

GENERATOR ROTOR PROTECTION
LOSS OF FIELD PROTECTION
POLE SLIPPING

by

Sanpreet Kaur
Student ID: 250447390

ES 586b : Theory and Application of Protective Relays

Project Report

Department of Electrical and Computer Engineering
The University of Western Ontario
London, Ontario, Canada
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1. Introduction

In this project I am going to discuss various protection methods used for rotor protection, loss of field and pole slipping.

In the rotor mainly faults are earth faults or inter turn faults these are caused by thermal and mechanical stresses.

The field system is normally ungrounded so when a single fault between field winding and rotor body exist does not give rise to any fault current. But when second earth fault exist it short circuit the rotor winding and therefore produce an unsymmetrical field system and unbalance force on the rotor. This causes vibration of the rotor and damage to the bearings. So rotor earth fault protection is provided to restrict the fault spreading.

Because of this fault, unbalance in three phase stator currents exists. As unbalance three phase currents have a negative sequence component, it rotates in a opposite direction at synchronous speed giving rise to double frequency currents. This results in overheating of the rotor and other damage to the rotor. So rotor temperature indicators are used for detecting the rotor overheating.

Rotor open circuit faults are very rare to exist causes arcing problems and reduced excitation. Loss of excitation or field failure occurs due to short circuit or open circuit in field winding. In this case generator start running as induction generator, supplying power at leading power factor. Due to loss of excitation loss of synchronism and system stability occur. In this case rotor protection can be done by using tripping scheme which opens field circuit breaker which will trip the generator unit breaker.

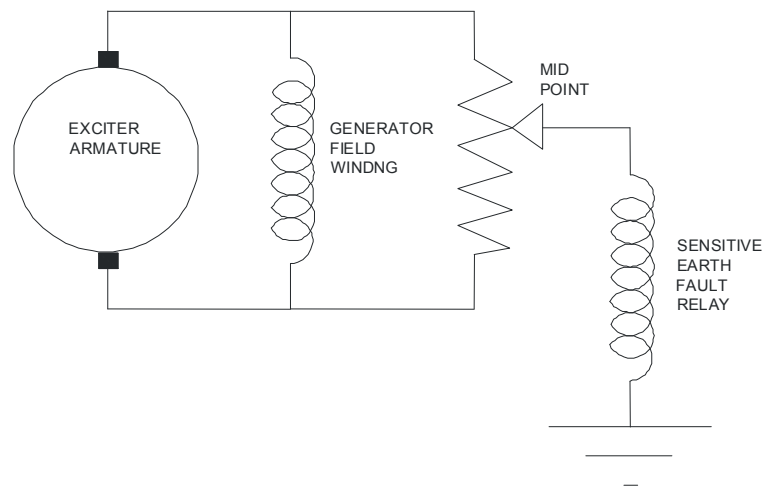
2. Rotor Protection

Different Protection schemes are used for protection of faults occurring in rotor. These schemes are:-

2.1 Rotor earth fault protection:-As the field circuit are operating unearthed a single earth fault does not affect the operation of the generator. But this fault increases the stress to the ground because stator transients induce an extra voltage in the field winding. So if there is only single earth fault but relay should be provided to give the knowledge that fault has occurred so the generator may take out of service until second fault occurs and cause serious damage. Two methods are used for rotor earth fault protection.

- **Method I-** In this method a high resistance is connected across the rotor circuit and its mid point is grounded through a sensitive relay. This relay detects the earth fault for whole circuit except the rotor center point

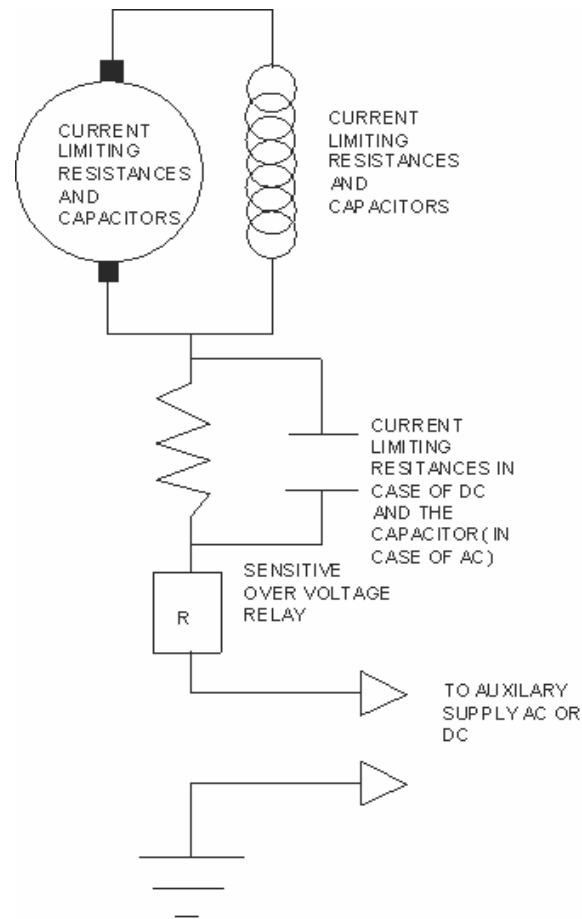
*Fig1: Rotor Earth
Fault Protection
Method I*



- **Method II-** In this method dc injection or ac injection method is used. In it either dc or ac voltage is connected between the field circuit and ground through a sensitive over voltage relay and current limiting resistor or capacitor. A single earth fault in the rotor circuit will complete the circuit including voltage source, sensitive over voltage relay and earth fault. DC injection method is simple and has no problems of leakage currents. If we use dc the over voltage relay will be more sensitive than if we use ac

because in case when we use ac the relay not picking up the current that flows normally through capacitance to ground and also care should be taken to avoid resonance between capacitance and inductance.

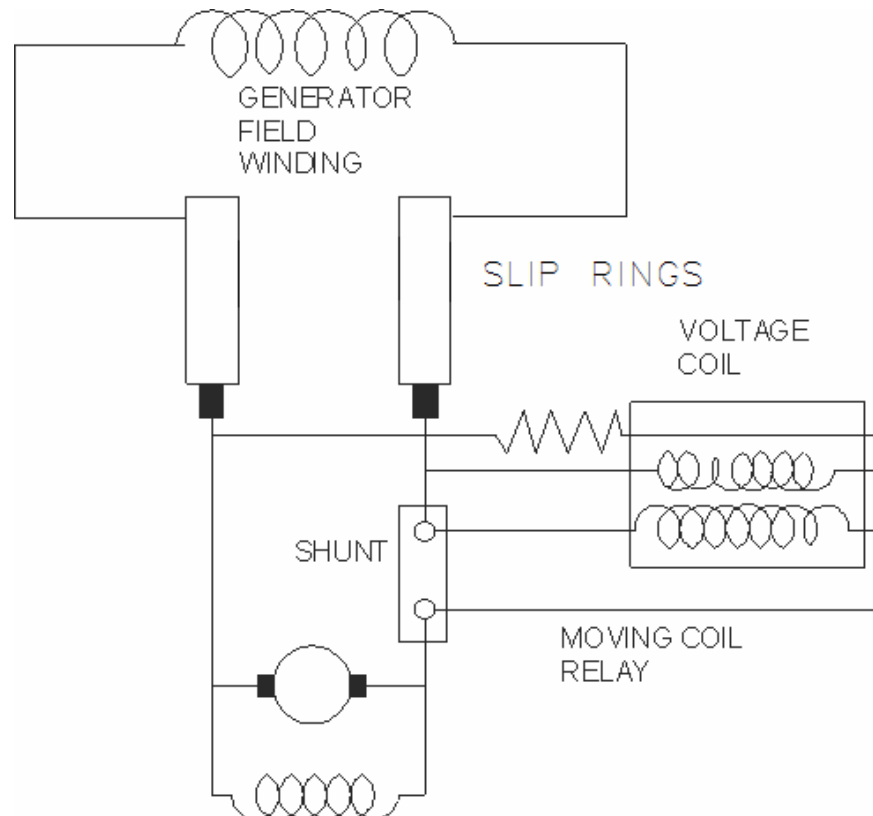
*Fig 2: Rotor Earth
Fault Protection
Method II*



2.2 Rotor overheating Protection:- Negative sequence component of the unbalanced currents of the stator winding causes double frequency current to be induced in the rotor winding due to this component overheating of the rotor take place. In case of over current due to over excitation in the rotor circuit, a dc relay is used. This relay senses and initiates alarm. Application of such relay is limited because relaying of dc quantities is relatively uncommon.

- **Rotor Temperature Alarm:-** This kind of protection is only provided in case of large generators. It gives the level of temperature. In it resistance is measured by comparing voltage and current by a double actuating quantity

moving coil relay. The operating coil being used as voltage coil and restraining coil used as current coil. The relay measure the ratio of voltage and current because resistance gives the measure of rotor temperature.



*Fig 3: Rotor
Overheating
Protection*

- **Automatic Field Suppression and Use of Neutral circuit Breaker:-**
When a fault on the generator winding exist even through the generator circuit breaker is tripped, the fault continues to be fed as long as the excitation will exist. For the quick removal of the fault, it is necessary to disconnect the field simultaneously with disconnection of the generator. So it is very necessary to discharge its magnetic field as soon as possible in short duration. Hence it should be ensured that all protection system not only the trip the generator circuit breaker but also trip the automatic field discharge switch.

2.3 Loss of Excitation Protection:- Loss of field failure or loss of excitation is same phenomena and same kind of protection is used. It is discussed here in the field failure topic.

4. Loss of Field Protection

Loss of field occurs due to tripping of the supply of the field current which occurs because of the reasons.

- (i) Loss of field to the main exciter.
- (ii) Accidental tripping of the field breaker.
- (iii) Short circuit in field circuits.
- (iv) Poor brush contact in the exciter.
- (v) Loss of A.C supply to the excitation system.
- (vi) Operating errors.

Field Protection Phenomena: - When the field supply is tripped, its speed increases and it starts behaving as an induction generator so heavy currents are produced in the teeth and wedges of the rotor. Because of the drop in excitation voltage the generator output voltage drops slowly to compensate this voltage current starts increasing then the generator becomes under excited and starts drawing reactive power 2 to 4 times the generator load. Before losing excitation, the generator is delivering power to the system. But when loss of field occurs this large reactive load is thrown on the system abruptly with loss of generator's reactive power and it further causes voltage reduction and extensive instability.

Protection against Loss of field:-

- If the system has capability to tolerate the difference of reactive power then automatic protection is not required but if the system will be unstable in this condition and has not capability to tolerate then automatic protection is required.
- Under current Moving coil relay is connected across a shunt in series with field winding. But in case of large generators which operate over a wide range of field excitation then this relay will not work properly because

field failure due to the failure of the excitation is not detected by it because it is held in by the ac induced from the stator.

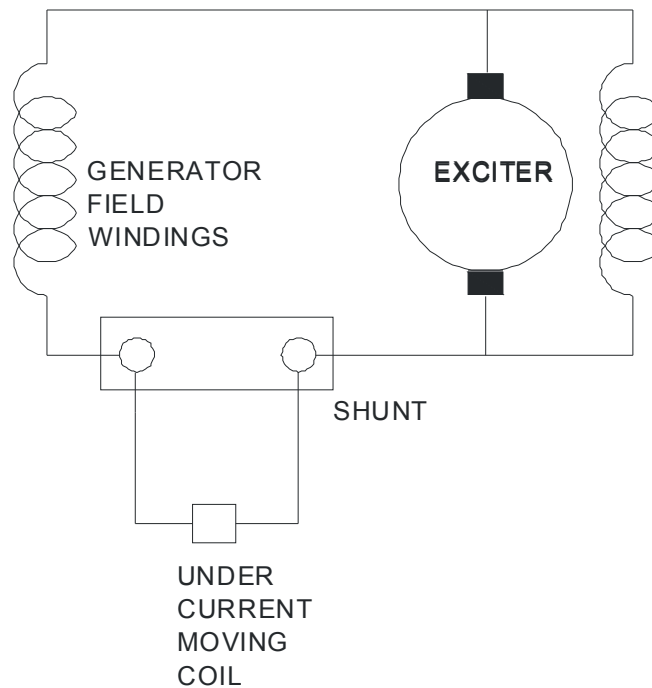
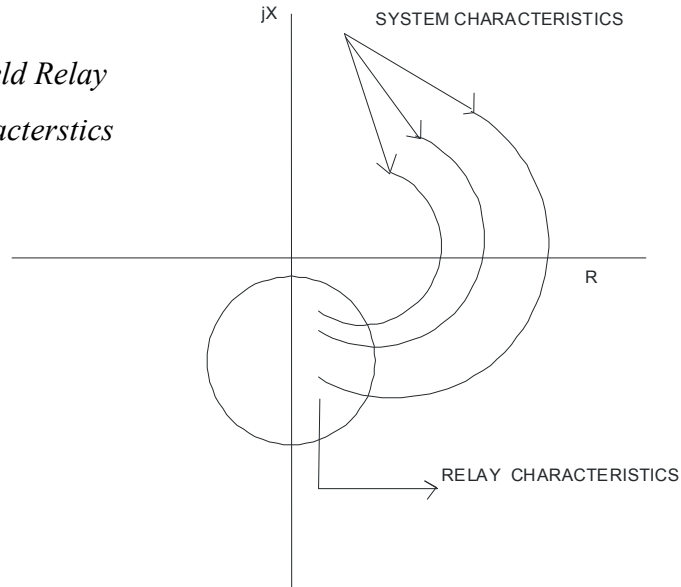


Fig 4: Loss of Field Protection

The most valid type of protection in this case is by using directional-distance type relay operating by alternating current and voltage at the generator terminals. In offset-mho relay is used and its setting is like that when the excitation goes certain value then this relay start operating because machine start running asynchronously. Its characteristics are shown on R-X diagram. When excitation is lost the generator impedance start a curve from the first quadrant to the fourth quadrant. This region is enclosed in the operating area of the relay so the relay will operate when the generator starts to slip poles and will trip the field breaker and disconnect the generator from the system. The generator may then return to service when the cause of failure is cleared.

*Fig 5: Loss of Field Relay
And system characteristics*



Effects produced by loss of field:-

- (i) It can endanger the generator , connected system or both.
- (ii) Loss of synchronism.
- (iii) Overheating of stator winding.
- (iv) Increased Rotor Losses.

5. Pole Slipping

When angular displacement of the rotor exceeds the stability limit then rotor slips a pole pitch or we can say rotor flux slips with respect to stator flux. This condition is called pole slipping.

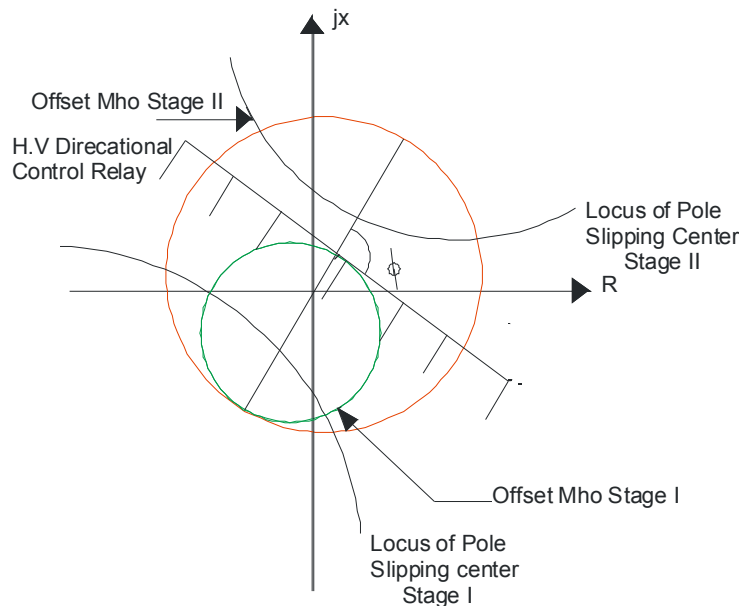
Causes:-

- (i) Power system fault that persists for long duration.
- (ii) Connecting line between two systems is opened.
- (iii) Because of the insufficient electromagnetic torque that keep rotor in synchronism
- (iv) Faulty excitation system.
- (v) Operating errors.

Pole Slipping Phenomena:- Pole slipping does not occur very often when faults are cleared very fast. When pole slipping occurs due to this synchronising power will start

flowing in reverse direction twice for every slip cycle. On drawing this synchronising power on the impedance plane the flow of it characterised by cyclic change in the load impedance and load impedance locus passes between +R and -R quadrants because real power flows in reverse direction. When the load impedance is very reactive in nature then two systems are 180 degree out of phase, this instant is when drawn on the jx axis the point corresponding to this instant is called transition point. At this stage only reactive power flows and system voltage reached to zero at the electrical mid point of the two systems. Mid point is that point where pole slipping take place and its location can be determined from the apparent load impedance to the point where the locus crosses the jx

Fig 6: Offset Mho type Pole slipping Protection



axis. Three parameters magnitude, direction and rate of change of load impedance with respect to the generator terminals tell us about the pole slipping, that is it taking place.

Need of Pole Slipping Protection:- High currents and torques can

- Loosen or causes wear off stator windings.
- Damage shaft and coupling.
- Stator and rotor overheating.
- Excitation system damage.

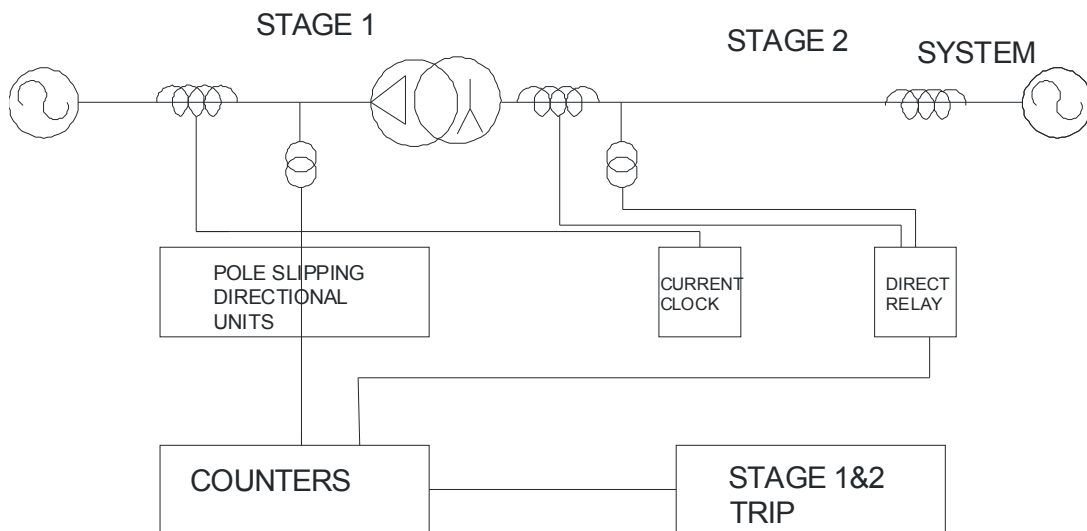


Fig 7: Block Diagram of the method used

This is protection against loss of synchronism. Impedance type protective relays are used in this case. There are two types relays connected to both current transformers and voltage transformers on l.v and h.v side of generator transformer respectively pole slipping detection relays and directional control relays. Protection can be done by two stages.

Stage I- Reaching through generator to neutral point into the transformer to cover the whole winding but not crossing the h.v terminals.

Stage II- Operation after adjustable no of pole slips whether the system center is in the generator transformer unit or out of it.

References

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