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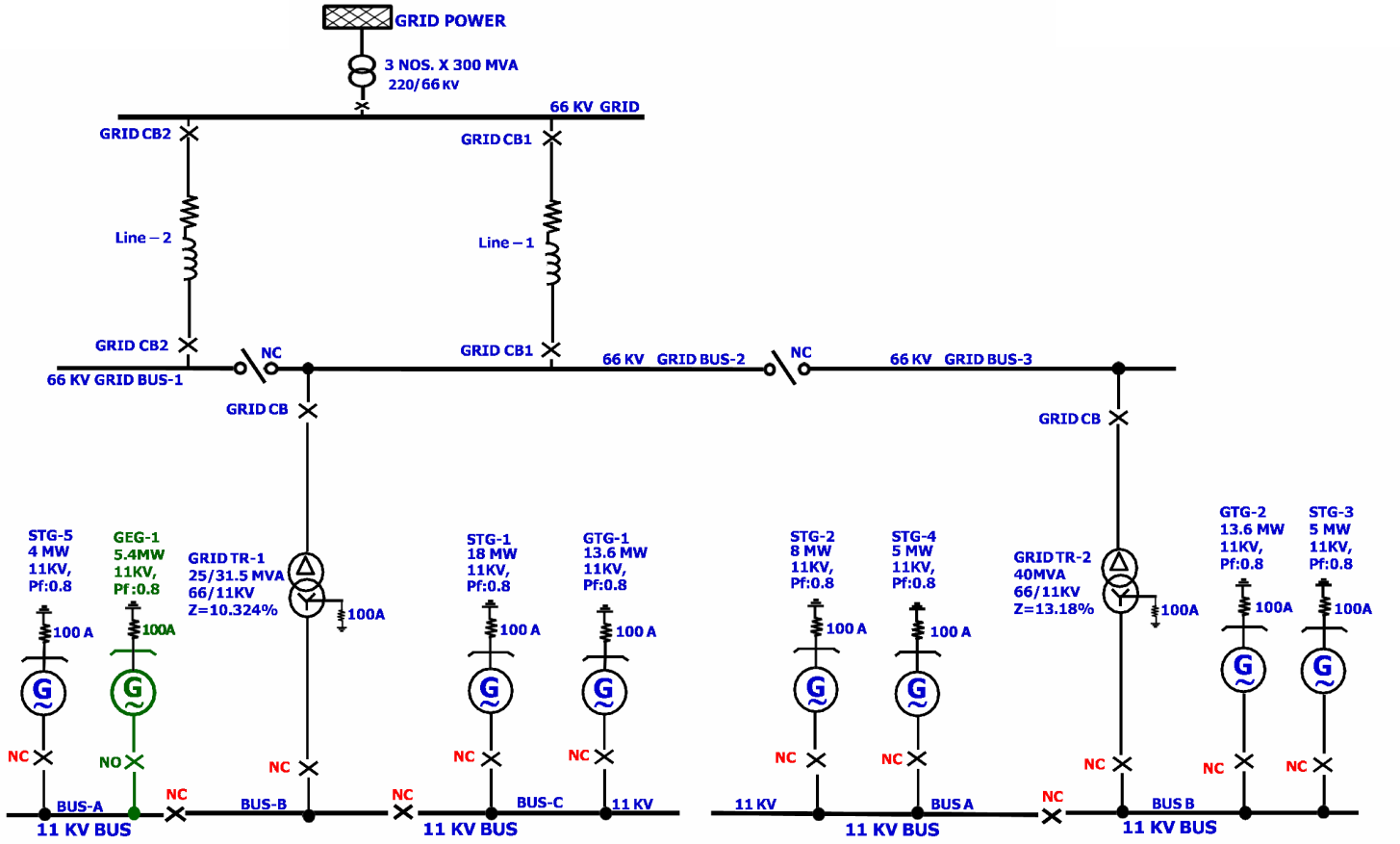
An Integrated Petrochemical complex with a load of app 90 MW and in-house Generation of app 72 MW is connected to grid power at 66kV. A typical distribution Key SLD is as follows.



This Plant experienced back to back faults in GTG 1 and GTG 2, Generator Main field excitation winding. The question being discussed in this Case Study-2 are;

- Why there are rotor faults and
- Why back to back failures for two GTG's for this power plant.

The reasons are as explained below with some introduction:

1. 0 : Types of Rotor Faults :

There can be two types of Rotor Faults:

1 : Inter turn(Between two turns) Fault and

2 : Winding to Earth Fault.

Field Excitation Winding of Generator i.e. Rotor winding is generally insulated from earth i.e. winding is ungrounded. So, on the occurrence of First Rotor Earth Fault, there is no immediate danger to the machine but on the occurrence of Second Rotor Earth Fault, there will be serious damage. The inter-turn fault is considered as a failure of insulation between two turns.

2. 0 : Why Rotor Earth Fault ?

The reasons for Rotor Earth faults can be anyone or multiples of the following reasons,

2.1 : Synchronization of Generator:

2.1.1 : When the generator is synchronized, the following four major parameters are required to be matched accurately,

a : Phase Sequence,

b : Phasing out,

c : Voltage matching and

d : Frequency matching.

2.1.2 : If any of the above parameters are not accurately matched as per set value then these can result in,

a : Large transfer of synchronizing power between two sources and

b : There are Chances of electrical pole slipping.

2.1.3 : This will result in,

a : Large Electromagnetic forces between, poles, the rotor turns and even between rotor and stator.

b : Lateral/transverse movements of the salient pole winding, resulting into friction between winding turns, thus damaging the thin insulation between two turns or turn to body insulation.

i : Rotor Winding Inter turn fault or

ii : Rotor Winding Turn to earth fault.

This occurance can be because of low skill manual synchronization.

In this occurance case of GTG-1 and GTG-2, it is understood that the "Auto Synchronizer" is utilized to synchronize the machine, thus such a possibility is ruled out unless Auto Synchronizer is bypassed and synchronization is done manually.

2.2 : Generators Directly Connected to Distribution Bus:

Review of Key SLD presented above indicates that Generators are directly connected to 11 kV Bus instead of Connecting through Generator Transformer to the bus.

As the Generators are directly connected to the 11 kV Distribution bus,

2.2.1 : All the faults within plant's 11 kV Distribution system are seen as direct terminal faults by Generator. This means that during every 11 kV distribution system faults, large electromagnetic forces are exerted between field poles, rotor and stator, resulting into the frictions between turns or turns to rotor body, thus the probability of rotor earth faults and failures.

2.2.2 : Generator 11 kV bus is also connected to Grid Power at 66 kV voltage system through 2 No's short 66 kV lines and 2 nos Power Transformers. So for all the faults in 66 kV lines, Grid 66 kV System or upstream 220 kV system, the fault current is contributed by the Generators. Again this results into large electromagnetic forces on field poles, winding and Stator and Rotor.

During the above fault conditions i.e. fault on 11 kV system and 66 kV system for electrically near faults with longer fault duration period above

CCT (critical clearance time) there are chances of electrical pole slipping, which can cause large forces and resultant effects as indicated above.

2.2.3 : Field Forcing during fault

Whenever there is a fault in the system, the fault current (MVAr) is to be supplied through enhanced excitation power. To achieve this requirement, the excitation system voltage is raised to field forcing state. This elevates the excitation voltage to 140 % or 170 % of nominal excitation system voltage along with higher excitation current. This operation can lead to failure of the field winding insulation if it is a frequent operation.

2.3 : Maintenance:

2.3.1 : It is understood that GTG-1 and GTG-2 both were sparingly utilized in recent past years. Coincidentally during the maintenance on this machine, the activity of the threading out of the rotor was not done for a long time.

2.3.2 : Being Gas Turbine machine, the Generators are mounted inside the enclosure. However, the Construction of this Generator is of inferior Class IP21 permitting the ingress of dust and moisture. IP21 Class construction permits solid bodies of less than 12.5mm diameter to get inside generator and water falling from any angle other than 90° inside the Generator. Also, the inlet Air comes with finer Coal dust from the surrounding area although required size / microns of Air filters were provided.

Because of this, the dust particles get accumulated between the pole windings (turns). The dust and moisture in an open environment where these two GT'S are installed are detrimental to the machine healthiness. The resultant electromagnetic forces during fault condition will damage the insulation which can result in turn to turn or turn to earth fault.

2.3.3 : For other Typical Size of Generator From,

a : Make-1: The IP Protection is of Class IP54.

b : Make-2: The IP Protection is of Class IP54.

Ip54 Class indicates that Machine is protected against the ingress of even dust particles and projections of water from all directions. Because of this, it is considered that two GT'S under discussion has very poor enclosure construction.

3. 0 : Why two generator's rotor faults failed on back to back

As narrated before both the GTG's were not in use for quite some time (Approx: 5 Years). Before these the machines were operating on full load, hence, overhauling and maintenance were not feasible for a long time. This resulted in back to back failure of the machine on rotor earth fault due to various reasons explained in item 2.0 above.

4. 0 : Recommendations for remedial measurement

The following are the recommendations to avoide recurring failure of rotor winding

4.1 : When the two machines rotor pole windings are being rewound, the rotor winding shall be provided with “Enamel fibreglass insulation”. This insulation will provide additional mechanical and electrical strength to respective windings.

4.2 : Every Generator circuit shall be connected to 11 kV distribution system through Generator Transformer. This will relieve / reduce the electromagnetic forces directly experienced by the Generator winding as well as field poles.

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4.3 : **As a part of regular maintenance,** once in 2 years Generator rotor shall be threaded out for maintenance, inspection, minor repair and rectification of stator as well as a rotor

4.4 : **During operation** whenever the Generator is loaded from the ambient temperature the Generator loading shall be raised slowly to permit uniform thermal loading. This will be like loading turbine to avoid thermal expansion.

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