International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 03 - Issue 02 || February 2017 || PP. 37-42

Loss of Excitation protection of generator in R-X Scheme

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Abstract: Generator is one of the most important equipment in the power system. So when a fault occurs in generator it affects entire power system. When loss of excitation (field failure) condition occurs on a generator, it causes severe damage both on generator as well as interconnected system. When a generator loss its field, the speed of the generator will increase and hence it will act as asynchronous generator, so it draws reactive power from the system, so the total reactive power load on the system will be nearly double the reactive power supplied by the generator earlier. If the system is enable to feed this large reactive power requirement, then the power system will be unstable resulting in collapse of voltage. In this paper focus on RX scheme for generator excitation protection during excitation failure and during external fault.

Keywords: Generator protection;loss of excitation protection;RXscheme,active and reactive power

I. INTRODUCTION

Loss-of-excitation (LOE) protection of synchronous generator is becoming more and more important with the development of power system. This is because LOE is a common fault for synchronous generators, which may cause serious damages to generators and the interconnected power systems. When loss of excitation occurs its speed will increase above the synchronous speed, and will start to operate as asynchronous generator and taking reactive power from the system instead of supplying it. This may cause severe damage to the generator itself and to the power system to which the generator is connected [1-2], since loss of excitation results in:

• Massive over loading of the generator armature winding, which generate eddy current at a slip frequency in a rotor winding so this results in massive thermal heating in the rotor body.
• Massive voltage fall in the transmission lines with the possible drop-out of these lines, and loss of system.
• Failure of the magnetic coupling between the stator and the rotor sides, immediately following the reduce in the magnetic coupling between them.

For this reason, fast detection of loss of field excitation is required because if faulty generator is not trip in time than it affects the entire power system and also the other generator which is run in parallel. The primary indicator of field failure is the large reactive power flow into the generator, which is detected by impedance relay. The relay is operate if the impedance which is measured at the generator terminal is with in criteria.

Excitation system is commonly consists of an Automatic Voltage Regulator(AVR) and exciter. The Directs field current excites the field winding and it produce rotor flux which generates an internal voltage which is in synchronism with and opposed to the system voltage. When field is failed , the rotor current fall at a rate determined by the field circuit time constant and field voltage is also decrease. So finally the generator starts to consuming reactive power from the system instead of supplying it.

The fall of internal voltage also weakliness the magnetic coupling between the rotor and stator. At some point during the reduction, the coupling will become too weak to transmit prime mover output to the electrical system and the generator will loss synchronism. [3]

The criterions used for Most of LOE is based on field under voltage/current criterion, impedance criterion and reverse reactive power criterion. These criterions are able to distinguish LOE from external fault and other disturbances such as power swing etc[5].

Generator loss of excitation can be caused by[4]
Short circuit of the field winding
Accidental tripping of a field breaker
Field open circuit
Voltage regulation system failure

According to the china statistics 60% of generator failure occur due to loss of excitation. For these reasons, LOE protection schemes are required to detect the Loss of Excitation condition rapidly as possible otherwise it affect the interconnected system [4].

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This paper shows the behavior of R-X scheme during Loss of Excitation condition and during External fault.

II. EXISTING PROTECTION SCHEMES

There are five Loss of Excitation protection schemes used, namely, R-X scheme, R-X with Directional element scheme, P-Q scheme, G-B scheme and V-I scheme. In this paper focus on R-X scheme which is widely used in power system[4].

Table 1: Different LOE Schemes

R-X Scheme	LOE protection scheme which is based on generator terminal impedance measurement in R-X plane.
P-Q Scheme	LOE protection scheme which is based on generator terminal admittance measurement in G-B plane.
G-B Scheme	LOE protection scheme which is based on generator active and reactive power output measured in P-Q plane.
V-I Scheme	LOE protection scheme which is based on the measurement of phase angle between phase voltage and current

a) Impedance measurement scheme(R-X)

The impedance measurement scheme is most commonly used for LOE protection. The protection scheme applies an offset mho relay, which receive the terminal voltage and current as input signals for calculating the terminal impedance.

1) Mho distance relay

The distance relay is a relay which measure the impedance at fault point from the relaying point and it compare the impedance with pre-defined value and if it come in criteria than the relay operates. Mho relay is the most common type of distance relay and the characteristic of mho relay is shown in below figure.

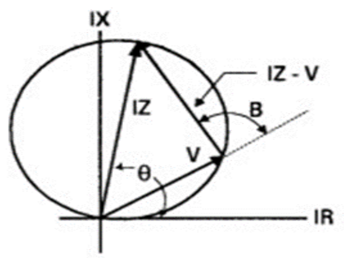

Figure 1 Mho relay characteristic

The origin of mho relay is determined by the relay PT and the angle between R axis and the line which extends through origin and center of characteristic circle, so called maximum torque angle.

The generator terminal impedance is calculated as:

$$
\begin{aligned}
Z &= V/I = V^2/(S^*) = [V^2*(P+jQ)]/(P^2+Q^2) \\
&= (V^2*P)/(p^2+Q^2)+j(V^2*Q) \\
&= R+jX
\end{aligned}
$$

Where V is positive sequence voltage and I is positive sequence current.

During normal operating condition the generator generates active and reactive power to the system so that both R and X are positive so the impedance located in the first quadrant in R-X plane.

When a generator lost its excitation, the speed of the generator will increase and hence it will act as an induction generator.so the generator starts to draws reactive power from the system and X becomes negative from the LOE relay point of view. As a result, the terminal impedance locus in R-X plane moves to the forth quadrant and the endpoint of terminal impedance ranges between the transient reactance and sub synchronous d axis reactance. The termination of endpoints depends on the initial load condition.

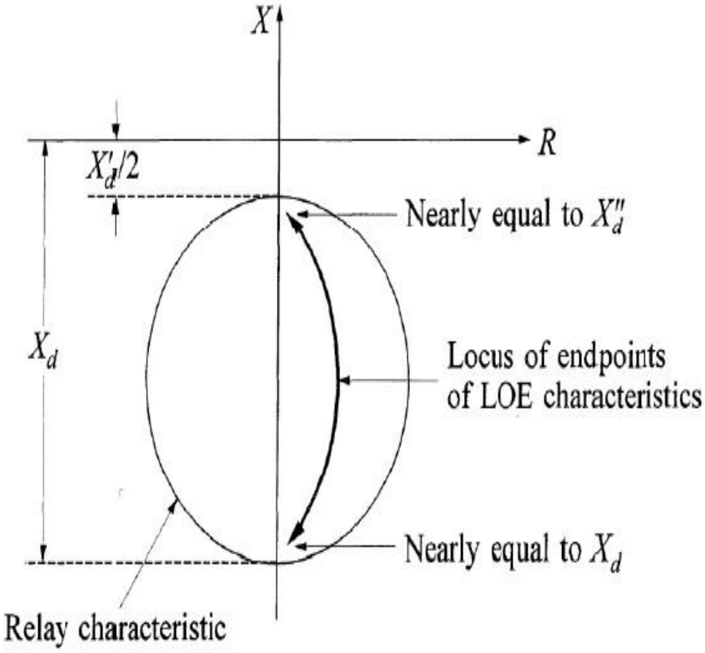

Figure 2 Terminal Impedance Characteristics after LOE[9]

2) Negative-offset mho element

The normal setting of the offset the offset mho in the impedance plane is a circle with a diameter of Xd and negative offset of Xd‟/2 as shown in figure. when the measured impedance comes into the operating region, the relay will be picked up and after a certain time delay to increase Sthe security for power swing, a trip signal will be sent to the generator main breaker.

The value of X_d for modern large generator is typically about 1.5-2 p.u. and the diameter of the LOE relay characteristic must be larger than X_d.

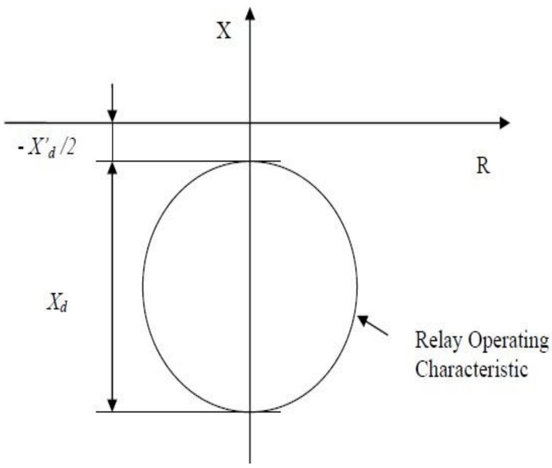

Figure 3 LOE protection scheme using a negative-offset mho element[9]

III. SIMULATION STUDIES & RESULTS:

Model Description:

The model is established in PSCAD and simulates the LOE of a hydro generator. The model configuration is shown in figure. The simulation model includes one salient pole generator [10] which are connected to a common bus via delta-star connection step-up transformer[10].

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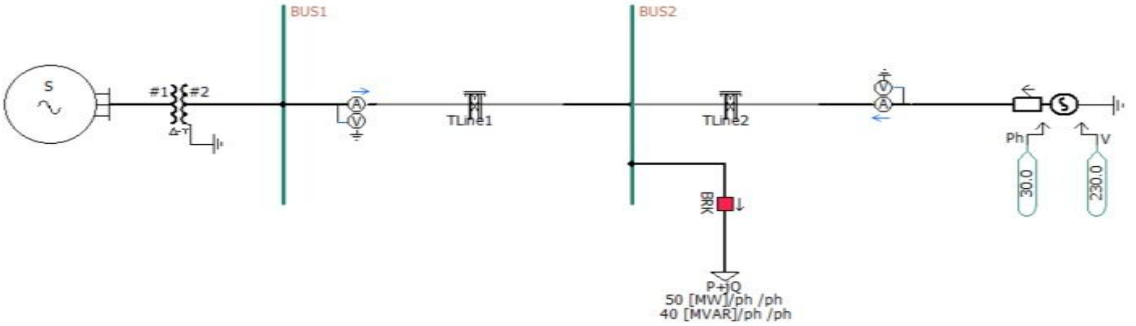

Figure 4 Simulation model

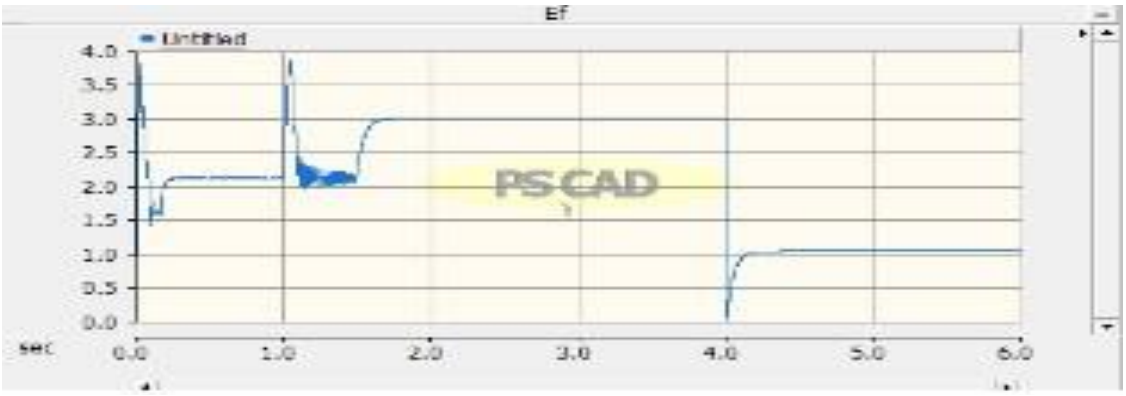

Figure 5 Excitation voltage wave form during LOE

FIGURE 6 FIELD CURRENT WAVEFORM DURING EXCITATION FAILURE

Figure 7Vrms during LOE

Figure 8Irms during LOE

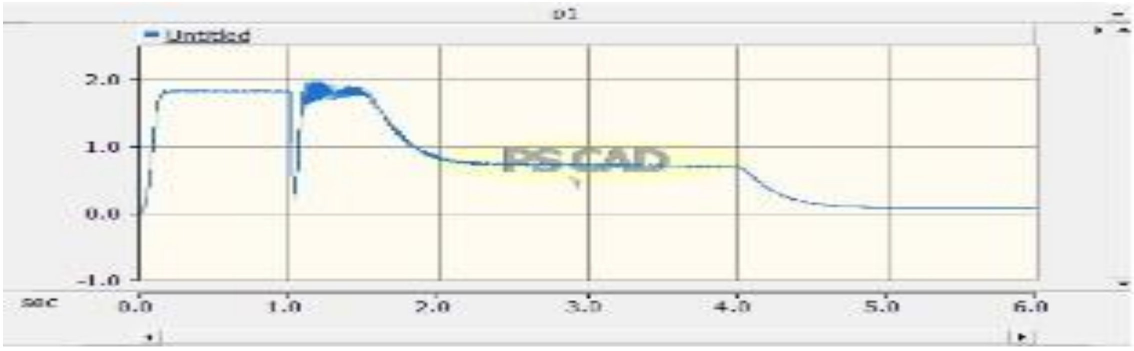

Figure 9 Active power during LOE

Figure 10 Reactive power during LOE

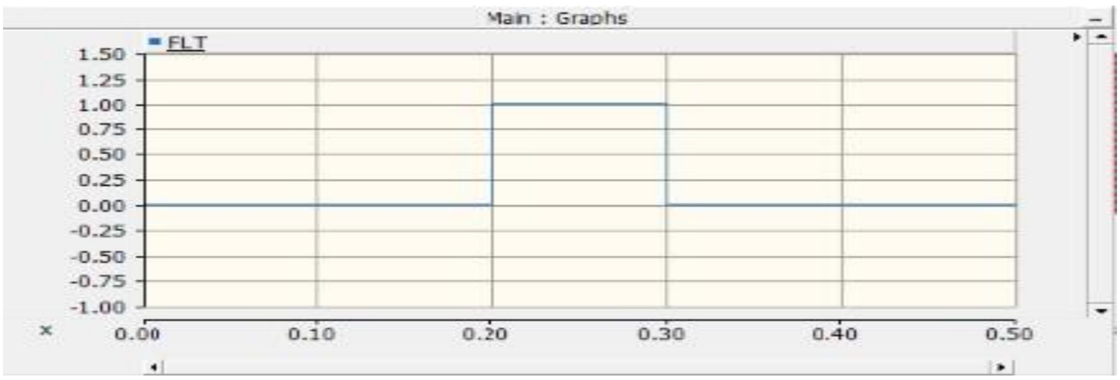

Figure 11 Fault signal

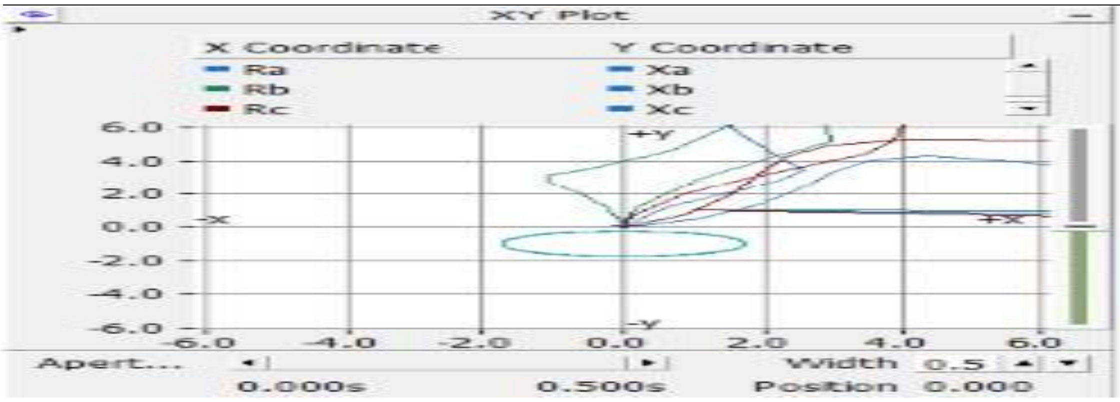

Figure 12 R-X Cha. during phase to phase fault

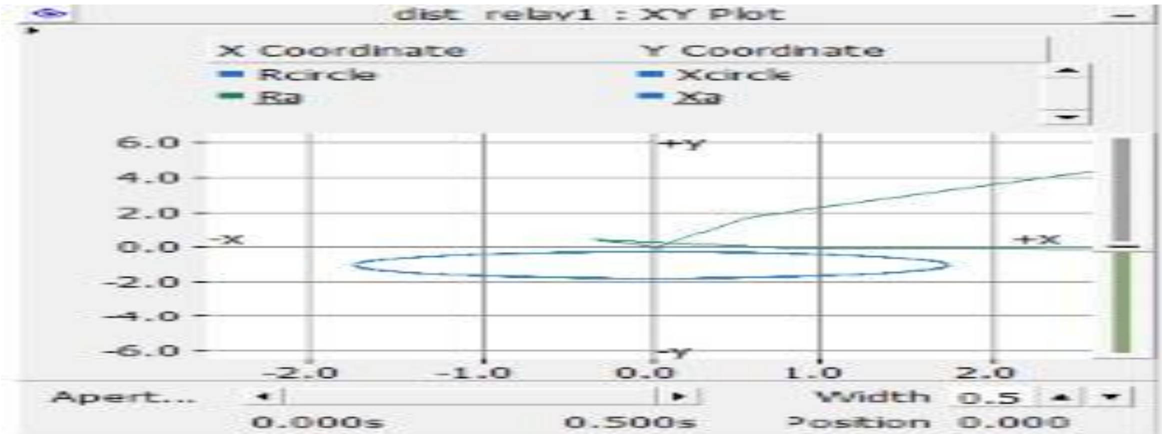

Figure 13 R-X Cha. during phase to ground fault

CONCLUSION:

From the results obtained, it has been found that when loss of excitation occurs the filed current decreases. The active power and reactive power also decreases. It has been also seen that during external fault such that when fault occurs on bus-bar the power swing characteristic does not enter in the R-X characteristic and this is the advantage of R-X scheme.

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