KING FAHAD UNIVERSITY OF PETROLEUM AND MIERALS

ELECTRICAL ENGENEERING DEPARTMENT

Summer Training Report
In Saudi Electricity Company

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Abbreviations

A.P.P : Al-Aflaj Power Plant.

ONAN : Oil Natural Air Natural.

ONAF : Oil Natural Air Forced.

ROTADUCT : from Rotating Semiconductor.

H.V : High Voltage side.

L.V : Low Voltage side.

Introduction:

This report is a summary of summer training in Al-Aflaj Power Plant. The period of my summer training was divided into three parts:

- First 2 weeks were spent in the layout of gas turbine. Also in the Operation section I learned the steps of operating the gas turbine. And in transmission section for overhead lines.
- Next 3 weeks were spent in the layout of the generator. And I got the basic idea about the control circuits of the generators and its protection system.
- Last 3 weeks were spent in the layout of transformers. Also I learned how the electrical power distributed inside and outside the plant.

My supervisor introduced and illustrated to me each topic related to Gas Turbine Generator by using manuals and sketches then look at the plant physically. I have worked practically in maintenance section.

Throughout the period of my training, I was able to refer to many catalogues of pertaining of Gas Turbine Generator operation and maintenance. In my first days, I find out a lot of changes between studying and training and I was surprising from many things like capacitor bank and transformers because it not like what we studied or what we thought.

Al-Aflaj Power Plant

Al-Aflaj Power Plant is one of the largest power stations in SCECO-Central region. A.P.P. was started working in 1407H. It is located between Wadi Al-Dwaser and Al-Kharj and it is not connected to any other power plant. It consists of three departments, which are control department, generation department and transmission department. A.P.P. contains 7 gas turbine units each one produces 25 MW of power and 2 emergency diesel generators. Also, there are seven starts up transformers from 13.8 KV to 33 KV for short transmission lines and two set up transformers from 33 KV to 132 KV for long transmission lines. Al-Aflaj power plant now is bigger than old and its one of the station that going to be part of new project and it will feed this project. The new project is going to connect all SEC stations in one network and this network will work as one body and will help the big cities to use the electric that unused in small stations. Al-Aflaj power plant is connecting six stations in six towns and they had a specific number for each station. And that stations are Lila and its no. 8700 then Satarah and its number is 8702 then Al-Ahmar and its no. 8703 then Al-Haddar and its no. 8704 then Al-Badyea and its no. 8705 also there a station for Aramco is feeding SEC.

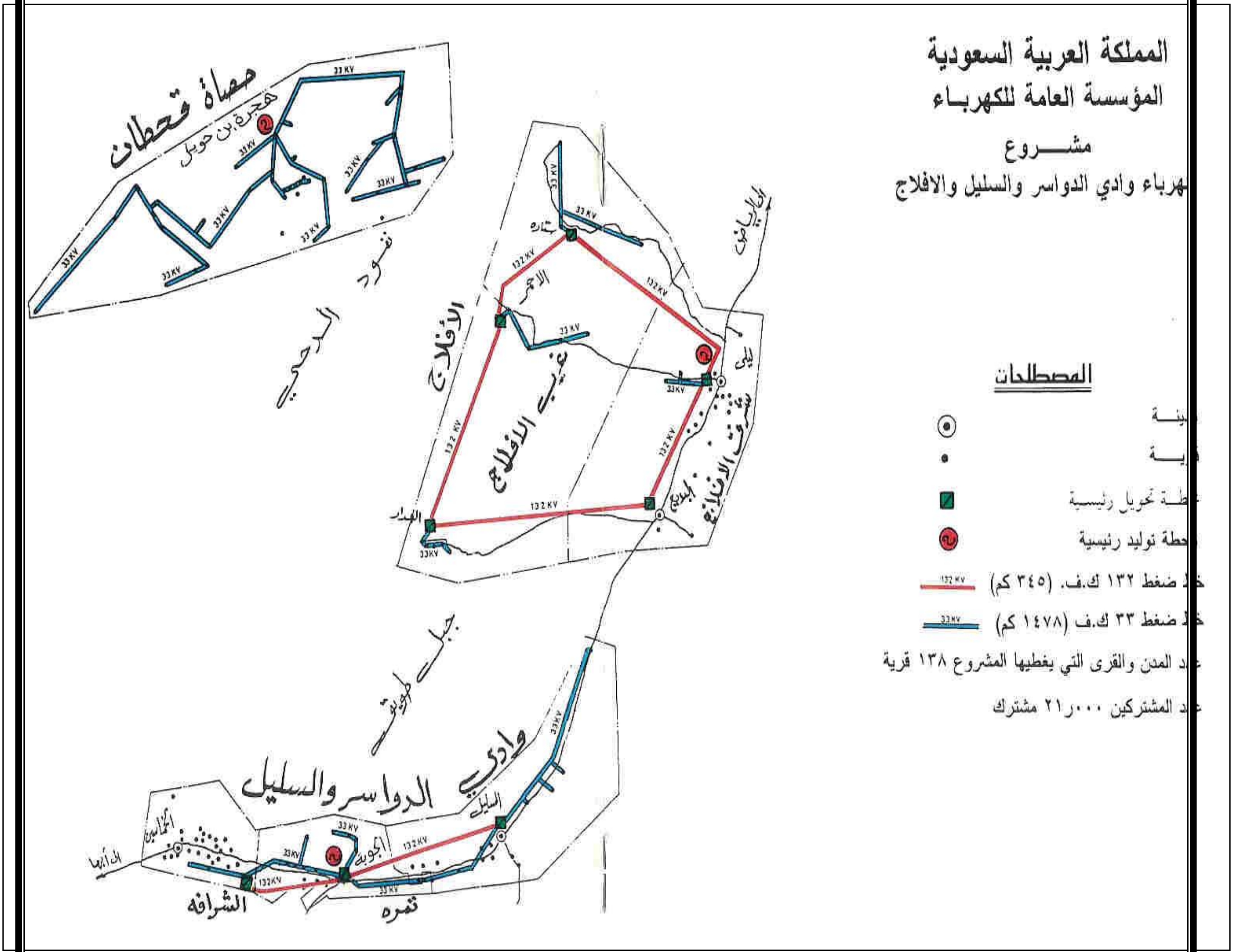

Figure 1: Al-Aflaj Power Plant region.

CHAPTR 1

Gas Turbine Generator

1.1 Starting:

Before the gas turbine can be fired and started it must be rotated or cranked by accessory equipment. This is accomplished by an electric induction motor, operating through a torque converter to provide the cranking torque and speed required by the turbine for startup. The starting system components also provide slow speed rotation of the turbine for cool down purpose after shutdown.

When the electric starting motor is energized, its output torque starts from zero and increases as the torque converter is filled with oil by the charge pump. Torque converter output is directly proportional to the difference between input and output speeds (maximum slip). The torque converter and reversing gear speed ratio were picked to crank the gas turbine at firing speed.

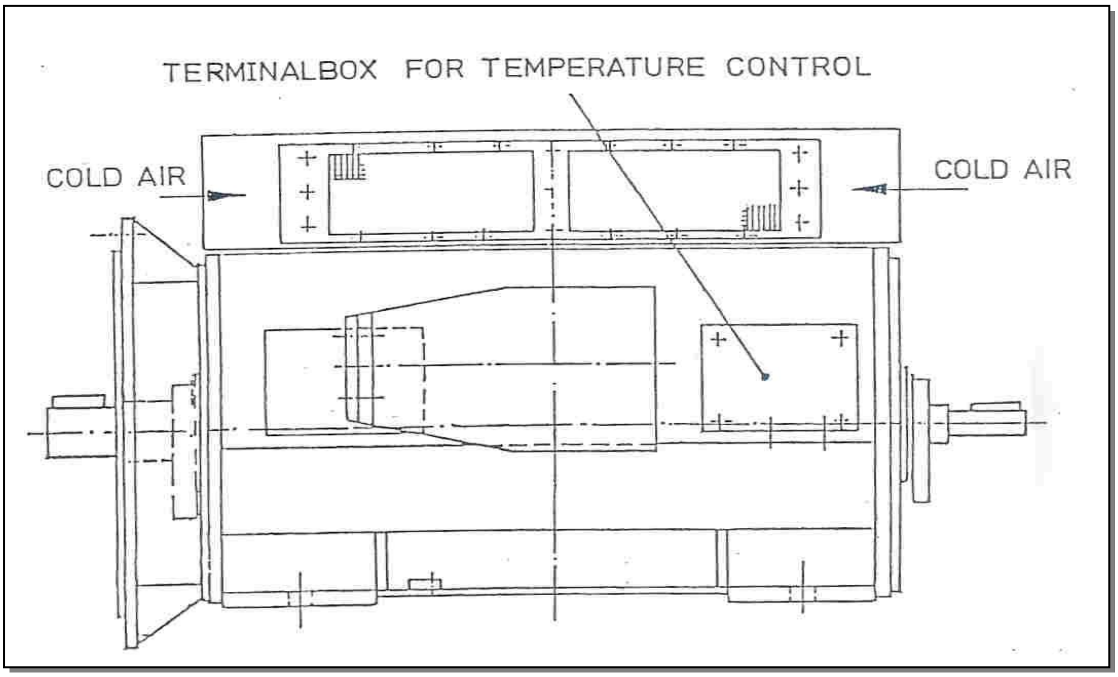

Figure 2: Starting Motor

1.2 Functional Description of Gas Turbine Generator:

The compressor has 17th stages. When the turbine starts up, the 11th stage extraction bleed valve opens and the variable inlet guide vanes are in the closed position. When the high speed real actuates at 95 percent speed, the 11th stage extraction bleed valve closes automatically and the variable inlet guide vanes are set to the normal turbine operation position. Compressed air from the compressor flows into the annular space surrounding the ten combustion chambers, from which it flows into the spaces and the combustion liners, and enters the combustion zone through metering holes in each of the combustion liners.

Fuel oil from an off base source is provided to ten equal flow lines. The fuel is accurately controlled to provide an equal flow into the ten nozzle feed lines at a rate consistent with the speed and load requirements of the gas turbine. The nozzles introduce the fuel into the combustion chambers where it mixes with air and is ignited by one or both of the spark plugs. At the instant when fuel is ignited in one combustion chamber, flame is propagated through connecting crossfire tubes to all order combustion chambers. After the turbine rotor reaches operating speed, combustion chamber pressure causes the spark plugs to retractile...e to remove their electrodes from the hot flame zone. The hot gases in the combustion chambers expand into the ten separate transition pieces attached to the end of the combustion chambers liners, and flow from there to the three stage turbine section of the machine. Each stage consists of a row of fixed nozzles followed by a row of rotable turbine buckets. In each nozzle row, the kinetic energy of the jet is increased, with an associated pressure drop; it is absorbed as useful work on the turbine rotor. After passing through the third stage buckets, the gases are directed into the exhaust hood and diffuser which contains a series of turning vanes to turn the gases from an axial direction to a radial direction, then it pass into the exhaust plenum and are introduced to atmosphere through the stack.

Resultant speed of compressor-turbine shaft is 5114 r.p.m. and using load gear this speed reduced to 3600 r.p.m. in the rotor of generator. The rotor rotates at this speed to produce electricity with 60 Hz frequency according to following formula:

$$f = \frac{pn}{60} = \frac{1 * 3600}{60} = \quad 60 \quad Hz$$

Where,

p : number pair of poles.   n: speed of the rotor (r.p.m.).

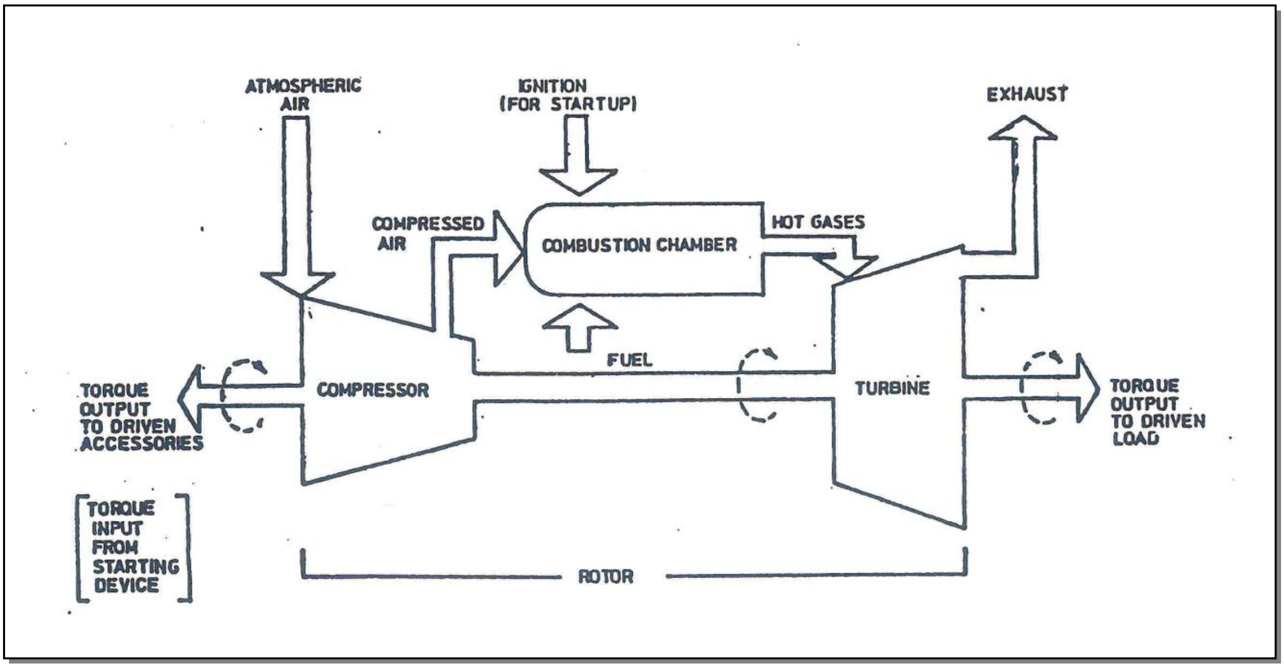

Figure 3: Simple Cycle Gas Turbine Flow Diagram.

CHAPTER 2

The Generator

2.1 Stator:

The stator is the largest and heaviest single part of the turbo generator. It consists of:

1. The housing
2. The sheet-steel laminations, and
3. The stator winding.

The stator housing is a single-piece welded fabrication of rolled steel and consists of the housing sheath, axial and radial ribs, side walls, footplates and cooling-air channels. The ribs are to provide rigidity and also to form channels for the cooling air.

The lamination stack, formed of overlapping layers of sheet-steel segments, is built into the stator housing. It is held by prisms, the stack being compressed by tensile bolts and clamping rings with end-fingers. In order to achieve uniformly high compression even during operation, the stator lamination stack, after being laid up, is artificially aged by heating for several hours.

To improve the cooling of the stator lamination stack, it is subdivided into separate sub-stacks during lay-up, separated by spacer ribs in such a way that radial air slots are formed.

The open slots house the two-layer stator winding which is designed as a Roebel winding to reduce eddy current losses. The individual bars are subdivided into a large number of parallel conductor elements of rectangular cross-section which are bound around with glass silk and impregnated with epoxy-based synthetic resin.

After installation, the entire winding is sprayed with an oil-resistant tracking-proof, artificial-resin varnish.

The six-phase endings are taken to six terminal bars outside the stator housing. In this way the star point can be formed outside the generator and is easily accessible for connecting current transformers or other equipment to be connected to the star point.

Figure 4: Stator Housing Complete with Stator Core

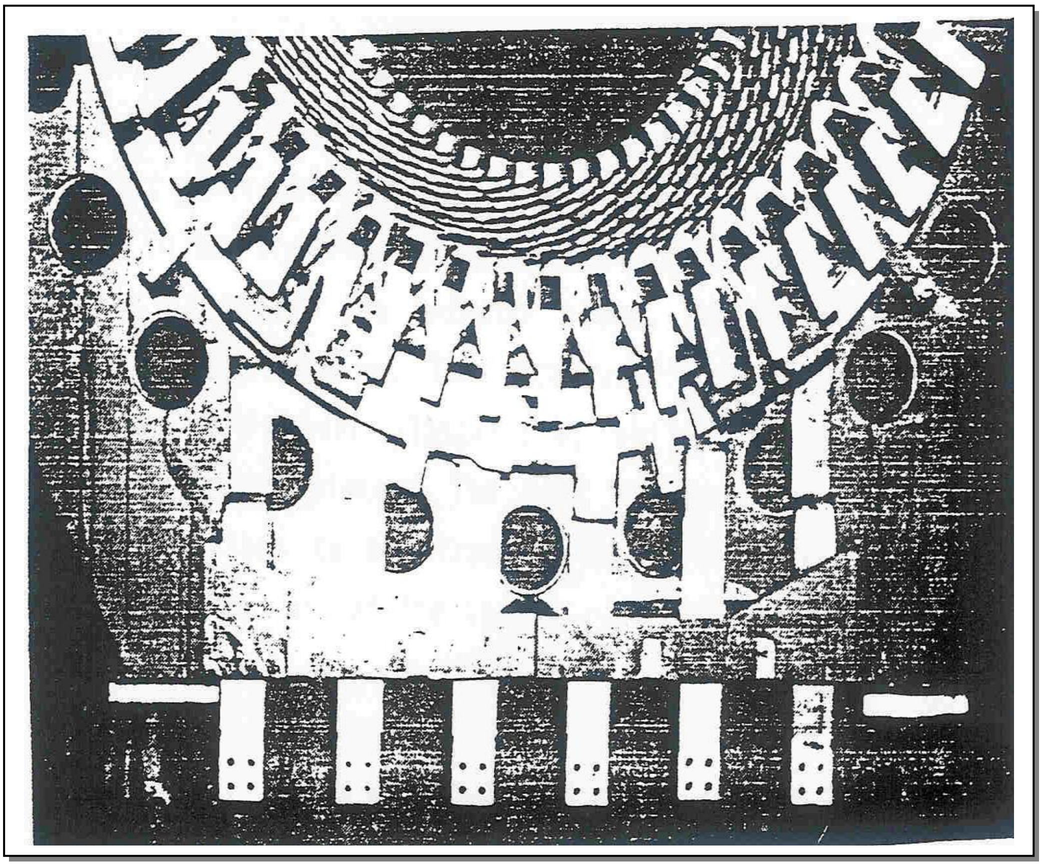

Figure 5: Generator Terminals

2.2 Inductor:

The inductor of the generator consists primarily of the rotor body, the inductor winding comprising two field coils, and the inductor end caps.

The inductor body, consisting of the core and the shaft extensions, is forged from a single block of high-grade steel. The part is given heat treatment to produce particular magnetic and mechanical properties, whose results are checked by a number of tests. In addition to magnetic and ultrasonic testing, samples are taken from various parts of the core and are tested to check the mechanical strength, expansion parameters and notched-bar impact strength.

Each of the field coils consists of several coil elements. These are preformed halfturns, split in the core region, and reconnected together by brazing in the end-winding area after being laid into the inductor slots. The coils thus formed are fed into the inductor grooves. The interturn insulation (split in the core area) is of hard woven glass-fibre, while the slot insulation is of L-shaped insulation pieces. The coil elements are likewise joined by brazing. Connections to and from the coils are taken through the hollow bore in the exciter end of the shaft.

Figure 6: Rotor body with field coils

2.3 Ventilation and Cooling:

The synchronous generator has a totally enclosed closed-circuit cooling system. Two fans, bolted onto the shaft ends, suck cold air from underneath the main frame, and blow it through the cooling-air passages in the stator and the inductor.

For cooling the stator, a number of pipes are welded axially into the stator frame to form air input and outlet chambers. The cooling-air flows from the input air chambers through the stator lamination stack and carries away the loss-current heat. The heated air flows through the stator lamination stack from inside to outside through the air gap and the ventilation outlet slots, to the outlet air chambers in the stator housing, and from there on to the heat exchangers.

The air flow necessary to dissipate the loss heat in the inductor enters it axially from both ends, in each case in two branch streams. One branch stream flows through the inductor end-windings inside the inductor ends-caps and leaves the inductor via holes in the ends of the rotor core.

The other branch stream enters the ducts at the base of the inductor core slots below the inductor winding and cools the winding directly. It flows radially first through the cooling slots of the exciter coils which are distributed over the entire length of the core. It then emerges again and mixes with the other branch flows in the generator air-gap and in the stator outlet-air slots.

The heated air flows through outlet-air connections to the air/air heat-exchanger located outside the machine building. After dissipating its heat to the ambient air, the cooling air is reintroduced into the generator.

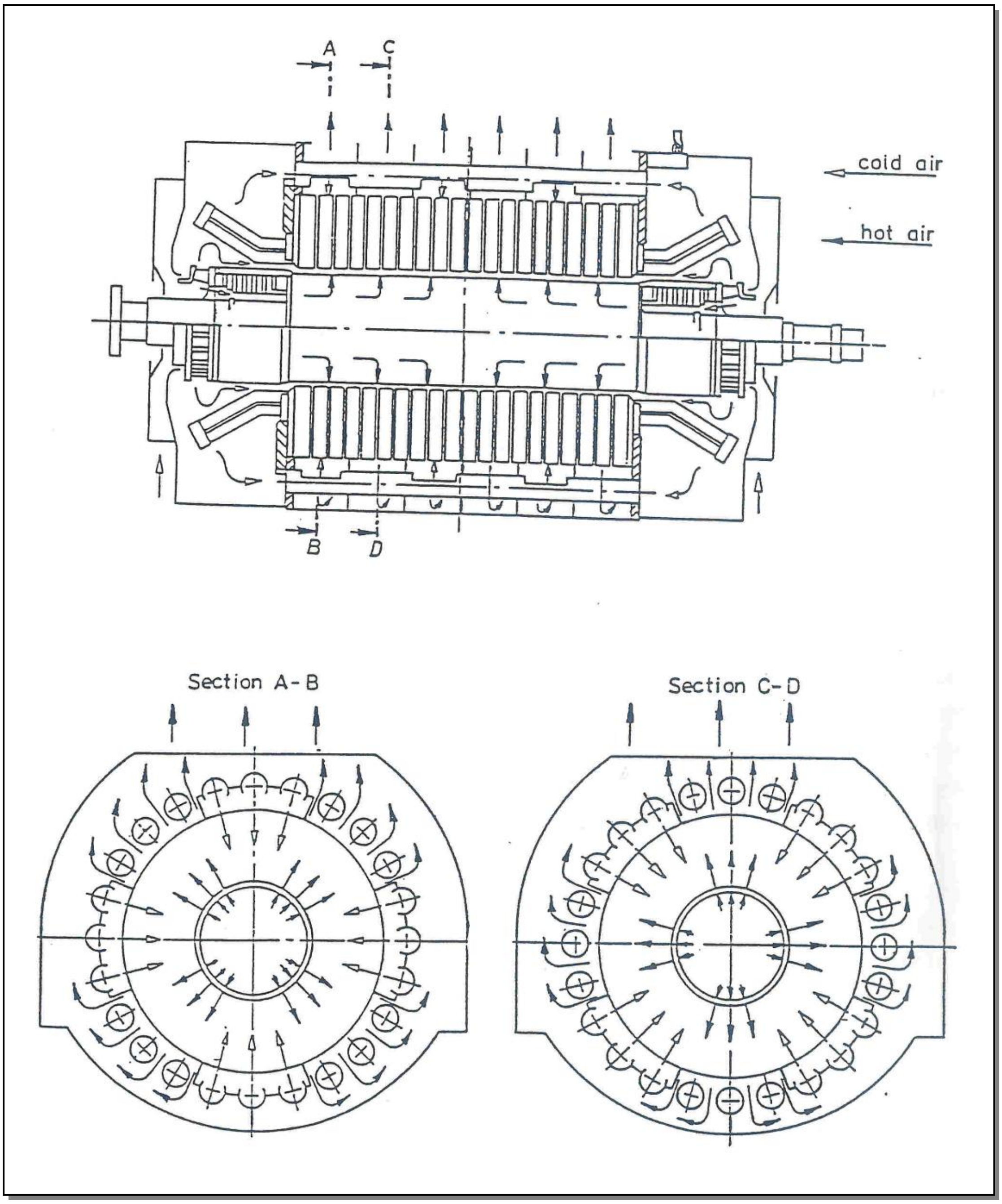

Figure 7: Cooling Schematic Diagram

2.4 Excitation System

The excitation system for the turbogenerator consists of:

- Exciter machine
- Rectifier unit and
- Control equipment.

The arrangement permits the necessary excitation current to be fed to the field winding of the main machine without any brush contact.

The shaft of the main revolving field machine carries the rotor of the ROTADUCT revolving-armature exciter machine. The stator of the exciter machine contains the stationary exciter poles, and its rotating armature contains a three-phase winding with rotating silicon diodes which rectify the armature current. Connecting leads run through a corresponding bore in the shaft to feed the DC current to the field winding of the main machine.

The control equipment compares at its inputs the reference value against the actual values from the main machine (for the parameters: voltage, reactive power or power factor etc.) and alters the necessary exciter current to the exciter machine as function of the difference between actual and reference values. The necessary excitation energy is supplied from a permanent-magnet generator (PMG) flanged onto the exciter machine.

The increase the magnetic flux of the PMG under load, a supplementary exciter winding around the permanent magnets is fed via an auxiliary rectifier from the armature winding of the exciter machine. This supplementary winding can also be used for magnetization if the permanent pole is weakened, e.g. after a long period of shut-down or of dismantled.

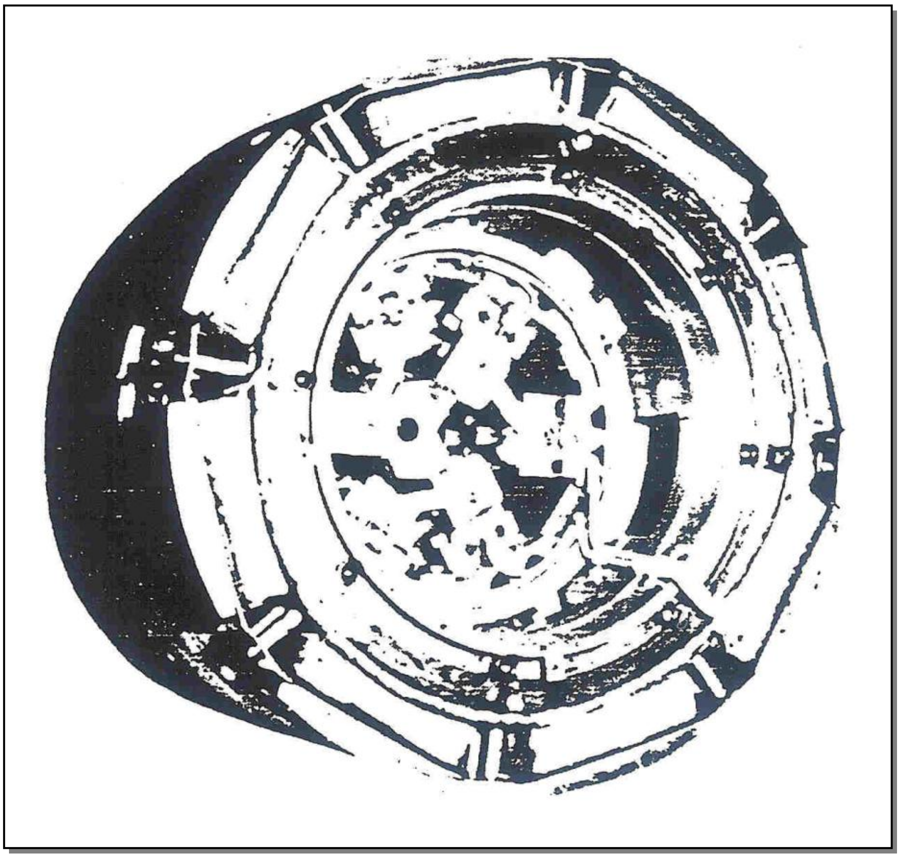

Figure 8: Rotor body of the Excitation System
In Front: Salient poles of the PMG

2.5 Monitoring Equipment

The monitoring equipment has the task of protecting the turbogenerator against impermissible operating states and, where necessary, i.e., in the case that limit values specific to this plant are exceeded, to initiate shut-down to prevent any consequential damage.

The parameters monitored are the temperatures and pressures of the stator winding, the cooling circuit and the journal bearings.

The monitoring equipment comprises measuring devices and signaling devices. The measuring devices serve to visually display the parameters measured, while the signaling devices give visual or audible signals if present limit values are exceeded.

CHAPTER 3

The Transformers

In A.P.P. there are four kinds of transformers:

- Generator transformer (42 MVA).
- Station transformer (5 MVA).
- Station auxiliary supply transformer (3.77 MVA).
- Unit auxiliary transformer (315 KVA).

All kinds of transformers almost have the same equipments but as the capacity rate of transformer increase, its size also increases. Also the cooling system becomes more complicated instead of ONAN in the small transformers, like unit auxiliary transformer, it's changed by ONAN/ONAF in big transformers. The following is the functional description of the largest one, which is the generator transformer.

3.1 Core

The three-phase core consists of grain oriented cold-rolled steel laminations. The thickness of the cold-rolled sheets is 0.30 mm. Both sides of the sheets have a thin film of insulating material based on magnesium silicate.

3.2 Windings

The H.V windings and also the L.V windings of transformers have multi layer windings.

In order to keep the stray losses as low as possible many numbers of drilled wires which are insulated to each other have been provided. The material used for windings is copper with paper insulation. The whole winding structure is mechanically sound and rigid and capable to withstand stresses and forces which can occur under short circuit conditions.

3.3 Tank and Cooling

Tank, cover plate and conservation are made of boiler plate steel withstanding an overpressure of 1.0 bar. Radiators are flanged on the tank using throttle valves for easy replacement, even during operation of transformer.

Transformers are designed for mixed natural cooling and forced cooling (ONAN/ONAF). Operating of fans starts automatically, if temperature of winding reaches the setting value.

3.4 Tap Operating Mechanism

Transformers are provided with on-load tap-changer on H.V-side. The selector part of tap-changer is located inside the main tank of transformer. Diverter switch compartment is separated from main transformer tank. This prevents that dirty oil can enter the main tank. Renewing of diverter oil is also separately possible.

3.5 Supervisory Equipment

The twin-float Buchholz relay is a protective device which responds to slow evolution of gas, loss of oil due to a leak and surge of pressure caused by large quantities of gas being evolved rapidly during severe arcing. Oil level of conservation can be observed at oil indicator gauge with alarm contacts for low level.

The transformers are provided with two dial-type thermometers (one of oil and the other for winding temperature). Both of them respond when setting temperatures has been reached.

The pressure relief vents response to overpressure inside the tank. Diverter switch compartment is provided with a special protective relay which responds to abnormal oil flow caused by arcing.

All terminals of protective devices are wired to the transformer control.

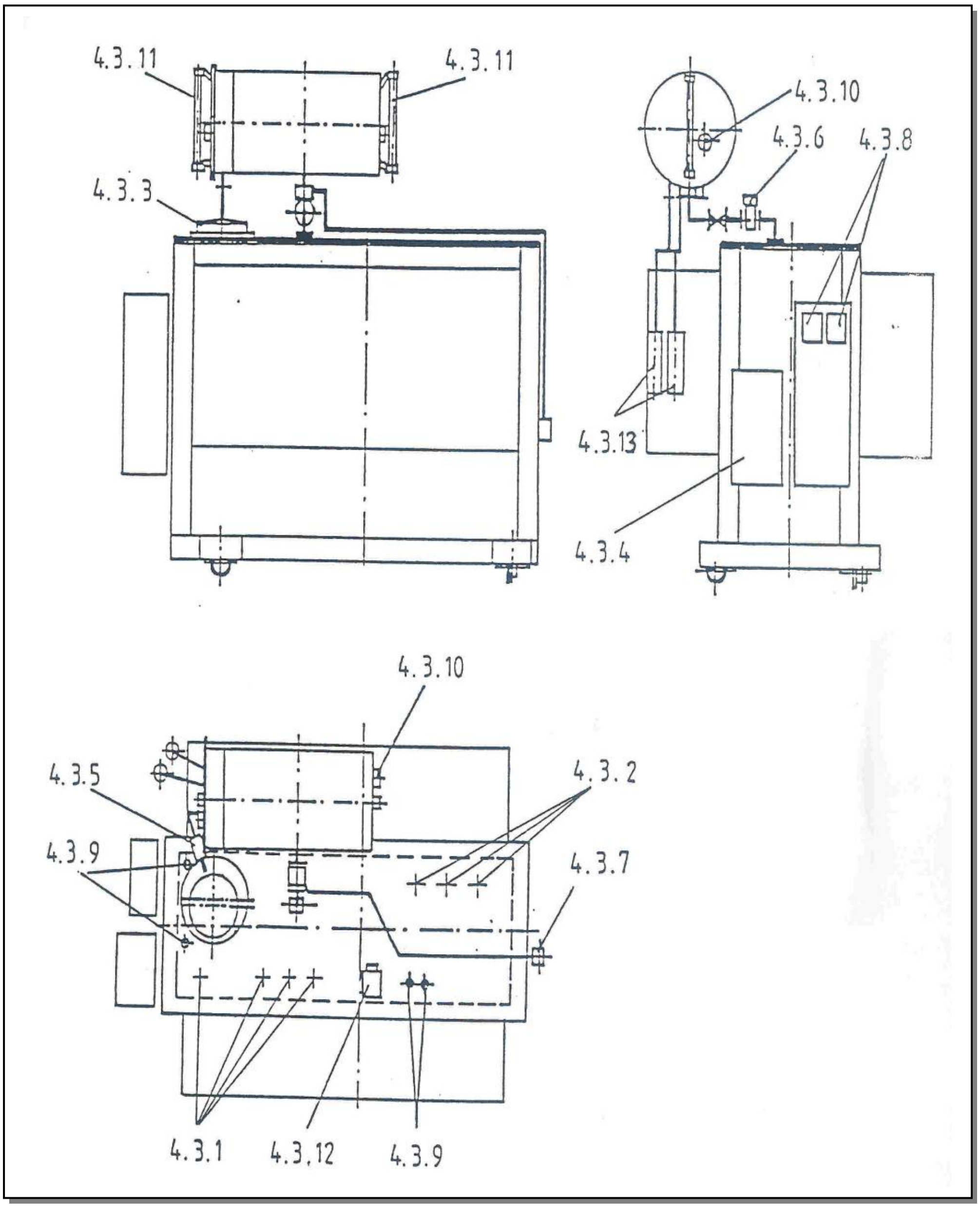

Figure 9: Schematic Diagram of the transformer.

Chapter 4: Overhead lines

4.1 Overview:

Electric trains that collect their current from an overhead line system use a device such as a pantograph, bow collector, or trolley pole. The device presses against the underside of the lowest wire of an overhead line system, the contact wire. The current collectors are electrically conductive and allow current to flow through to the train or tram and back to the feeder station through the steel wheels on one or both running rails. Non-electric trains (such as diesels) may pass along these tracks without affecting the overhead line, although there may be difficulties with overhead clearance.

Construction:

To achieve good high-speed current collection it is necessary to keep the contact wire geometry within defined limits. This is usually achieved by supporting the contact wire from above by a second wire known as the messenger wire (UK) or catenary (US & Canada). This wire is allowed to follow the natural path of a wire strung between two points, a catenary curve, thus the use of *catenary* to describe this wire or sometimes the whole system. This wire is attached to the contact wire at regular intervals by vertical wires known as droppers or drop wires. The messenger wire is supported regularly at structures, by a pulley, link, or clamp. The whole system is then subjected to a mechanical tension.

Parallel overhead lines:

An electrical circuit requires at least two conductors. Trams and railways use the overhead line as one side of the circuit and the steel rails as the other side of the circuit. For a trolleybus there are no rails to send the return current along—the vehicles use rubber tires and the normal road surface. Trolleybuses use a second parallel overhead line for the return, and two trolley-poles, one contacting each overhead wire. The circuit is completed by using both wires.

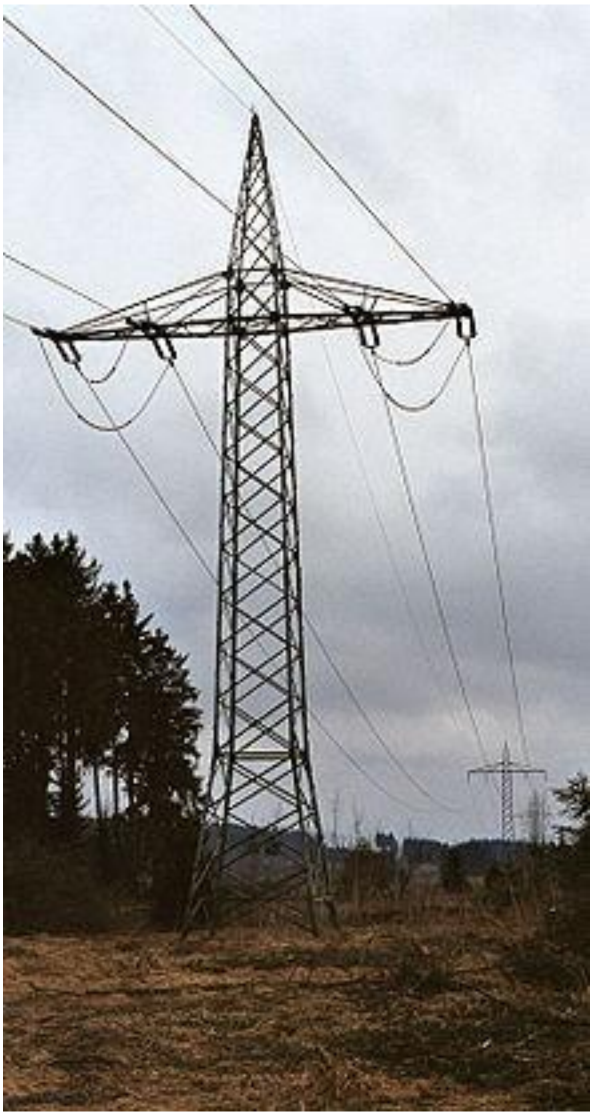

Figure: parallel overhead lines.

4.4 Breaks:

To allow maintenance to sections of the overhead line without having to turn off the entire system, the overhead line system is broken into electrically separated portions known as sections. Sections often correspond with tension lengths as described above. The transition from section to section is known as a section break and is set up so that the locomotive's pantograph is in continuous contact with the wire.

For bow collectors and pantographs, this is done by having two contact wires run next to each other over a length about four wire supports: a new one dropping down and the old one rising up until the pantograph smoothly transfers from one to the next. The two wires never touch (although the bow collector/pantograph is briefly in contact with both wires). In normal service, the two sections are electrically connected (to different substations if at or near the halfway mark between them) but this can be broken for servicing.

Figure: break in overhead lines.

Now, manufacturers are producing an advance overhead lines which contain inside it an optical vipers which give a huge service for communication to go run faster than old method. Overhead lines connecting cities and towns and loading 132KVA.

Conclusion:

In conclusion, during my summer training period I have learned many interested things related to my major .in this summer training also I have learned many things related to the work itself such as the communication with other people and employees and how to discover the problem and solve it in proper way as team work.

I have taken courses in my college really helped me to understand and work with my summer training such as EE 360 which related to power systems. In the training we are facing many strange things like the huge transformers, capacitors banks, bus bars, Scacda (communication device) and breakers. It was a good idea and good chance to expose to the work environment that we will have to face and practice after we graduate. In my point view, tow months is not enough to learn everything but at least we can see how the work is is going on in that plant.