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Simulation of Generator Negative Sequence Protection Using Matlab

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Abstract:
A three phase synchronous generator is vital and one of the critical component of power system used in captive, co-generation and independent power plants in various capacities. It is most important and costly equipment in power system and accompanied by prime mover, excitation system, and voltage regulators and cooling system so, It's protection becomes very complex and elaborate. To protect the generator against power system abnormalities or fault within itself, it requires quick isolation from the system for maintaining stability in the system. As generators are exposed to more harmful operating conditions than any other power system element, therefore sophisticated and innovative protection schemes are required. However selection of protection scheme requires throughout knowledge of protection philosophy of machine and depending upon its design data. As the pace of technological change has rapidly accelerated so, In today's scenarios electromechanical type of relays are absolute which were used earlier for each individual protection and instead of that a single multifunction digital/numerical relay with various features are used as a complete generator protection module. One of the major advantage of these relays are that these are working in a common platform/protocol (IEC61850) irrespective of its make (SIEMENS, ABB, AREVA, GENERAL ELECTRIC) and facilitate the logics blocks as per the necessity of end user. These relays are accepts various current inputs from neutral side and phase side CTs and voltage inputs from machine terminals through VTs for various computations and algorithms both for protection and measurements. These relays could also be interfaced with work stations and DCS for on line monitoring and extracting fault records and disturbances. In this project we are considering negative sequence protection scheme of generator and simulate the function using Matlab Simulink. In this case Turbine, generator and excitation system are considered as a dynamic sources and pick-up of a protection function initiates opening of Generator CB, shut-off driving mechanical input to turbine (Pm) and field excitation (E) which enables the generator output power to drops down to zero instantaneously. Simulation diagrams are shown in subsequent pages with events in its respective work-sheets

Keywords: Gen Circuit breaker (52), Negative sequence relay (46G), Emergency stop valve (ESV), Unit lock-out relay group-1 /2(86G-1/86G-2), Unit auxiliary transformer (UAT), Generator Transformer (GT), Turbine trip relay (86T)

I. INTRODUCTION

In a generating station, Turbine, Generator, Transformer and other high voltage switch gears are critical as well as expensive equipment and hence it is advisable to employ a passive protective system so that it can be isolate the faulty equipment at minimum possible time and keep the healthy section in normal operation to ensure un-interruptible power supply to customer and to maintain grid stability. The basic electrical quantities which are deviated under abnormal fault conditions are voltage(V), current(I), phase angle(Φ) and frequency(Hz), the protective relays senses/utilizes one or more of these quantities to detect abnormal conditions in the system and isolate it. As a standard cost of protective system would be 6-7% of total electrical installation cost. For achieving high performance and long functional life of generator it requires periodic maintenance and testing activities to be conducted at regular intervals for diagnosis and healthiness of machine. The generator is subjected to various internal and external faults during its operational life which deteriorates it's winding, insulation (F-class), core, field winding, retaining rings etc. Therefore a generator has to be protected not only from electrical faults (stator and rotor related faults) but also mechanical problems (e.g. Related to turbine, boilers etc). Under certain conditions like severe internal faults machine has to be quickly isolated and in certain alarming conditions like loss of field, generator over voltage stage-1, generator under voltage stage-1 etc it will issue an alarm signal to alert the operator. Hence different type of primary and back-up protections is employed for generators which are described here further.

II. METHODS AND SYSTEM MODEL

Generator faults are classified as per the following methodology Class-A Trip- It includes all those faults which are related with generator and excitation system (electrical faults) which required instantaneous shut down of generator from bus bar, excitation system (field CB switched off) and turbine (closing of emergency stop valve) Class-B Trip- When fault initiated from turbine end and ESV get closes resulting of which Low forward power comes into picture and initiates trip pulses to both Generator load breaker and excitation system. Class-B trip differentiates the fault that whether fault is from generator end or turbine end. Class-C Trip- This trip is initiated basically for those faults which are outside of machine, in this situation machine disconnected from bars and turbine runs at rated rpm with excitation ON.

a) Faults on generators:

Faults on generators are classified in different manners which are described as

Stator faults

i) Phase to phase fault on windings.

ii) Phase to ground faults

iii) Inter-turn faults that is shorting of same phase winding
Phase to phase faults and inter-turn faults are less common and these are developed into earth faults but inter-turn faults are difficult to be detected.

Rotor Faults
i) Phase to ground fault in rotor winding
ii) Shorting of turns of field windings
iii) Loss of excitation protections
iv) Protection against rotor over heating because of over excitation
v) Rotor high temp alarm
vi) Automatic field suppression and use of neutral circuit breaker
vii) Alternate arrangement for field suppression

Abnormal operating conditions
i) Over/under voltage in stator winding
ii) Over loading condition
iii) Over/under frequency
iv) Loss of field
v) Negative sequence protection against unbalanced loads
vi) Motoring or Loss of Prime-mover
vii) Protection against vibration
viii) Overheating of bearings
ix) Sub-synchronous oscillation
x) Loss of synchronism (Out of step)
xi) External fault back-up protection

b) ANSI/IEEE standard for generator protection
Revised generator protection standards are as mentioned below

Standards	**Description**
C37.101	IEEE guide for generator earth fault protection
C37.102	IEEE guide for generator protection
C37.106	IEEE guide for abnormal frequency protection for generating units

Note- These are created/maintained by IEEE, PSRC (Power system relaying and control committee) and IAS (Institute for advanced study) and updated for every 5 years.

c) Device nomenclature for generator protection

Each generator is protected with some of standard protection functions some of which are called as unit/primary protection and other are called as back-up/secondary protection schemes, generators above 25MW are equipped with all these protections as tabulated below. These device nomenclatures are as per IEEE norms and each device number has specific function name used for generator and transformer protection. These protection functions names are unique which are used for various electrical equipment and switchgears such as generators, motors, feeders, line protection, transformers, HV/LV distribution boards etc. In present scenario, most of the protections are incorporated in a single multifunction relay as detailed above. For costlier and critical equipment such as generators two similar protective relays are used witch are incorporated with all important protections and acts as 100% back-up and redundancy for machine.

Table.1. Generator protection nomenclature

SR NO	DEVICE NOMEN	FUNCTION DISCRIPTION	PRIMARY / BACKUP
1	87G	Gen Diff Protection	Primary
2	59G1, 59G2	Gen Over voltage	Primary
3	59N1, 59N2	Neutral over volt (95 - 100%) stator E/F	Primary
4	64S	Stator E/F	Primary
5	51VG	Voltage dependent O/C	Primary
6	32G	Gen Rev Power	Primary
7	46G	Neg Seq Protection	Primary
8	64F	Rotor E/F Protection	Primary
9	81O	Over Freq Protection	Primary
10	24G	Over Flux Protection	Primary
11	87T	Trafo Dff Protection	Primary
12	87O	Overall Diff Protection	Primary
13	50BF	Local bkr back-up Protection	Primary
14	27/40G	Loss of field with U/V	Primary
15	40G	Loss of field W/O U/V	Secondary
16	27G	Stator U/V Protection	Secondary
17	81U	U/F Protection	Secondary
18	78	Out of step Protection	Secondary
19	21G	Back-up Imp Protection	Secondary
20	47G	Unbalance Protection	Secondary
21	49	Stator thermal O/L	Secondary
22	60	Voltage balance	Alarm
23	86	High speed master trip relay	Trip
24	25	Sync- check relay (SKE)	For Syn

d) Constructional block diagram for generator:

In the Fig-A below shown the block diagram of generator, which is driven by prime-mover, it may be steam turbine, hydro turbine or diesel engine. Generator is supplying power to 3 phase load and output sinusoidal waveform of generator is shown in the block. Generator field is supplied with DC regulated source called AVR (Automatic voltage regulator panel) which tuned to machine capability limits. There are different configuration of AVR system basically it is either **Static** or **Brush-less excitation**. For static system it derives input power from generator terminals through excitation transformer of adequate rating and for brush-less system main exciter and PMG (Permanent magnet generator) are used. In present scenario brush-less system is more favored owing to large maintenance at slip rings of generator rotor due to large magnitude of field current in static system. Small generators (up to 25 MW) are directly connected to distribution board with generation voltage of 6.9/11 KV but for large generators (up to 600 MW) we are using UNIT system having one GT (Generator transformer) and UAT(Unit auxiliary transformer) with High impedance earthing by using NGT (Neutral grounding transformer) and generation voltage selected as 16.5KV.

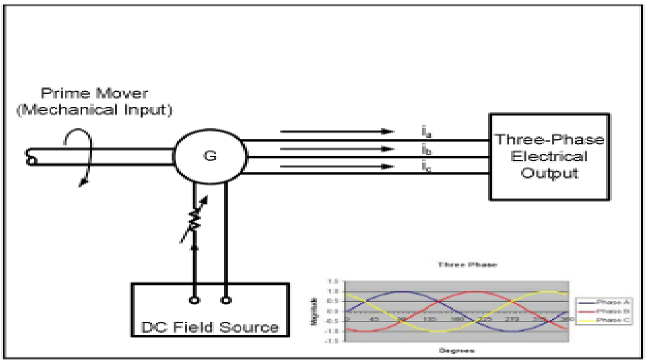

Figure.1. Generator block Diagram

e) Protection scheme diagram for unit connected generator with bus bar:

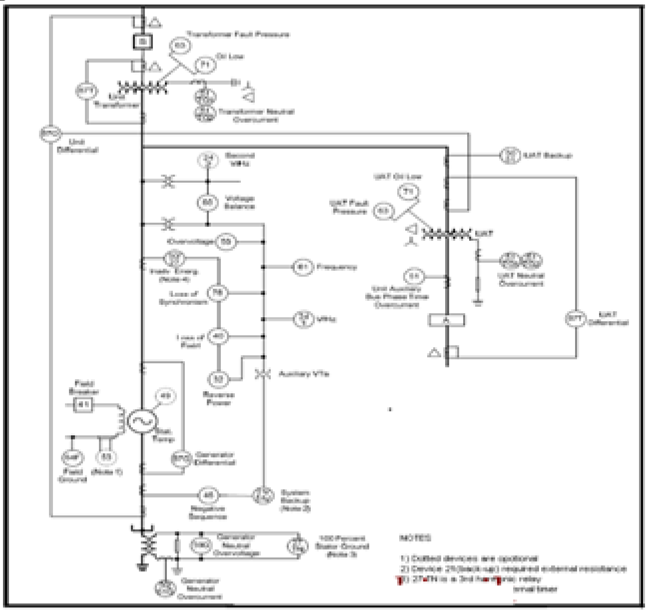

Figure.2. Unit protection scheme

The fig-B above shows the typical protection model for a unit connected generator there are three major and critical equipment for unit connected scheme ie

i) Generator

ii) Generator transformer (GT)

iii) Unit auxiliary transformer (UAT)

Each equipment in this scheme has individual differential protection as well as with combined overall differential (87O) which acts as back-up for individual differential relay. Generator has high impedance grounding with 3rd harmonic stator earth fault protection with generator neutral over voltage relay. GT and UAT are additionally equipped with over current, earth fault protection with its gas operated mechanical protection such as Buchholz, OSR, PRV, WTI and OTI. Generator rotor is protected with 1st rotor E/F and 2nd rotor E/F protection in addition to field failure protection (40G). In unit protection scheme as a standard practice for vector group of GT and UAT are YNd11 and DYn1 respectively. Generator CT and VT are connected to current and voltage coil of individual protective function as shown in the figure. For higher rated machines connectivity of power circuit between generator, GT and UAT is through Independent phase bus duct (IPBT) which are having individual bus ducts for each phases with aluminum rectangle channels depending upon current rating of machine and it's fault rating and for lower rated machines it is Segregated phase bus duct(SPBT).

III. DISCUSSION AND SCOPE OF RESEARCH

a) Description of Negative sequence protection:

Negative sequence currents are produced because of the unbalanced currents in the power system. Flows of negative sequence currents (I2) in electrical machines (generators and motors) are undesirable as this current generates high and possibly dangerous temperatures in very short time. This high temperature can damage the insulation of the machines. Phase current and voltage in the three phase system can be represented in the form of three single phase components. Positive sequence components, Negative sequence components and Zero sequence components. Positive sequence components will have the sequence component rotation (vector rotation) in the same direction as the power system voltage and current components. Positive sequence currents exist during the balanced load condition. In a generator if the phase currents are equal and the vectors are displaced by 120^{o} (supplying balanced load), only positive sequence components flow in the power system. When any unbalance exists in the system, unbalances exist in voltage and current components both in magnitude and phase angle then only negative sequence components will flow in the power system. These negative sequence components will have same magnitude as positive sequence components but rotate in opposite direction to the positive sequence components in the power system. The zero sequence components flows during unbalanced condition will cause the current to flow through the neutral of the power system. There are more than one reasons which causes flow of unbalance current in generators, some are

- Unbalance loading in the system whether machine is connected with grid or runs in Is-land mode
- Unbalance system faults (line to ground faults, two phase faults, three line to ground faults, double line to ground faults)
- Open phases (open circuit faults)

These negative sequence components induce double frequency currents in the surface of the rotor, the slot wedges of the rotor, the retaining rings, and the filed windings of the rotor of the machines. This doubly induced high frequency currents will rise the rotor temperature very high and damages the machine if operates continuously. This is explained below.

Rotor heating phenomenon in rotating machines- Unbalanced currents will generate negative sequence components which in turn produces a reverse rotating field (opposite to the synchronous rotating field normally induces emf in to the rotor windings) in the air gap between the stator and rotor of the machines. This reverse rotating magnetic field rotates at synchronous speeds but in opposite direction to the rotor of the machine. With respect to the rotor surface, this reverse rotating magnetic fields induces double frequency currents into the rotor body in the case of cylindrical rotating machines (generators driven by steam turbine and motors) and induce double frequency currents in the pole faces in case of salient pole machines (generators driven by hydro turbines). This resulting induced currents into the rotors will provide high resistance path to the normal induced currents (generated due to synchronous rotating magnetic field) resulting in the rapid heating. This heating effect in turn results in the loss of mechanical integrity or insulation failures in electrical machines within seconds. Therefore it is undeniable to operate the machine during unbalanced condition when negative sequence currents flows in the rotor and has to be protected.

In case of Induction motors, 5% unbalance exist can cause the reduction in the motor power by 25% even the induction motor continues to get the rated current before unbalancing. This reduction electrical power of the induction motor attributes to heating in the rotor. The unbalance present in the supply voltage by 3% can increase the rotor heating by approximately 20%. This proper protection shall be provided against the unbalanced currents in induction motors.

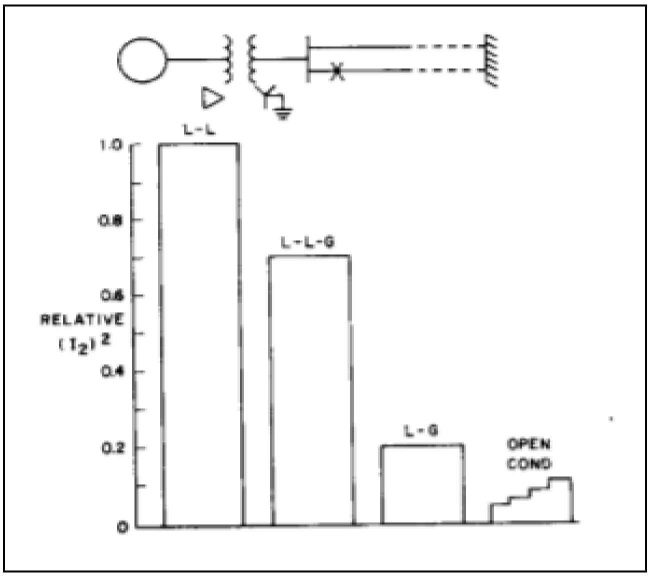

Figure.3. Relative negative sequence duties for system unbalance conditions

Fig. C illustrates the relative severity of these disturbances in terms of I2, which is proportional to the rate of generator rotor heating, and indicates that the line-line fault is the most severe from this standpoint. The "open conductor" cases are the least severe but perhaps are the most insidious in that they may more easily escape detection. An open phase condition caused by a broken conductor will usually be accompanied by a fault with prompt clearing times. An open phase resulting from mis-operation of one of pole of a 3phase circuit breaker requires other means than the normal line fault relaying to detect.

ANSI Requirements (1965) for Unbalanced Faults on Synchronous Machines

Types of Synchronous Machine -	Permissible I_2^2t
Salient pole generator	40
Synchronous condenser	30
Cylindrical rotor generators indirectly cooled	30
Directly cooled	10

Progress made in the design of large turbine generators has again suggested a review of power system needs and generator capabilities for unbalanced faults, and a proposal for standards revision for directly cooled generators has been made by the ANSI C50.1 Subcommittee on Synchronous Machines. This proposal has the form of a relationship between generator I_2^2t capability and generator kVA rating as shown in the Fig D. In addition to that generator should capable to withstand thermal effect of unbalance faults at terminals including decaying effect of Field current, where protection is provided by causing field current reduction, such as with an exciter field breaker or equivalent and DC component of stator current.

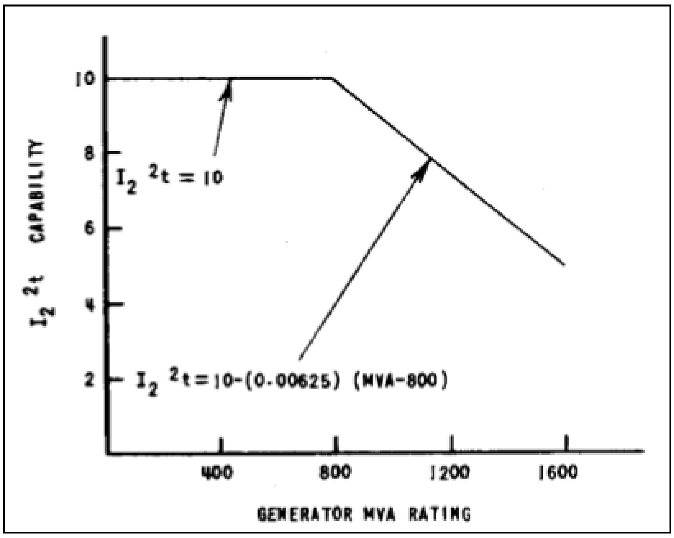

Figure.4. Unbalance fault capability (I_2^2t) of machine as a function of generator MVA rating

At the request of the ANSI C-50.1 Subcommittee the IEEE Power System Relaying Committee was asked in late 1971 to develop specifications for continuous withstanding capacity for negative sequence current of machine as detailed above.

- For salient pole machine- 12%
- For cylindrical rotor- 10%

(Note- above values are specified provided that rated machine KVA is not exceeded its rated and the maximum current does not exceed 105 percent of rated in any phase. Negative phase sequence current is expressed in percent of rated stator

b) Circuit diagram for NSR and its characteristics:

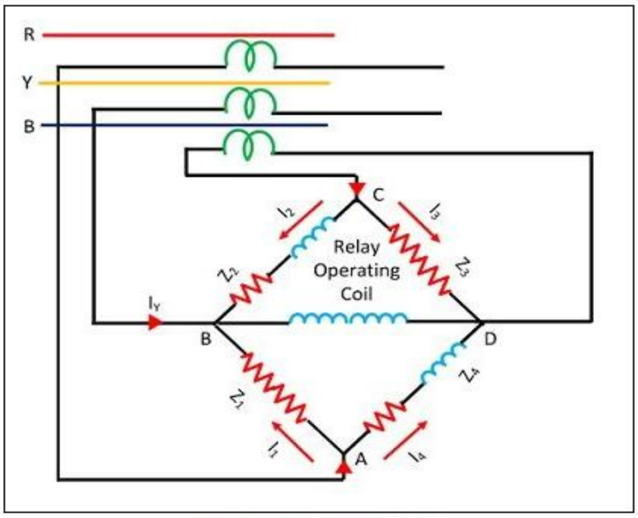

Figure.5. Circuit diagram for negative sequence relay

The figure E- shown below illustrates the scheme used for negative phase sequence relay. A network consists of four impedance Z_1, Z_2, Z_3 and Z_4 of equal magnitude connected in a bridge formation is energized from three CTs. A single pole relay having an inverse-time characteristic is connected to the circuit shown as above. Z_1 and $Z_2$are non-inductive resistors while Z_2 and Z_4 are composed of both resistance and inductance. The value of Z_2 and Z_1 are so adjusted that the current flows through them lag behind those in impedance Z_3 and Z_1 by 60º. The relay is assumed to have negative impedance. The current from phase R at junction A is equally divided into two branches as I_1 and I_4, but, I_4 will lag behind I_1 by 60º.

$$I_1 = I_4 = \frac{I_R}{\sqrt{3}} \qquad I_R^2 = I_1^2 + I_4^2 + 2I_1I_4\cos 60^\circ$$

Similarly, current from phase B split at junction C into two equal components I_3 and I_2, I_2 lagging behind I_3 by 60º.

$$I_2 = I_3 = \frac{I_B}{\sqrt{3}}$$

I_1 leads I_R by 30º while I_4 lags behind I_R by 30º. Similarly, I_2 lags behind I_B by 30º,whereas I_3 leads I_B by 30º. The current through the relay operating coil at junction B will be equal to phasor sum of I_1, I_2 and I_Y.

$$I_{relay} = I_1 + I_2 + I_Y$$

$$\frac{I_R}{\sqrt{3}} = leading\ I_R\ by\ 30^\circ + \frac{I_B}{\sqrt{3}} lagging\ I_B\ by\ 30^\circ + I_Y$$

The flow of Positive Sequence Current –The phasor diagram of positive sequence components is shown in the figure below. When the load is in balanced conditions, then there is no negative sequence current. The current flow through the relay is given by the equation

$$I_1 + I_2 + I_Y = 0$$

$$I_1 + I_2 = -I_Y$$

So the relay remains in-operative for a balanced system.

The flow of Negative Sequence Current – In the bridge circuit it is shown that the current I_1 and I_2 are equal but opposite to each other, so they cancel each other and I_Y current flow through the relay operating coil. Thus the relay operates due to the flow of the I_Y. A low setting value well below the normal full load rating of the machine is provided with comparatively small values of unbalanced current produces a great danger.

The flow of Zero Sequence Current– The current at junction B of the relay is represented by the phasor diagram from which it is observed that the current I_1 and I_2 are displaced from each other by 60º, so the resultant of these current is in phase with current I_Y. Thus the relay would operate by the twice of the total current flow through it. For making the current inoperative, the CTs are connected in delta as shown in the figure and then no zero sequence current can flow in the network circuit.

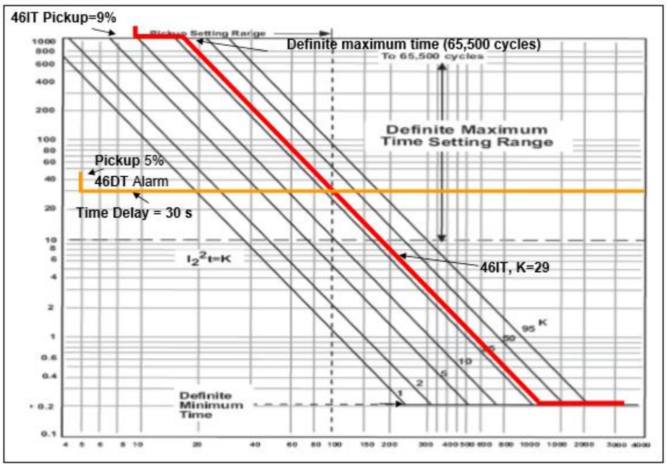

Figure.6. Characteristics for negative sequence relay

c) Method of calculating I_2:

Symmetrical components are most commonly used for analysis of three-phase electrical power systems. The voltage or current of a three-phase system at some point can be indicated by three phasors, called the three components of the voltage or the current. This article discusses voltage however, the same considerations also apply to current. In a perfectly balanced three-phase power system, the voltage phasor components have equal magnitudes but are 120 degrees apart. In an unbalanced system, the magnitudes and phases of the voltage phasor components are different. Decomposing the voltage phasor components into a set of symmetrical components which helps analyse the system as well as visualize any imbalances. If the three voltage components are expressed as phasors (which are complex numbers), a complex vector can be formed in which the three phase components are the components of the vector. A vector for three phase voltage components can be written as

$$\mathbf{v}_{abc} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

Further decomposition of vector into three symmetrical components could be expressed as

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} V_{a,0} \\ V_{b,0} \\ V_{c,0} \end{bmatrix} + \begin{bmatrix} V_{a,1} \\ V_{b,1} \\ V_{c,1} \end{bmatrix} + \begin{bmatrix} V_{a,2} \\ V_{b,2} \\ V_{c,2} \end{bmatrix}$$

Here 0, 1, 2 are representates zero, positive and negative phase sequence respectively which are symmetrical components and displaced with each other by 120* or 2π/3 radians.

For representating vectors we use operators α, which rotate the vector counterclockwise by120 degree.

ie $\alpha = 2/3 * e^{(2\pi/3)}$

Here It is to be noted that $\alpha^3 = 1$ and $\alpha^{-1} = \alpha^2$

The zero sequence components have equal magnitude and in phase with each other, therefore

Vo = Vao = Vbo = Vco

and the other phase sequences have the same magnitude, but their phases differ by 120°

so, $V_1 = V_{a1} = \alpha^* V_{b1} = \alpha^{2*} V_{c1}$

$V_2 = V_{a2} = \alpha^{2*} V_{b2} = \alpha^* V_{c2}$

Thus

$$\mathbf{v}_{abc} = \begin{bmatrix} V_0 \\ V_0 \\ V_0 \end{bmatrix} + \begin{bmatrix} V_1 \\ \alpha^2 V_1 \\ \alpha V_1 \end{bmatrix} + \begin{bmatrix} V_2 \\ \alpha V_2 \\ \alpha^2 V_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix} = \mathbf{A}\mathbf{v}_{012}$$

where

$$\mathbf{v}_{012} = \begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix}, \mathbf{A} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix}$$

Therefore sequence components are derived from this analysis equation

$$V_{012} = A^{-1} * V_{abc}$$

Whereas

$$\mathbf{A}^{-1} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}$$

The above two equations tell how to derive symmetrical components corresponding to an asymmetrical set of three phasors:

- Sequence 0 is one-third the sum of the original three phasors.

• Sequence 1 is one-third the sum of the original three phasors rotated counter clockwise 0°, 120°, and 240°.
• Sequence 2 is one-third the sum of the original three phasors rotated counter clockwise 0°, 240°, and 120°.

Visually, if the original components are symmetrical, sequences 0 and 2 will each form a triangle, summing to zero, and sequence 1 components will sum to a straight line.

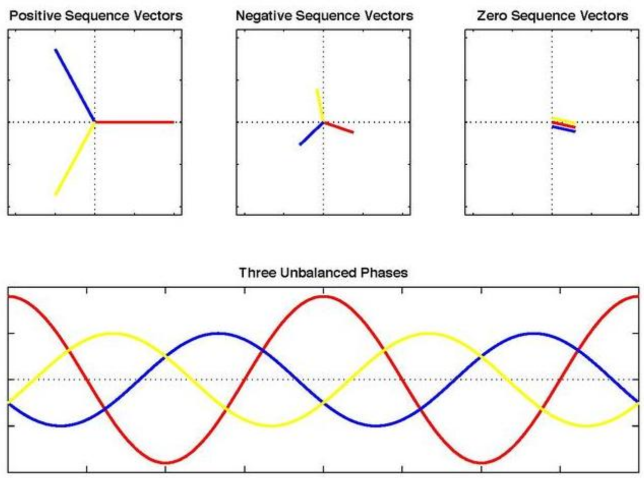

Figure.7.Representation of positive, negative and zero sequence components

d) Type of relay used:

Any micro-processor based standard makes relay ie SIEMENS, ABB, GE, AREVA could be used for negative sequence protection and generally it is incorporated as one of the function in multifunction relay used for complete generator protection package. It has two measuring stages with time delay and wide setting rang. Stage1- is having DT characteristic with 105% (rated gen current) pick-up with standard time delay of 30 sec Stage2- is having IDMT characteristic and for K= of 29 (I_2^2t) it comes around 65500 cycles(3.2sec) .

IV. PROPOSED METHODOLOGY

With reference to our earlier discussion we came to know that negative sequence currents in the system are developed because of unbalanced current (I_2) present in the system . The reasons of production of I_2 are anyone such as unbalance loading, unbalance faults and open phases. These unbalance current produces emf in the rotor body of machine whose direction is opposite to the original synchronous field of m/c a the undesirable heating in the mechanical parts of rotor as well as damages the insulation. Therefore machine has to isolate from bars quickly as it crosses the trip limit with reference to characteristic as given above. Herewith I am trying to explain negative sequence phenomenon by adopting MATLAB Simulink procedure, which is further categorized in three basic block diagrams as mentioned below.

a) Three phase Simulink diagram of machine.
b) Negative phase sequence Relay (Subsystem-1)
c) Control system (subsystem-2)

a) Three phase Simulink diagram of machine:

With reference to figH- Generator is assumed as dynamic source with specification as 36MVA, 11KV and 50 Hz 3-phase AC source supplying to load through three single phase breakers whose initial conditions are assumed as closed. Connected load is configured as three phase Y connected but having unbalance in nature ie 10MW, 10MW and 1 MW in R, Y and B phases respectively. CT are in-cooperated between machine and CB both for measurement and giving analog input to relay for protection purpose. This three phase diagram is consisting of two sub systems ie 'Negative sequence block' and 'control system' respectively which are explained subsequently in this chapter.

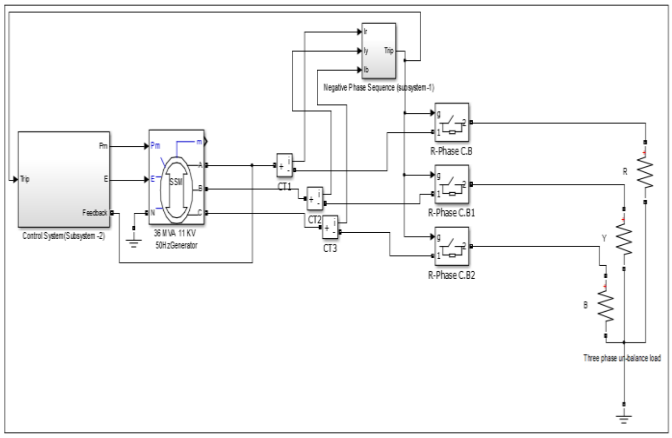

Figure.8. Three phase Simulink diagram for generator

b) Negative phase sequence relay:

With reference to Fig I- below, R, Y, B phase currents are taken as input to this block and given to adder. One thing to be noted is R-phase currents are taken directly, Y-phase, B-phase currents are shifted -120* and -240* for simulating negative sequence current after wards adder output is converted into p.u value by dividing it through rated generator current and given to scope. Then further these values are given to two no of 'IF' blocks and it issues trip command after set delay of 4 sec and current magnitude 10% (set value). The output trip signal of this block is used to issue trip command to the generator circuit breaker as well as issues signal to control block for reducing P_m and E to zero simultaneously.

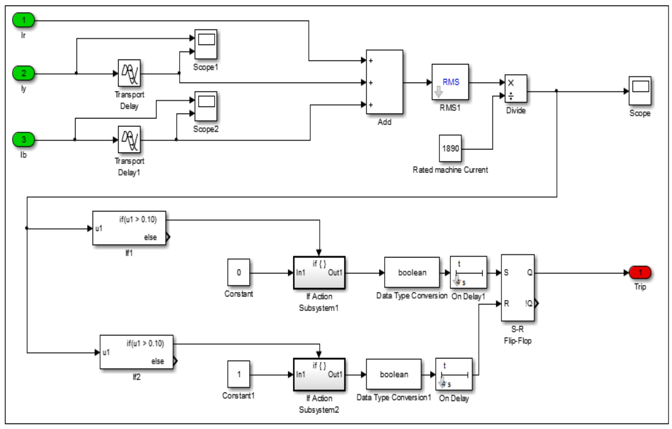

Figure.9. Simulink diagram for NSR (Subsystem-1)

c) Control system:

With ref to Fig J below feedback-1 is tapped from generator terminals to voltage measurement block and further it is converted into frequency in convertor module. This frequency signals given to switch-1and converted into p.u value at 50 Hz base, further switch-1 output is given to 1/R2 gain block. Here two blocks are taken into control module ie governor and turbine transfer function blocks which are [1/(2s+1)] and [(1/(s+1)] respectively. The output of this control block which are having integrator, adder and different gains are given to switch-2 for generation of mechanical power Pm which is input to turbine. Here 30 MW (30e6) are reference input to switch-2 which is machine rating. Machine excitation E is taken as constant value to produce 11000 volts at generator terminals. When trip command issued from negative sequence relay it will make P_m and E to zero instantaneously which is assumption that machine got tripped.

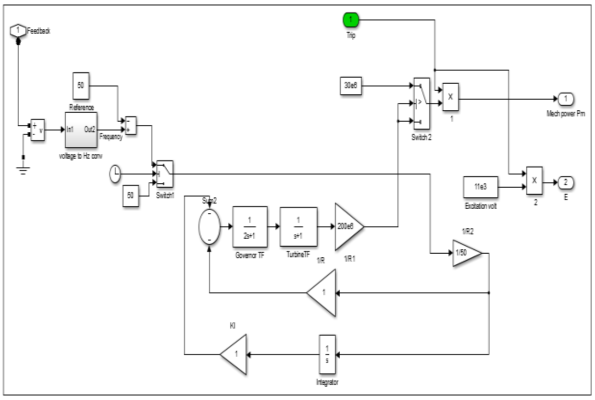

Figure.10. Simulink diagram for control system (Subsystem-2)

V. EXPERIMENTAL RESULTS

a) R-Phase waveform- With reference to fig below, R-phase waveform has been shown which is without any shift given to adder for p.u conversion and scope.

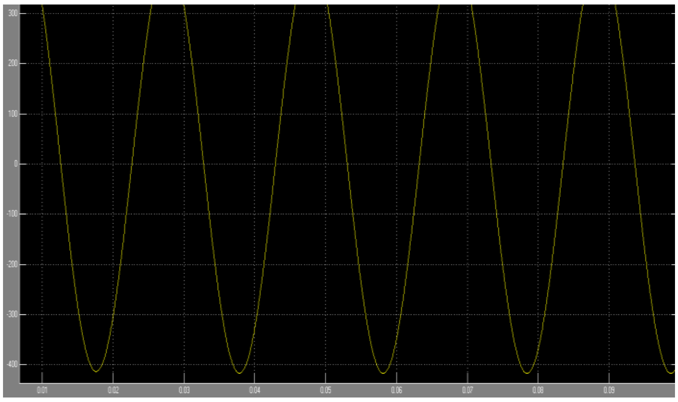

Figure.11. R-Phase current wave form without any Phase shift

b) Y-Phase waveform- With reference to Fig-L below, top waveform is Y-phase current and bottom one is Y-phase current with 120* lag or delay

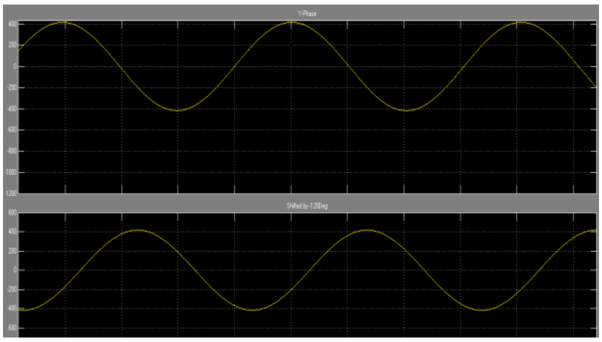

Figure.12. Y-Phase current wave form before and after phase shift

c) B-Phase waveform-With reference to Fig-M below, top waveform is B-phase current and bottom one is B-phase current with 240* lag or delay. Here current magnitude is lower as compared to R and Y phases because load applied on B-phase is 1e6 (1 MW) as compared to other two phases. Time duration for capturing waveform is same for 100mSec. The above has done for simulating negative phase sequence current and operation of relay.

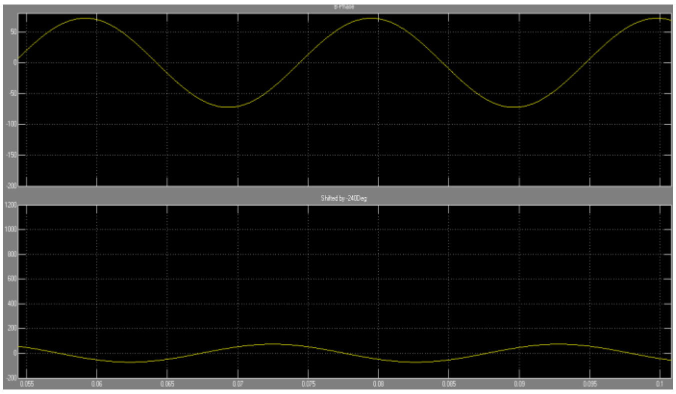

Figure.13. B-Phase current wave form before and after phase shift

d) Magnitude for Negative phase sequence current trip- With reference to fig N- below, trip value has set to 0.1 amps for 4.0 Sec delay to operate relay, so relay operated at 0.14 amps (>0.1 amps) and issues trip command after 4.0 sec and trip the circuit breaker connected to load, P_m as well as excitation E. Here relay characteristics are set as definite time (DT) for illustration but as per the earlier discussion DT characteristics are used to generate alarm at low set and IDMT characteristics is used to generate trip command for machine at 12% of rated generator current OR max value of phase current in the event of fault with calculated time delay of 40-50 sec as an standard settings.

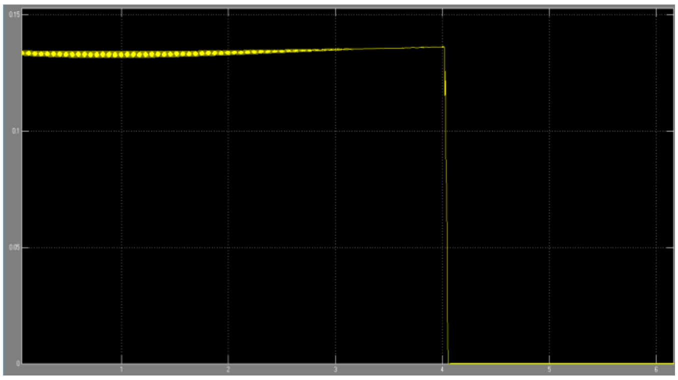

Figure.14. Representation of Negative sequence current (I2)

VI. CONCLUSION

It is already stated that Negative phase sequence Protection is one of the primary protection used for rotating machines ie Generators and AC motors to protect machine rotor from its undesirable effect of heating which results of insulation failure and damage core metals. Two different characteristics are used for this protection viz. DT is used for giving alarm signal to operator at low values of I_2 and IDMT characteristics are used for issuing trip signal to machine. Here I am using DT characteristics for explain functioning of Negative sequence current.

VII. REFERENCES

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