators; especially steam-driven sets. When not running at nominal frequency, abnormal blade resonance's can be set up that, if prolonged, could lead to turbine disc component fractures.

Over frequency:

Over frequency running of a generator arises when the mechanical power input to the alternator is in excess of the electrical load and mechanical losses. The most common occurrence of over frequency is after substantial loss of load. Over frequency protection may be required as a back-up protection function to cater for governor or throttle control failure following loss of load or during unsynchronized running. Moderate over frequency operation of a generator is not as potentially threatening to the generator and other electrical plant as under frequency running.

Setting calculation:

Under/Over frequency protection should be set as per Off-frequency turbine limit but general typical data are considered in this report also these values can be changed as follow customer requirement.

a. ∴Under frequency protection

IEEE standards:

F<1 Setting ∴ 48.0 Hz

Time Delay ∴ 10 s

F<2 Setting ∴ 47.0 Hz

Time Delay ∴ 3 s

F<3 Setting ∴ 46.0 Hz

Time Delay ∴ 2 s

F<4 Setting ∴ 45.5 Hz

Time Delay ∴ 0.1 s

b. Over frequency protection

F<1 Setting ∴ 52.0 Hz

Time Delay ∴ 5 s

F<2 Setting ∴ 53.0 Hz

Time Delay ∴ 1 s

Over fluxing

Over fluxing is most likely to occur during machine start up or shut down whilst the generator is not connected to the system. Failures in the automatic control of the excitation system, or errors in the manual control of the machine field circuit, could allow excessive voltage to be generated. Over fluxing occurs when the ratio of voltage to frequency is too high. The iron saturates owing to the high flux density and results in stray flux occurring in components not designed to carry it. Overheating can then occur, resulting in damage. The problem affects both direct-and indirectly-connected generators. Either excessive voltage, or low frequency, or a combination of both can result in over fluxing, a voltage to frequency ratio in excess of 1.05p.u. , normally being indicative of this condition.

Excessive flux can arise transiently, which is not a problem for the generator. For example, a generator can be subjected to a transiently high power frequency voltage, at nominal frequency, immediately after full load rejection.

Setting calculation:

1p.u V/Hz setting = 11000 x 110/11000 / 50Hz = 2.2 V/Hz V/Hz Alm Set
= 2.2 V/Hz x 1.1 = 2.42 V/Hz
Time Delay = 0.5s (for alarm)
V/Hz> 1 set =2.2 x1.1 =2.42 V/HZ
Time Delay = 45 Sec
V/HZ > 2 Set = 2.2 X1.15 = 2.53 V/HZ
Time Delay = 6 Sec
V/HZ >3 Set =2.2 X 1.2 = 2.64 V/HZ
Time Delay =2 Sec
V/HZ > 4 Set = 2.2 X 1.25 =2.75 V/HZ
Time Delay =1 Sec
Loss of Excitation Protection

A loss of field (LOF) occurs when excitation to the generator field winding fails. This may be a result of equipment failure, inadvertent opening of the field breaker, an open or short circuit in the excitation system, or slip ring flashover. Whatever the cause, this condition poses a threat to the generator and to the power system. The DC current input to the field

winding excites the rotor magnetic circuit to establish rotor flux. This flux generates an internal voltage in synchronism with and opposed to the system voltage. When excitation is lost, the rotor current decays at a rate determined by the field circuit time constant. The internal generator voltage will decay at the same rate. If the generator is initially supplying Vars to the power system, the Var output will decrease through zero as the generator draws increasing reactive from the power system to replace excitation formerly provided by the field circuit. Var consumption can exceed the generator MVA rating. The reduction of internal voltage also weakens the magnetic coupling between the rotor and stator. At some point during the decay, the coupling will become too weak to transmit prime mover output power to the electrical system and the generator will lose synchronism.

This is similar to the loss of steady-state stability, to visualize the loss of synchronism following a LOF event; we refer to the power angle equation:

PPee=EEEE EEEEXXXXS SSSSδδ Equation 3. 1

Setting calculation:

Z_b = (Base kV2 / Base MVA) x (CT Ratio / VT Ration) =
(11^2/ 70.6) x (5000 / 100) = 85.6 Ω
$X_d = X\acute{d}$ (Pu) x Z_b = 0.18 X85.6 =15.408 Ω
X_d Ω =1.66 X 85.6 =142.096 Ω
a. Impedance element 1

Ffail -X_{a1} =0.5 X_d = 0.5 X 15.408 =7.7 Ω
Ffail- X_{b1} =X_d = 142.96
Ffail Time Delay = 0.5 Sec
b. Impedance element

Ffail - X_{a2} = 0.5 X'_d = 0.5 x 15.408 =7.7 Ω
Ffail - X_{b2} = KV_2 /MVA = 85.6 Ω
Ffail Time Delay = 0 Sec
Generator Differential Protection

The circulating current differential protection operates on the principle that any current entering and leaving a zone of protection will be equal. Any difference between these currents is indicative of a fault being present in the zone

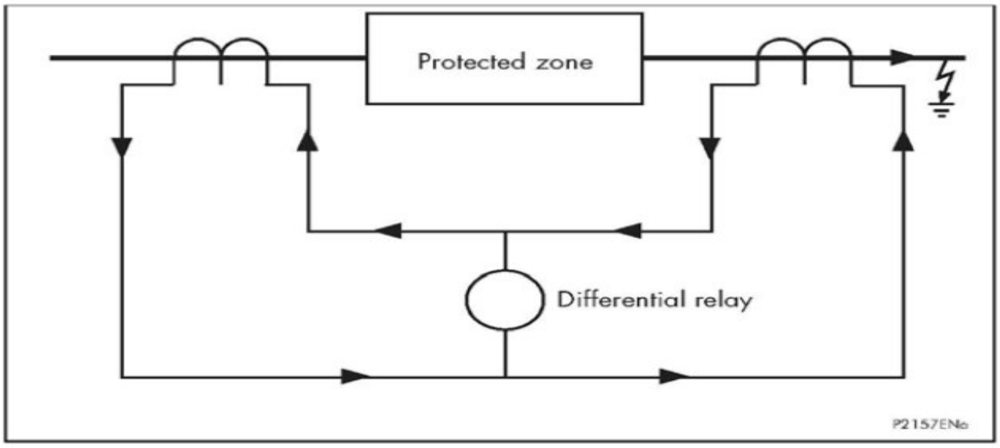


Figure.4. Principle of circulating current differential protection

It can be seen that current flowing through the zone of protection will cause current to circulate around the secondary wiring. If the CTs are of the same ratio and have identical magnetizing characteristics they will produce identical secondary currents and hence zero current will flow through the relay. If a fault exists within the zone of protection, there will be a difference between the outputs from each CT; this difference flowing through the relay causing it to operate. The calculation is performed on a per phase basis. The differential current is the vector sum of the phase currents measured at either end of the generator. The mean bias current (Ibias) is the scalar mean of the magnitude of these currents.

Setting calculation:

FLC = 60 x 1000 / (√3 x 11 x 0.85) = 3704.92A

Gen Diff Is1 = 0.1 x 3704.92 x (1/5000) = 0.07A ∴0.1 A

Gen Diff Is2 = 1.2 x 3704.92 x (1/5000) = 0.89 A ∴0.9 A

Gen Diff k1 = 10% (IEEE Std. 242 recommendation) ∴10 %

Gen Diff k1 = 150% (Manufacture recommendation) ∴150%

Stator earth fault protection

Earth fault protection must be applied where impedance ear thing is employed that limits the earth fault current to less than the pick-up threshold of the overcurrent and/or differential protection for a fault located down to the bottom 5% of the stator winding from the star-point. The type of protection required will depend on the method of ear thing and connection of the generator to the power system.

Setting calculation:

The maximum generator neutral transformer secondary voltage;

$VVVVVVVV$ **= (11000/√3) x (0.11/6.3) V = 110.887 V**

For 95% protection of the windings, the relay should be set as follows;

IN1>1 Current = 0.05 x (110.887/0.191) x (1/1000) A = 0.029A ∴0.03 A

Time Delay = 0.5s ∴0.5 s

[Calculation for 100% stator earth fault protection, 3rd harmonic method] 100% St. EF VN3H = 1% of input voltage

= 0.01 x110.887 V = 1.1088V ∴1.1 V

Time Delay = 1 s ∴1 s Existing value 1s should be considered.

over current protection

The system requires discriminative protection designed to disconnect the minimum amount of circuit and load that will isolate the fault. Correct over current relay application requires knowledge of the fault current that can flow in each part of the network. Since large-scale

tests are normally impracticable, system analysis must be used, the relay settings are first determined to give the shortest operating times at maximum fault levels and then checked to see if operation will also be satisfactory at the minimum fault current expected thus, the relay farthest from the source has current settings equal to or less than the relays behind it

Discrimination by current

Discrimination by current relies on the fact that the fault current varies with the position of the fault because of the difference in impedance values between the source and the fault. Hence, typically, the relays controlling the various circuit breakers are set to operate at suitably tapered values of current such that only the relay nearest to the fault trips its breaker. The figure illustrates the method

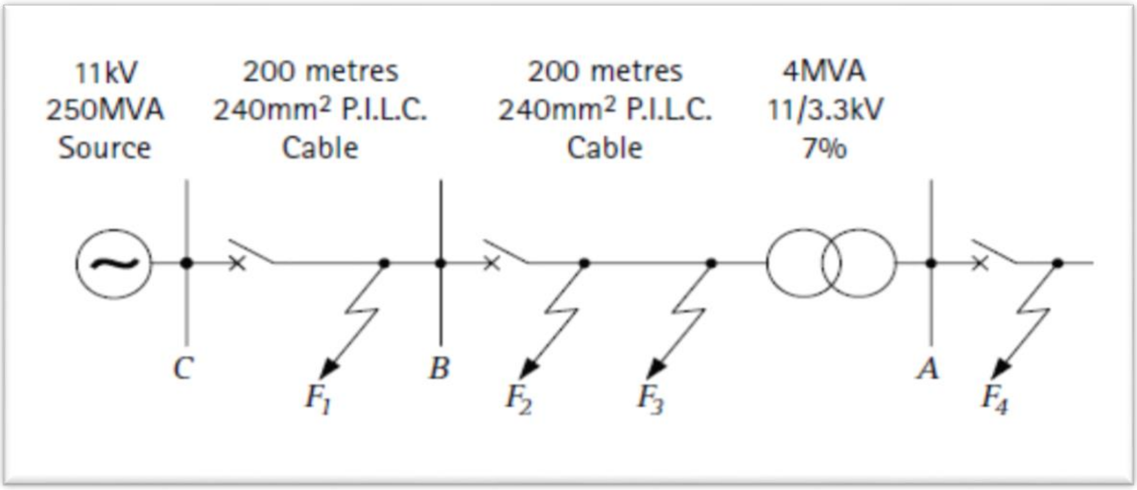


Figure 5. Method of Discrimination by current

The figure illustrates that the relay at zone A trip first, then the relays at zone B, and finally the relay at zone C. it is not practical to distinguish between a fault at F1 and a fault at F2, since the distance between these points may be only a few meters, corresponding to a change in fault current of approximately 0.1%

$PPP\ PPPPPPPP = 11.55 \times GGGGGGGG\ GGGGGGGGGG\ nn\ nn$

$ccC\ PP\ PP$ Equation

Relay setting

By using current discrimination and from ETAP model in the next chapter Relay6 Time Dial 0.025s Relay7 Time Dial 0.05s Relay 8 Time Dial 0.075s Relay 9 Time Dial 0.1s

SIMULATION AND RESULTS

Protection system was simulated by using power system software program called ETAP (Electrical Transient and Analysis Program).

ETAP Software

ETAP power system software is the most comprehensive analysis platform for the design, simulation, operation and automation of generation, distribution and industrial power system.

ETAP offers a suite of fully integrated electrical engineering software solutions including arc flash, load flow, short circuit, transient stability, relay coordination, optimal power flow and more. Its modular functionality can be customized to fit the needs of any company, from small to large power system.

Circuit

The following diagram (figure 5) illustrates a single line diagram of the circuit used to simulate the generator protection system.

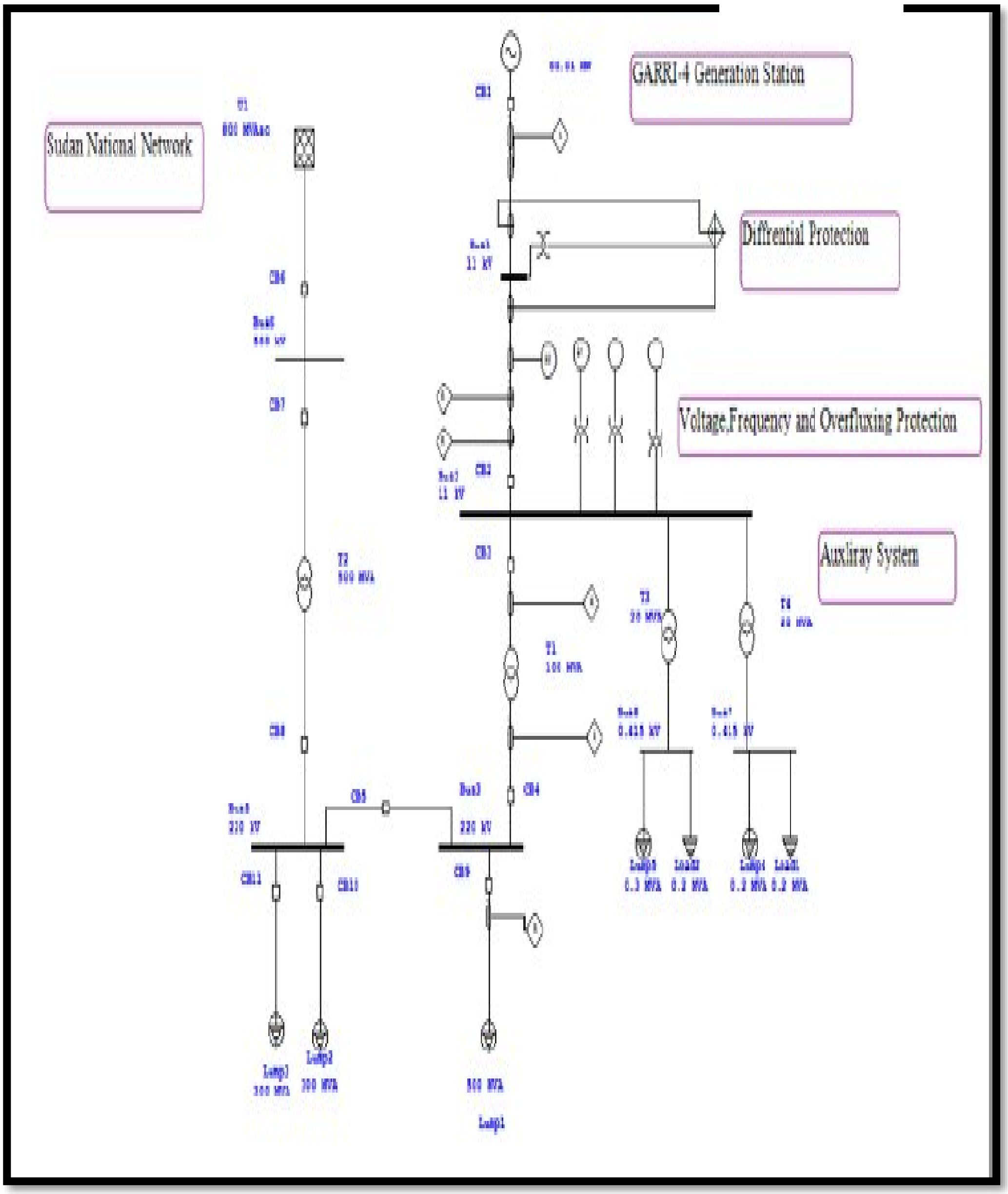
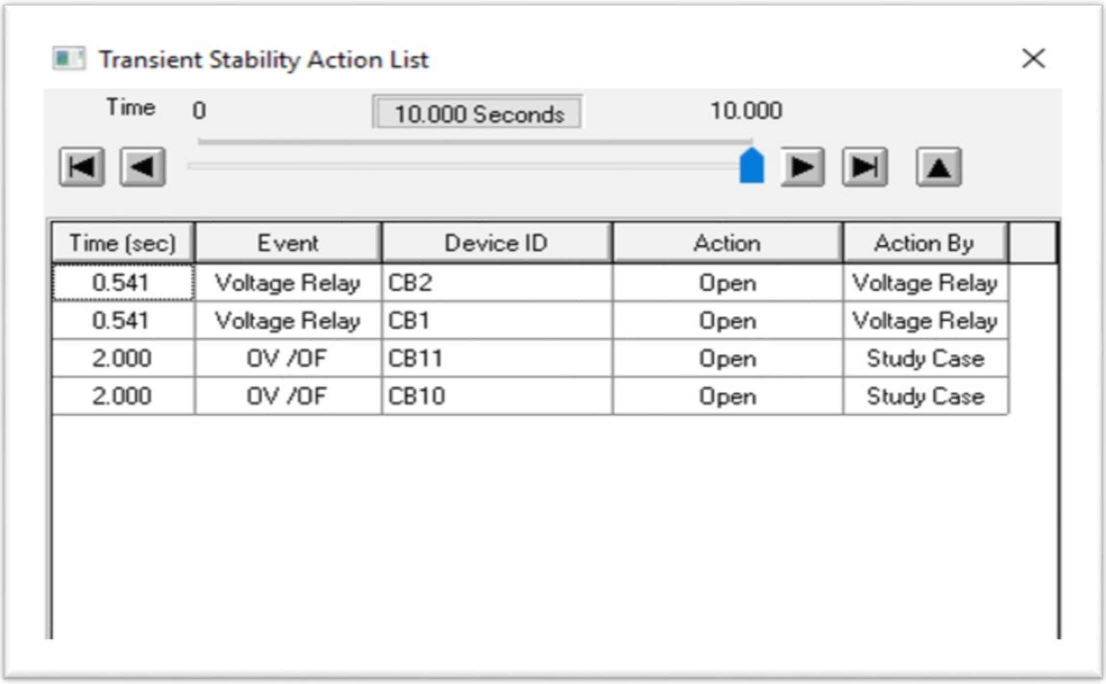


Figure .6. Single line Diagram of Simulation Circuit

ETAP simulation result
Over Voltage Protection


Transient Stability Action List

Time 0 10.000 Seconds 10.000

Time (sec)	Event	Device ID	Action	Action By
0.541	Voltage Relay	CB2	Open	Voltage Relay
0.541	Voltage Relay	CB1	Open	Voltage Relay
2.000	OV /OF	CB11	Open	Study Case
2.000	OV /OF	CB10	Open	Study Case

Figure .7. Over Voltage Action List

• The over voltage scenario was created by opening CB 10 and CB11 to disconnect large loads

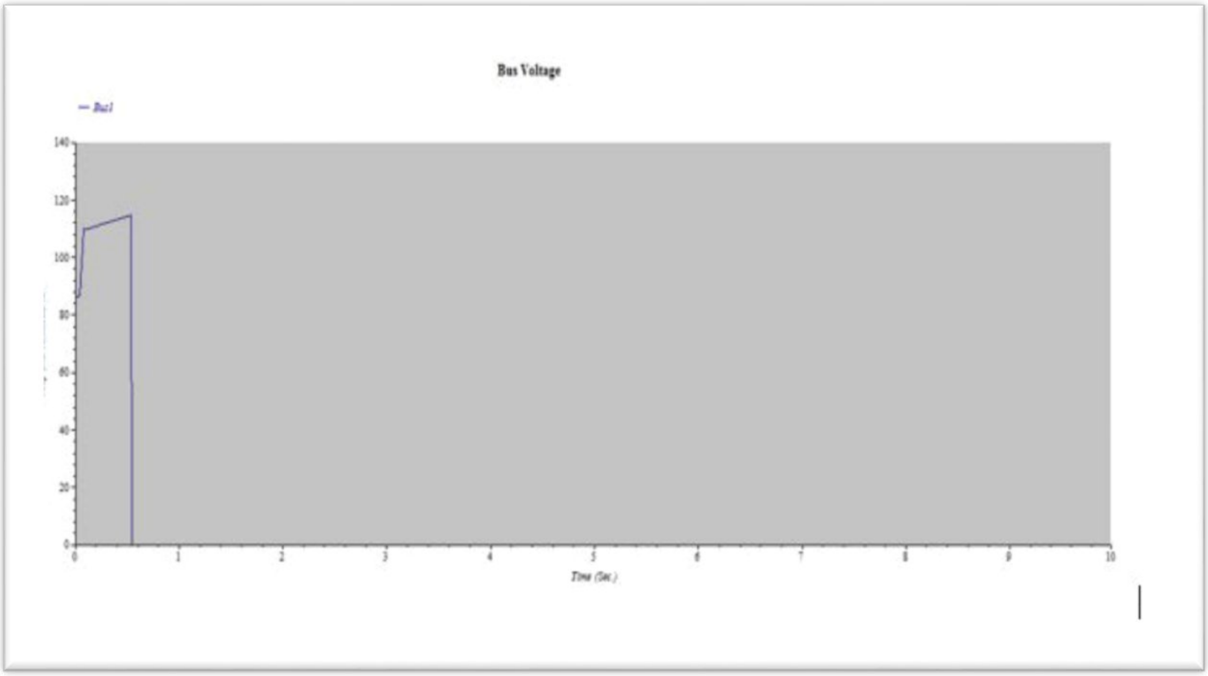
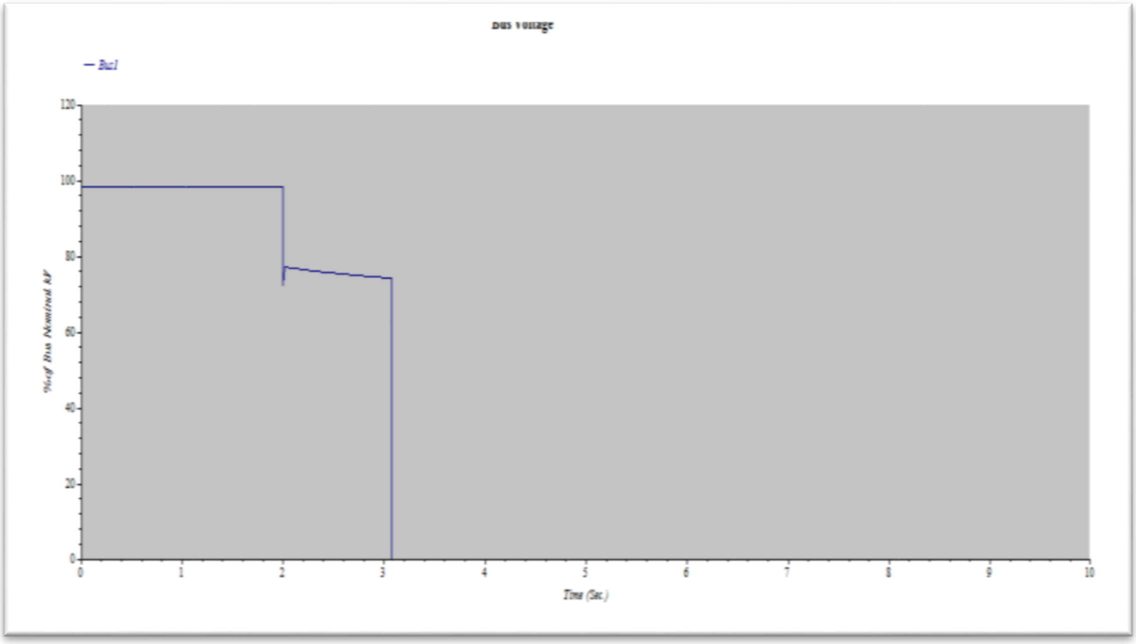
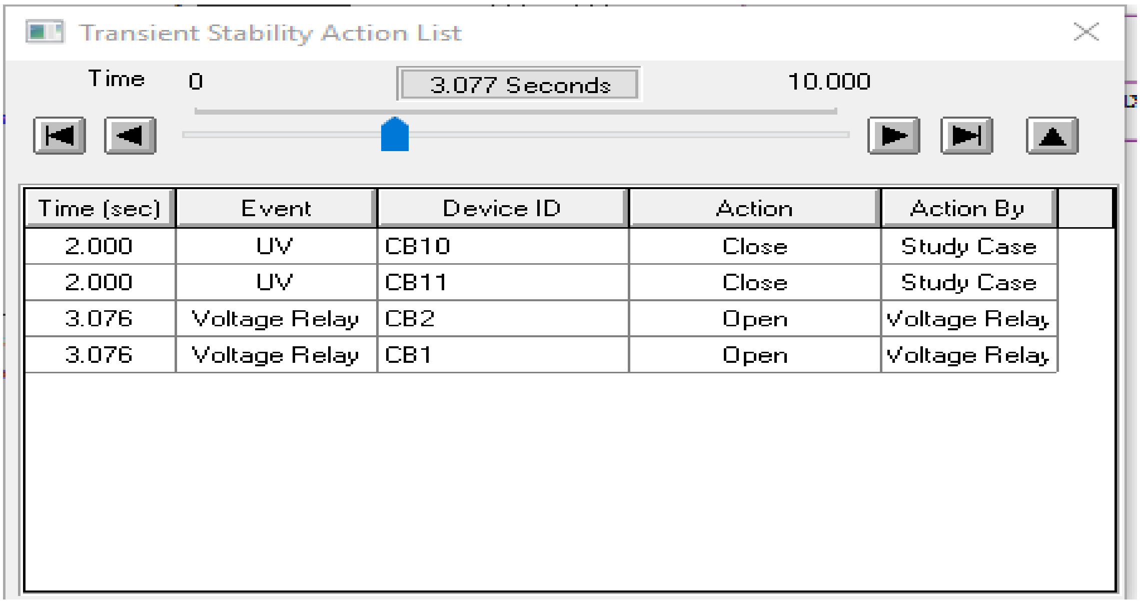


Figure. 8. Over Voltage (Voltage vs. Time) Graph at Bus1

- Bus 1 (generator terminal) voltage reached the relay setting, hence, the voltage relay trips



Under Voltage protection



Time (sec)	Event	Device ID	Action	Action By
2.000	UV	CB10	Close	Study Case
2.000	UV	CB11	Close	Study Case
3.076	Voltage Relay	CB2	Open	Voltage Relay
3.076	Voltage Relay	CB1	Open	Voltage Relay

Figure .9. Under Voltage Action List4

The under voltage scenario was created by closing CB 10 and CB11 to insert a large load

Figure. 10. Under Voltage (Voltage vs. Time) Graph at Bus1

CB 1 and CB 2 trip after detecting the under voltage fault in Bus 1 (Generator terminal).

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Loss of Field

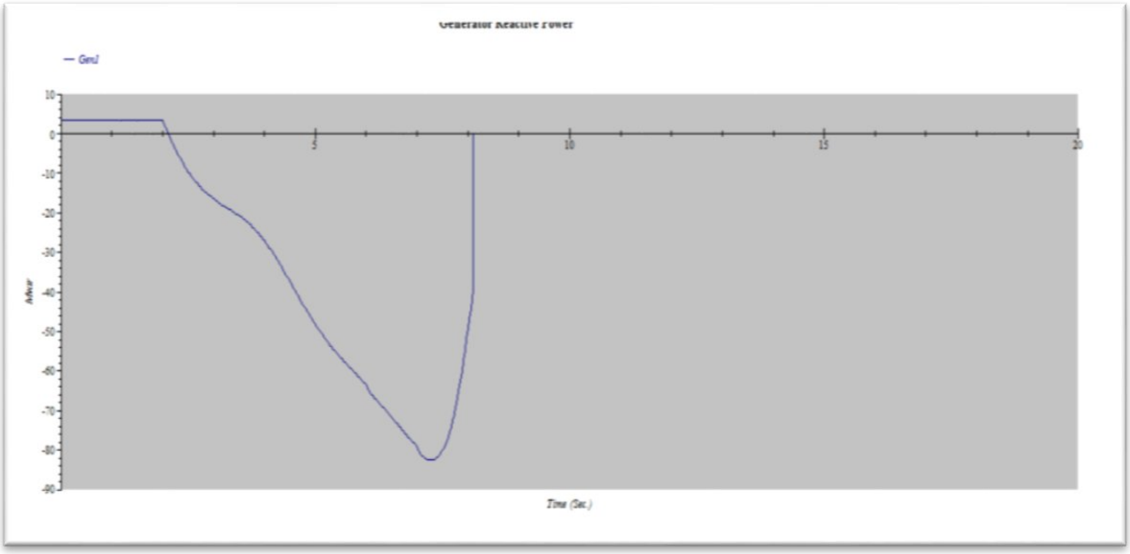
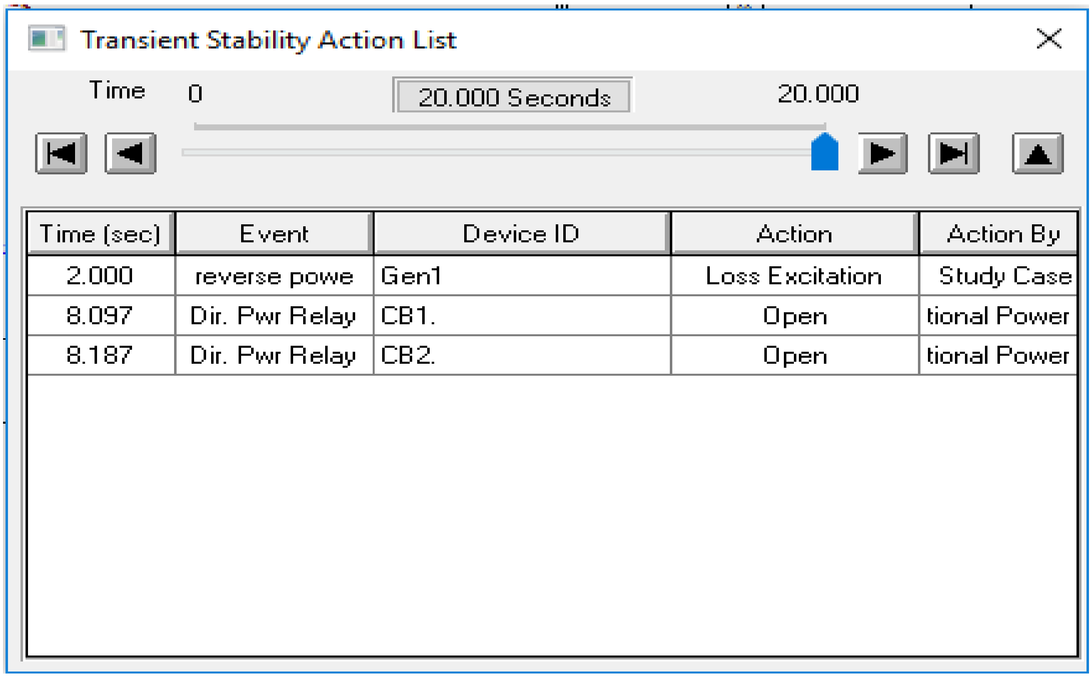


Figure. 10, Loss of Field (Generator Reactive Power Vs. Time) Graph

It is created by choosing loss of excitation option from transient stability analysis.

• The reactive power draw from the system before the condition is detected by the relay and then trip.

Reverse Power Protection


Transient Stability Action List

Time 0 20.000 Seconds 20.000

Time (sec)	Event	Device ID	Action	Action By
2.000	reverse powe	Gen1	Loss Excitation	Study Case
8.097	Dir. Pwr Relay	CB1.	Open	tional Power
8.187	Dir. Pwr Relay	CB2.	Open	tional Power

Figure. 11, Reverse Power Action List

The relay waits 8 seconds then trips.

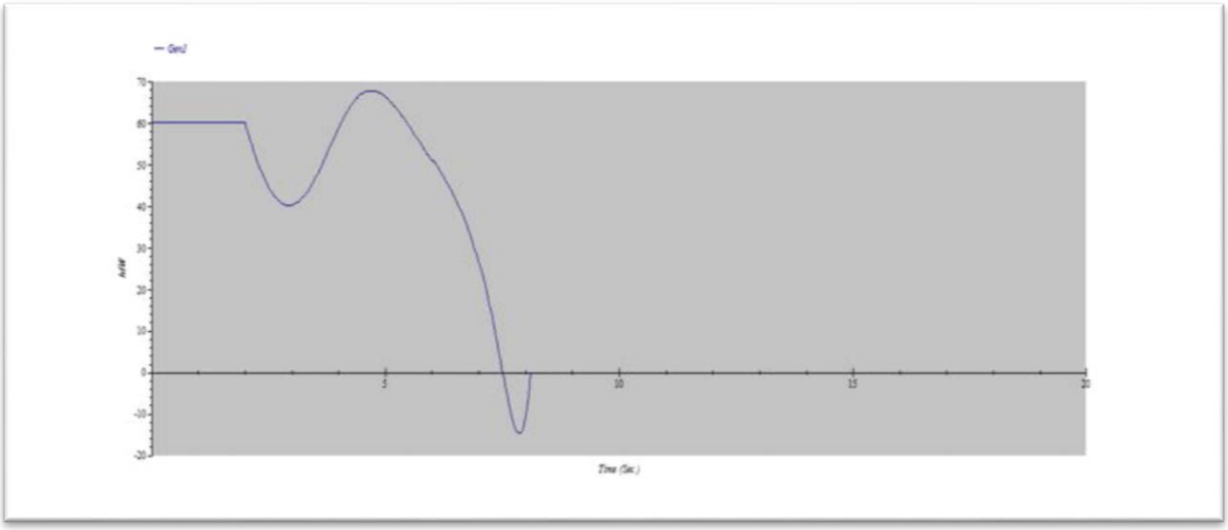


Figure. 12. Reverse Power (Generator Active Power vs. Time) Graph

• It is created by choosing loss of excitation option from transient stability analysis.

• The direction of the real power reverses before the relay detects the condition.

Unbalanced Loading Protection

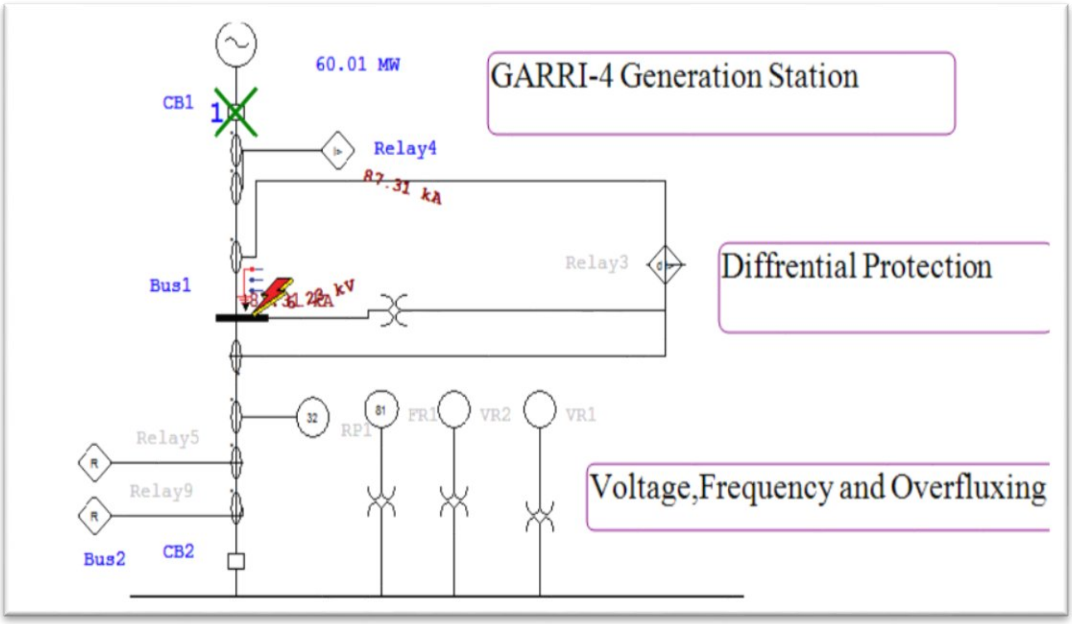
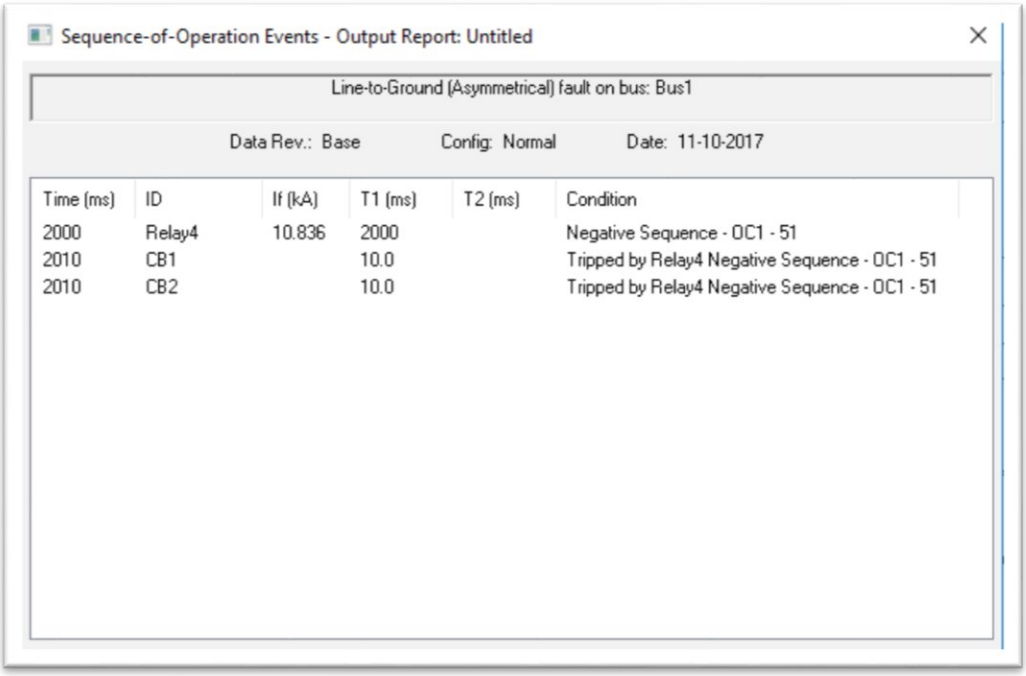


Figure. 12 .Protection Operation of Un Balanced Loading Fault

In the normal condition positive sequences are applied to the system.

• Negative sequence event created by choosing line to ground fault at Bus1 since the fault occurs. Negative sequence current will appear in the system



Sequence-of-Operation Events - Output Report: Untitled

Line-to-Ground (Asymmetrical) fault on bus: Bus1

Data Rev.: Base Config: Normal Date: 11-10-2017

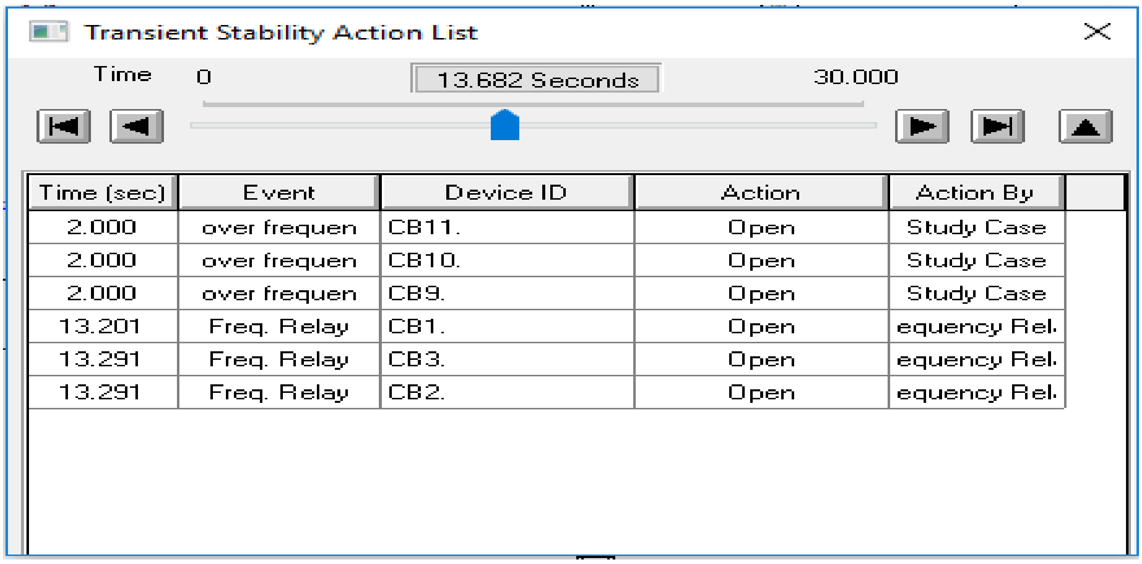
Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
2000	Relay4	10.836	2000		Negative Sequence - OC1 - 51
2010	CB1		10.0		Tripped by Relay4 Negative Sequence - OC1 - 51
2010	CB2		10.0		Tripped by Relay4 Negative Sequence - OC1 - 51

Figure .13. Negative Sequence Event Recorder

• The Multifunction relay used as negative sequence current protection relay to detects the faulty condition.

• CB1 and CB2 trips after 0.01 second from the detected fault.

Over frequency protection



Transient Stability Action List

Time 0 13.682 Seconds 30.000

Time (sec)	Event	Device ID	Action	Action By
2.000	over frequen	CB11.	Open	Study Case
2.000	over frequen	CB10.	Open	Study Case
2.000	over frequen	CB9.	Open	Study Case
13.201	Freq. Relay	CB1.	Open	equency Rel.
13.291	Freq. Relay	CB3.	Open	equency Rel.
13.291	Freq. Relay	CB2.	Open	equency Rel.

Figure .15. Over Frequency Action List

The over frequency scenario was created by opening CB 9, CB 10 and CB11 to disconnect large loads.

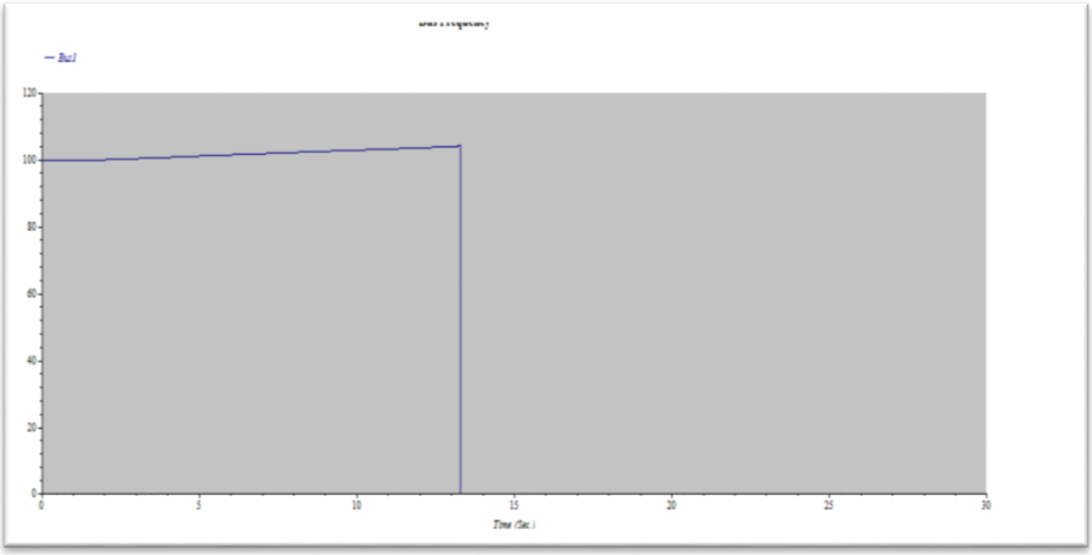


Figure. 16. Over Voltage (Voltage vs. Time) Graph at Bus1

• Bus 1 (generator terminal) frequency reached the relay setting, hence, the frequency relay trips

Under frequency Protection

Transient Stability Action List

Time 0 17.957 Seconds 30.000

Time (sec)	Event	Device ID	Action	Action By
2.000	underfrequen	CB10.	Close	Study Case
2.000	underfrequen	CB9.	Close	Study Case
2.000	underfrequen	CB11.	Open	Study Case
17.686	Freq. Relay	CB1.	Open	equency Rel
17.776	Freq. Relay	CB3.	Open	equency Rel
17.776	Freq. Relay	CB2.	Open	equency Rel

Figure. 17. Under Frequency Action list

The under frequency scenario was created by closing CB 9, CB 10 and CB11 to insert a large load.

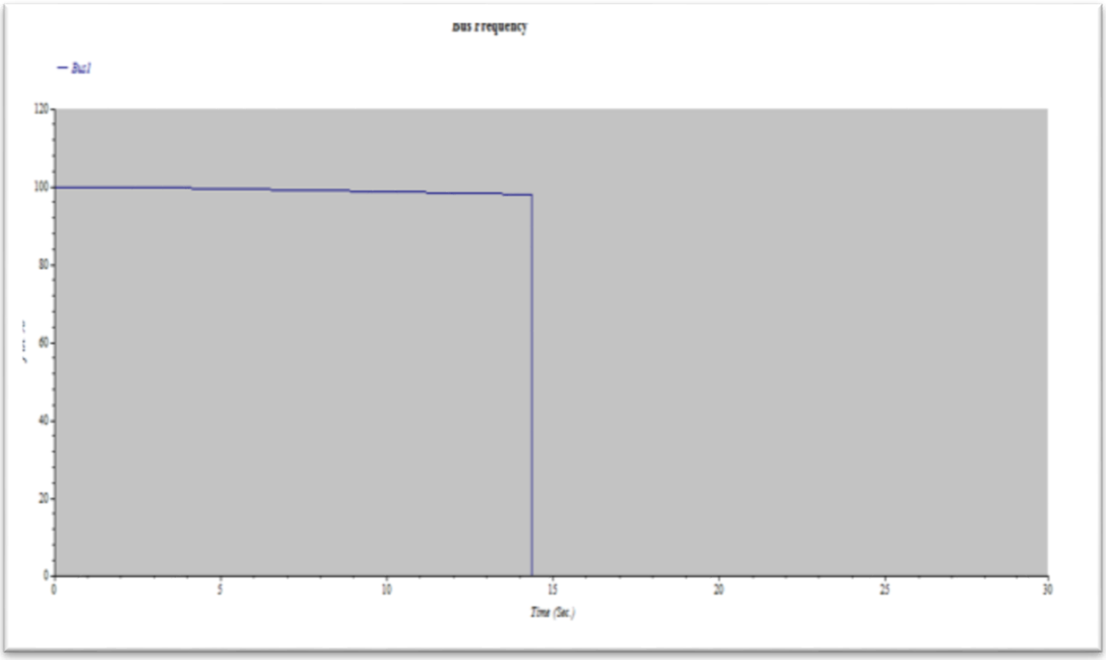
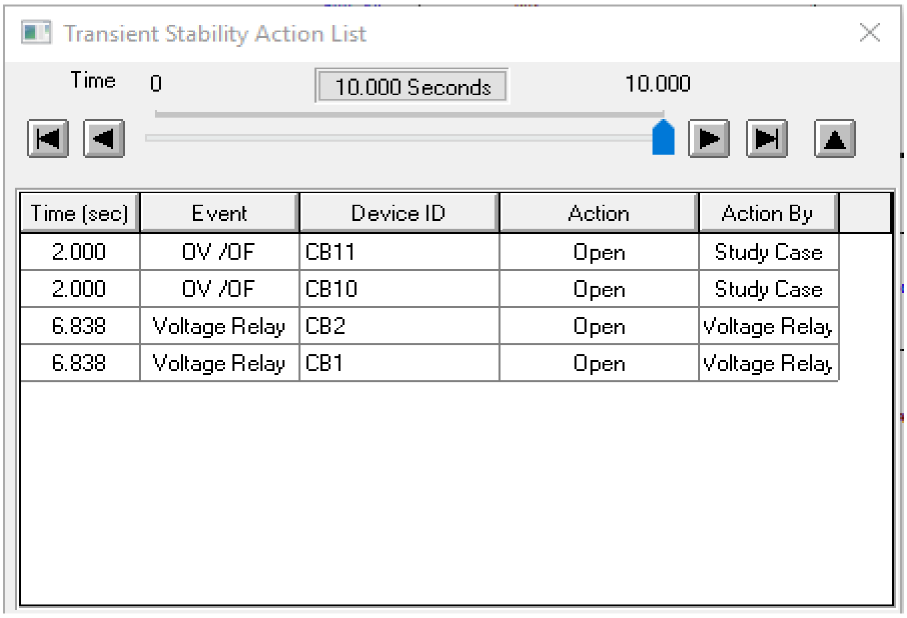


Figure. 18. Under Frequency (Frequency vs. Time) Graph at Bus1

Bus 1 (generator terminal) frequency reached the relay setting frequency after 15 seconds from event occurring.

Over fluxing Protection



Transient Stability Action List

Time 0 10.000 Seconds 10.000

Time (sec)	Event	Device ID	Action	Action By
2.000	OV /OF	CB11	Open	Study Case
2.000	OV /OF	CB10	Open	Study Case
6.838	Voltage Relay	CB2	Open	Voltage Relay
6.838	Voltage Relay	CB1	Open	Voltage Relay

Figure. 19. Over fluxing Action List

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• **The over fluxing scenario was created by disconnecting large loads from the system by opening CB10 and CB11.**

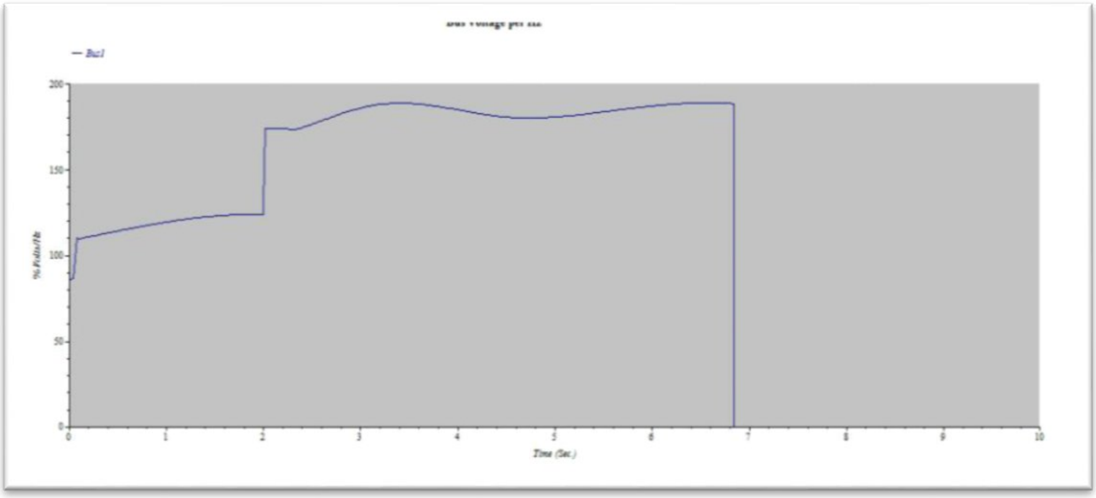


Figure .20. Over Fluxing (V/F vs. Time) Graph at Bus1

• **CB1 and CB2 trips after Bus1 voltage over frequency ratio reached the relay setting.**

Differential Protection

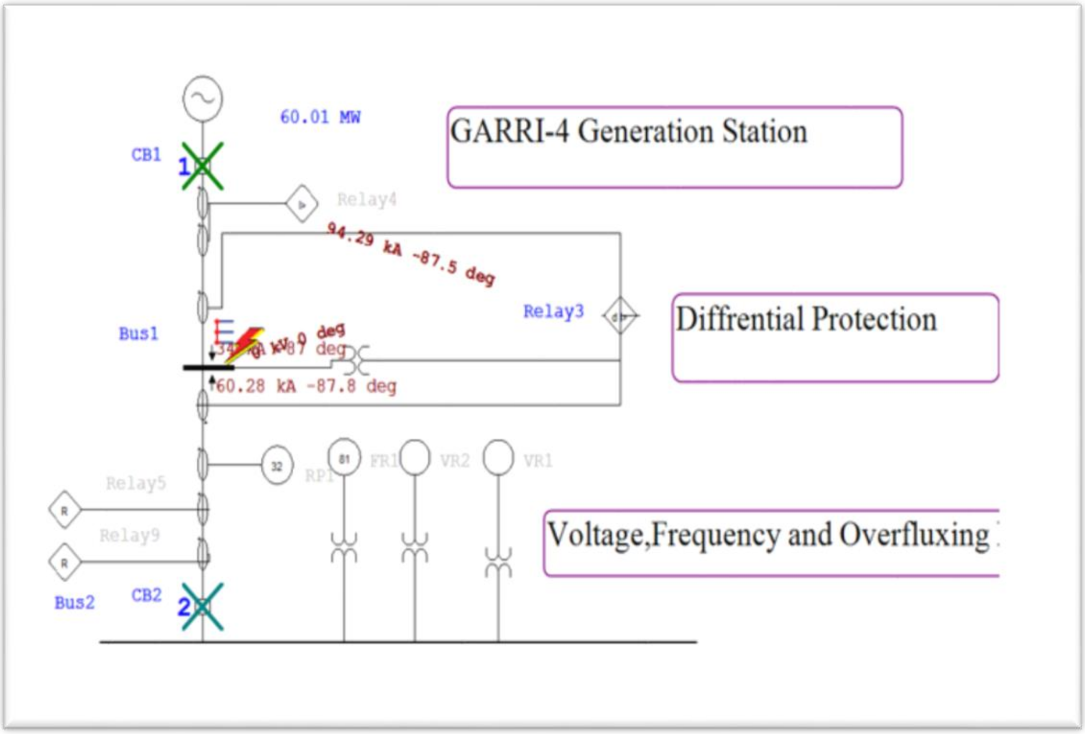
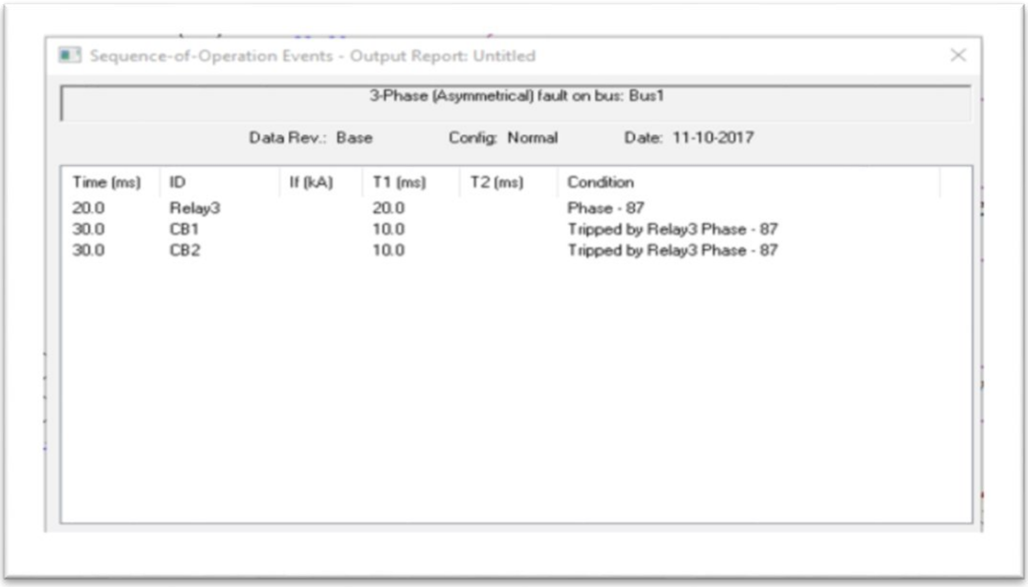


Figure .21. Internal fault

• Unit protection for Bus1 was applied by using two current transformers CT 20 and CT 21 with opposite polarity.

• In this case 3 phase fault occurred in the protected zone (Bus 1).


Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Asymmetrical) fault on bus: Bus1

Data Rev.: Base Config: Normal Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
20.0	Relay3		20.0		Phase - 87
30.0	CB1		10.0		Tripped by Relay3 Phase - 87
30.0	CB2		10.0		Tripped by Relay3 Phase - 87

Figure. 22. Differential Protection Event Recorder18.

CB1 and CB2 trips after 0.01 second from detecting the fault by differential relay.

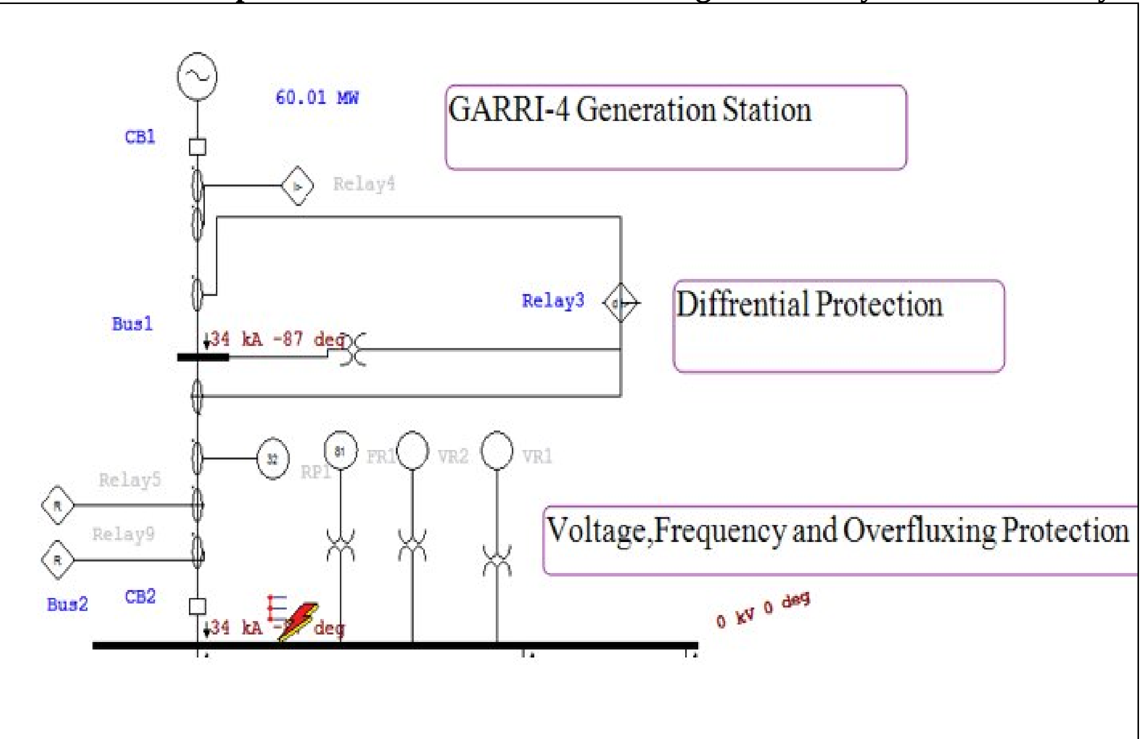


Figure .23. External Fault

• **The fault occurs outside the protected zone bus 1 with the same polarity of CT.**

Stator Earth Fault Protection

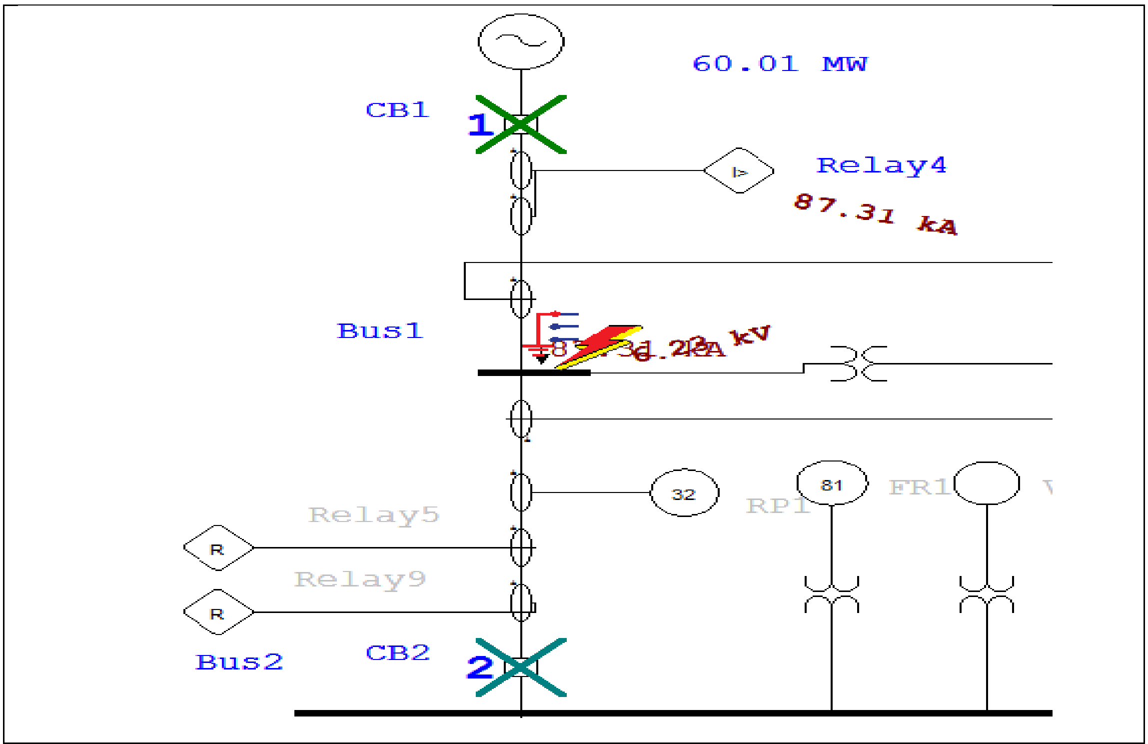
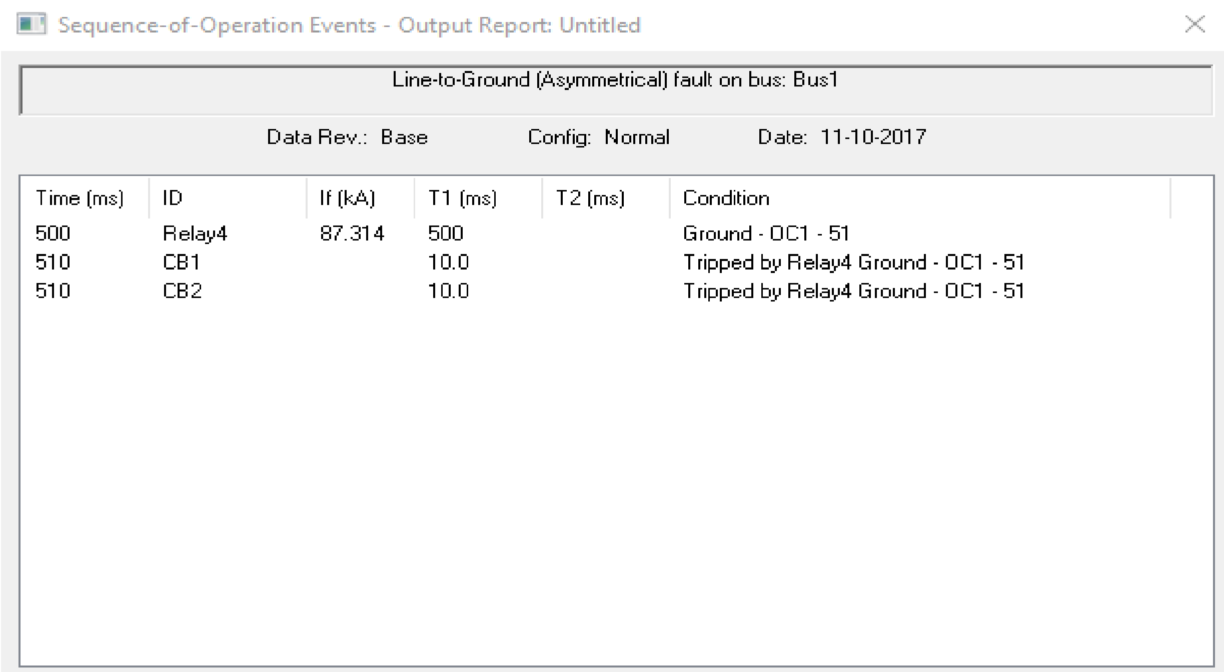


Figure .24. Protection Operation of stator Earth Fault

• Stator earth fault event created by choosing line to ground option at bus1 since the fault occurs.


Sequence-of-Operation Events - Output Report: Untitled

Line-to-Ground (Asymmetrical) fault on bus: Bus1

Data Rev.: Base   Config: Normal   Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
500	Relay4	87.314	500		Ground - OC1 - 51
510	CB1		10.0		Tripped by Relay4 Ground - OC1 - 51
510	CB2		10.0		Tripped by Relay4 Ground - OC1 - 51

Figure. 25. Stator Earth Fault Event Recorder

• Multifunction relay was used to detects the faulty condition

• **CB1 and CB2 trips after 0.01 second**

Overcurrent Protection

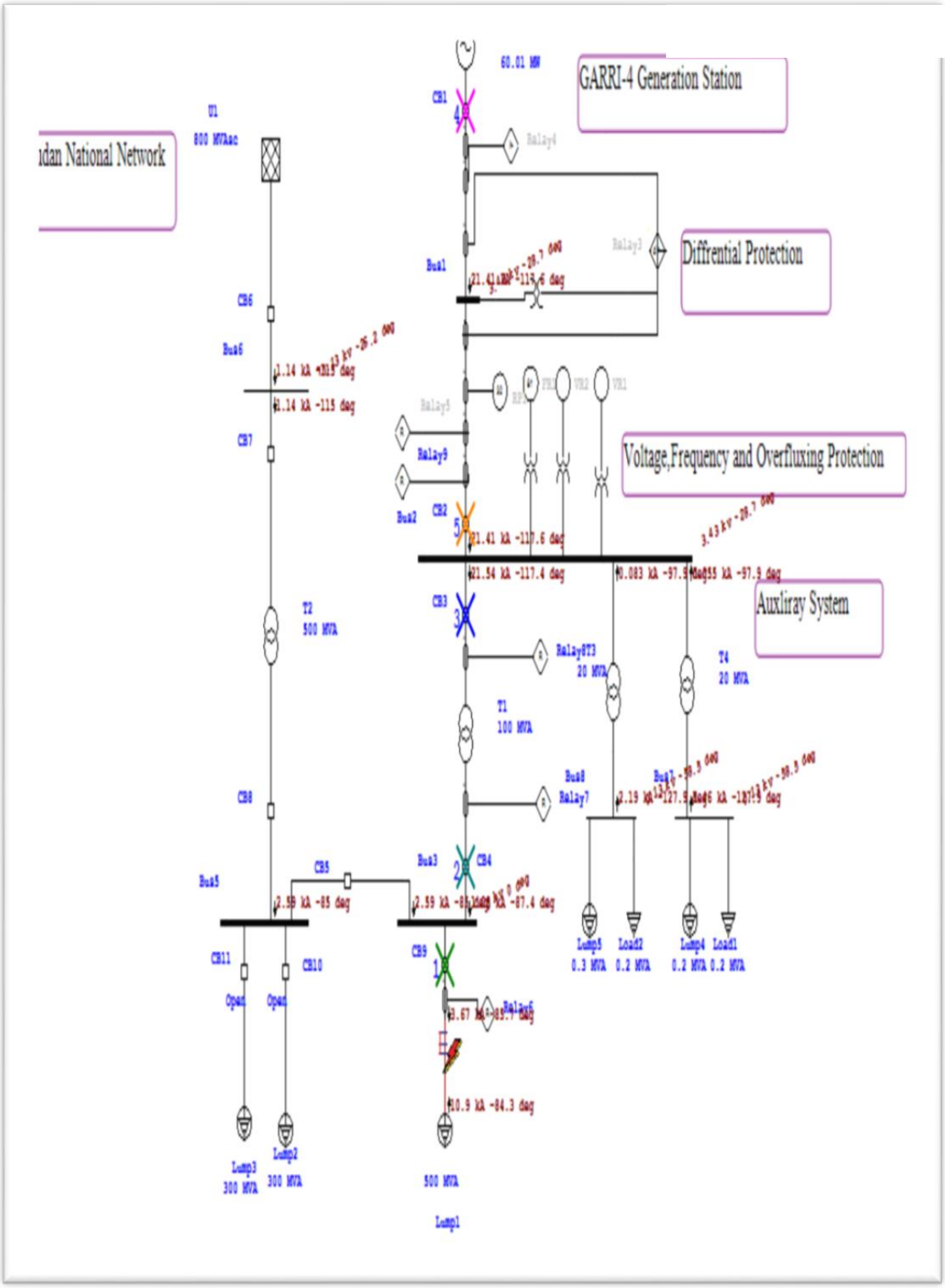


Figure. 26. Protection operation of Over Current

• **For over current protection four relays and CT were used**

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Asymmetrical) fault on connector between CT8 & Lump1. Adjacent bus: Bus3

Data Rev.: Base Config: Normal Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
305	Relay6	3.668	305		Phase - OC1 - 51 - Forward
315	CB9		10.0		Tripped by Relay6 Phase - OC1 - 51 - Forward
497	Relay7	1.077	497		Phase - OC1 - 51
507	CB4		10.0		Tripped by Relay7 Phase - OC1 - 51
750	Relay8	21.538	750		Phase - OC1 - 51
760	CB3		10.0		Tripped by Relay8 Phase - OC1 - 51
1009	Relay9	21.408	1009		Phase - OC1 - 51
1019	CB1		10.0		Tripped by Relay9 Phase - OC1 - 51
1019	CB2		10.0		Tripped by Relay9 Phase - OC1 - 51

Figure. 27.Overcurrent Event Record

• **CB4, CB3, CB2 and CB1 trip in a sequence order.**

Summary

• The generators start withdraw reactive power from the system in the event of loss of filed. The event will be detected by the revers power relay which trip the Circuit Breaker. This event is designed using ETAP transient stability analysis by loss of excitation event.

• In reverse power event the direction of the active power reverses. The reverse power relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating loss of excitation for transient stability analysis

• The generator frequency drops when the system is overloaded. Relay measures the frequency of voltage signal given through VT. Under frequency relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating Under Frequency for transient stability analysis.

• Over Frequency event appears when the load is lost or when the generation excessed the load. Relay measures the frequency of voltage signal given through VT, over frequency relay trip the Circuit Breaker when the frequency of the system rises above the set value. This event was implemented using ETAP by activating Over Frequency for transient stability analysis.

• Over fluxing event appears when disconnecting a high load. If the percentage V/F increased above the set value, the over fluxing relay trips the Circuit Breaker. This event was implemented using ETAP by activating Over Fluxing event for transient stability analysis.

• Overvoltage event appears when the load is suddenly lost. Relay measures the voltage s through VT, over voltage relay trip the Circuit Breaker when the voltage of the system rises above the set value. This event was implemented using ETAP by activating over voltage for transient stability analysis.

• Under voltage event occurs when the system is overloaded, so, the generator delivers larger current and the voltage of the system drops. Under voltage relay operates when the voltage of the system goes below the set value. This event is designed using ETAP transient stability analysis by adding a high load.

• The generator voltage drops when the system is overloaded. Relay measures the voltage signal given through VT. Under voltage relay detects this event and trip the Circuit This event is designed using ETAP transient stability analysis by removing a high load

CONCLUSION AND RECOMMINDATION

Paper review

• Generator is very large unit, so that the protection is very important for security and stability purpose.

• A real time of multifunction relay for scaled generator is applied in this project.

• Type of fault has a big impact on the design of generator, so detection and correction mechanism of fault must be taking into account.

• All abnormal condition has been detected by ETAP.

• An average tripping time is achieved for all kinds of fault.

Recommendation

The lack of main and reliability back-up protection schemes in the event of abnormalities and faults, the lack of comprehensive monitoring, the occurrences of abnormalities and faults without protecting the supply units from them is the main reason for instability of power supply.

To make a comprehensive and effective protection for the generation units at Zawia Oil Refining Company (ARC), generator protection design scheme must also take into account some additional considerations to increase the performance of the protection scheme, such as Scheduling maintenance for generation units to avoid frequent outage of the electrical supply, in the event of very sever fault the relay must trip the Circuit Breakers in very short time like what happened in the transient study of over frequency by using ETAB implementation .

Also Study and simulation for generation unit (both generator and its step-up transformer) could be done using protection relays of ETAP software besides online relay testing.

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