Presented at "Short Course on Geothermal Drilling, Resource Development and Power Plants",
organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, January 16-22, 2011.

UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME

LaGeo S.A. de C.V.

OPERATION AND MAINTENANCE OF AHUACHAPAN POWER PLANT, EL SALVADOR

Godofredo A. López
LaGeo S.A. de C.V.
15 Av. Sur, Col. Utila, Santa Tecla
EL SALVADOR
glopez@lageo.com.sv

ABSTRACT

In El Salvador, like many countries in the world, the production of electricity from geothermal resources is considered as base load and is very important from environmental and economical points of view as their gas emissions are cleaner and the production costs are lower compared with those producing electricity using fossil fuels. The geothermal energy production in El Salvador dates back to 1975, with the first 30 MW unit in Ahuachapán. Today, there are two geothermal fields in operation: Ahuachapán and Berlín with an installed capacity of 95 MW and 109 MW, respectively. The production of electricity with geothermal resources contributes 25.4 % (average July October 2010, according UT) to the energy consumption of the country. This paper describes the operation and maintenance of Ahuachapan geothermal power plant.

1. INTRODUCTION

With regards to the supply of electrical generation, the market in El Salvador shows the leading position of thermal generation, with almost half of the total energy generated. Hydro generation takes the second place, and finally an important portion of geothermal generation.

Maximum capacity installed in June 2009 showed an increase with respect to June 2008 to 7.2% (50MW).

According to Figure 1, it can be observed that thermal generation would tend to increase and geothermal production would decrease during its maintenance activities, therefore the production of hydroelectric plants must be in its normal capacity to maintain the distribution of energy production. (SIGET, 2009)

Prices vary according to the source of energy production. The low costs are obtained first from hydroelectric and then geothermal, while the high ones correspond to the thermal production due to its dependence on the price of fuel (Figure 2).

It is the objective of this paper to provide the best way to undertake maintenance activities in geothermal power plants by reducing the working time, and preventing excess participation of the thermal production.

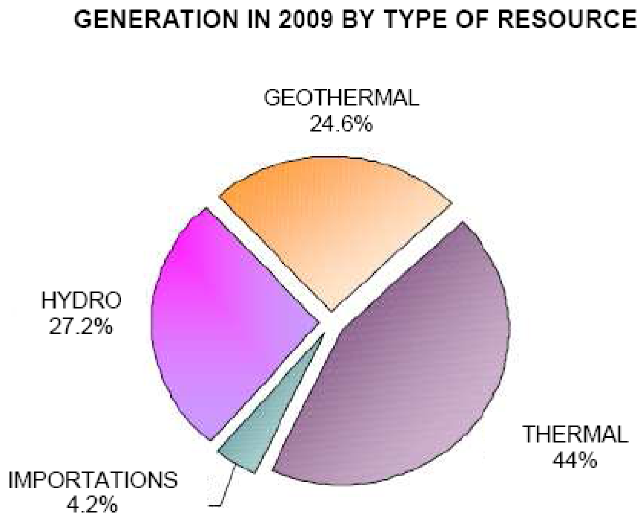


FIGURE 1: Energy mix

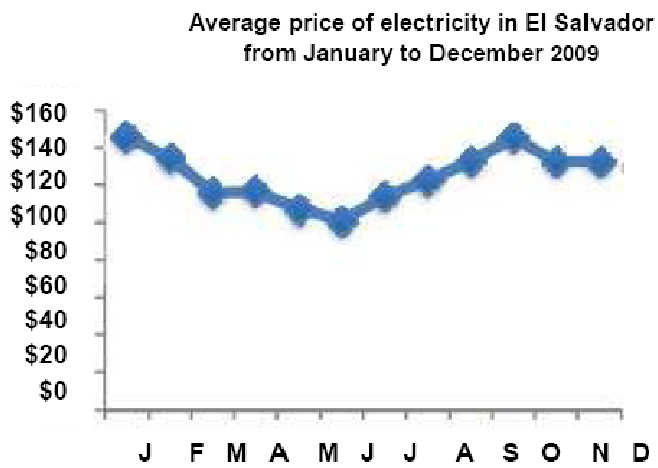


FIGURE 2: Prices according to the statistical report of UT 2009

2. DESCRIPTION OF THE AHUACHAPAN POWER PLANT

2.1 General information

The Ahuachapán geothermal power plant is located 103 km west of San Salvador, the capital city and 3 km east of Ahuachapan city (Figure 3).

The operation of the power plant started with the installation of a Mitsubishi unit (30 MWe single flash condensing type) in 1975 and a few months later in 1976 an additional, identical Mitsubishi 30 MWe unit was added. In 1980, a new Fuji 35 MWe, unit 3 (double flash) went on line using the separated brine to produce low pressure steam, bringing the total installed capacity to 95 MWe. The reservoir pressure from 1975 to 1983 was maintained, however it experienced a pressure drop which was considered to be overproduction of the reservoir.

In 1983, the power plant operated with three units but not to their full capacity. In 1984, the operation programme was changed, with only two units working, while the other one was in standby as there was not enough steam to run the three units at the same time. New sites in the southern part of the actual production zone are being evaluated to find more steam to put the other unit in operation.

FIGURE 3: Map of El Salvador

The three units were put into operation again, increasing the total output from 65 to 80 MW as shown in Figure 4. Rodriguez (2007) estimated the reservoir pressure drop to be almost 1 bar. Figure 5 shows the evolution of the reservoir pressure in Ahuachapan geothermal field.

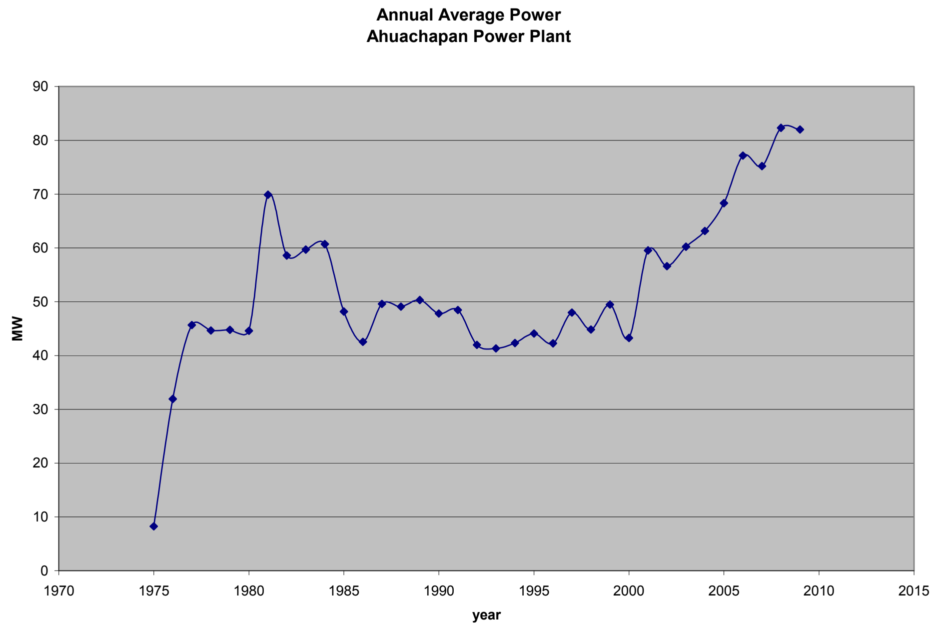


FIGURE 4: Annual average production of Ahuachapan power plant

2.2 Operation characteristic in Ahuachapan power plant

The energy production of the power plant is provided by the three units: two single flashes condensing units with an output of 30 MW each, both supplied by Mitsubishi; and one double flash of 35 MW by Fuji. The full load steam consumption of these turbines is 460 t/h (127 kg / s) of saturated steam at a

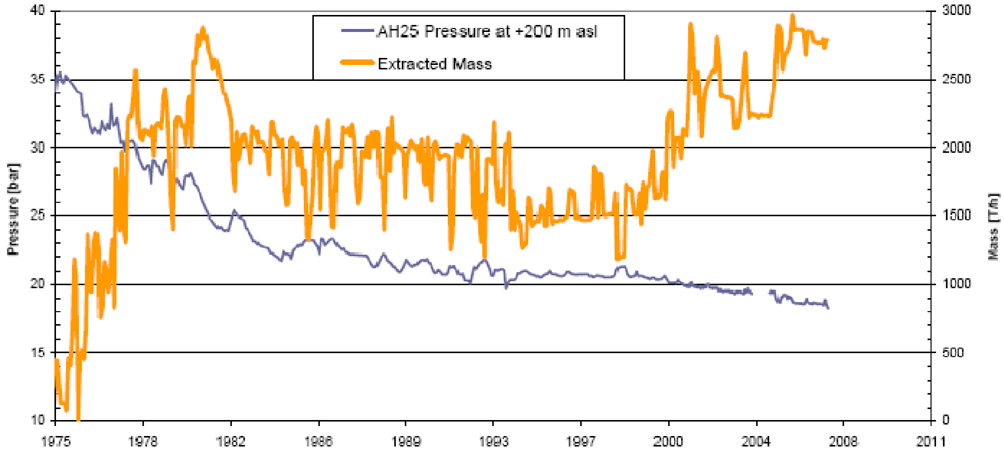


FIGURE 5: Reservoir pressure in Ahuachapan field

pressure of 4.6 bar g that comes from two pressurized tanks called steam headers, which collect the steam produced by a number of producing wells (Figure 6).

At the exit of the turbine, a direct contact barometric condenser is located, where cooled water is sprayed to condense the exhaust steam. This water comes from a cross flow, forced draft cooling tower with five cells. The total flow of cooling water is approximately 8650 m3/h and the ambient temperature is 27 degrees C; the average pressure in the condenser is 0,085-bar. The condenser is connected to a gas extraction system such as steam-jet ejectors, which has a cooling system that cools 0.2% by weight of non-condensable gases that go along with geothermal steam (Figure 6).

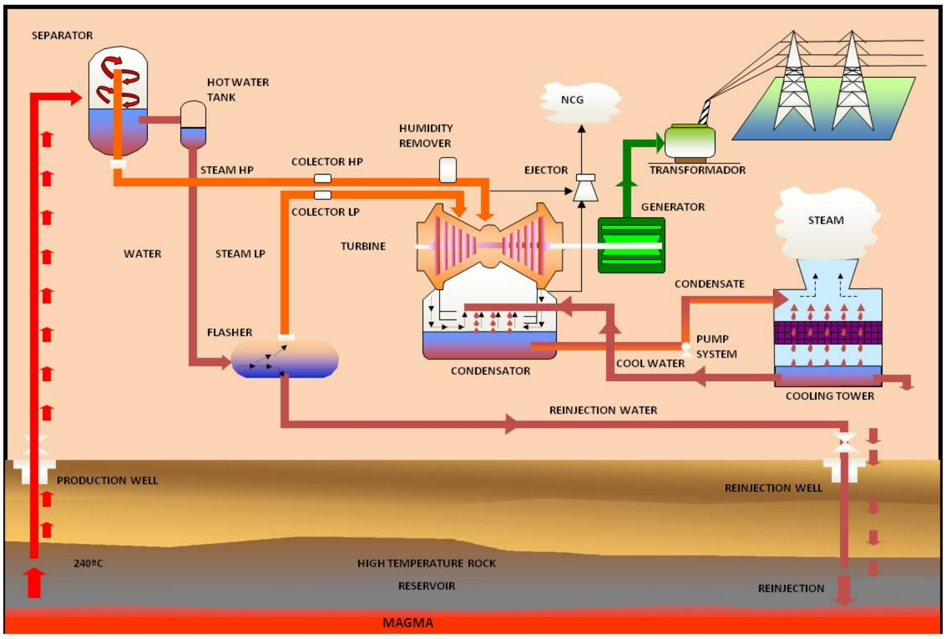


FIGURE 6: Simplified process flow diagram for a geothermal power plant

The gas extraction system has two stages with inter condenser and after condenser. These ejectors are required to operate a steam flow of 4100 kg / h of steam to compress gas from the vacuum in the condenser to external weather conditions in the discharge zone.

The turbines are attached directly to a synchronous generator with a brushless exciter and a closed air cooling system to prevent contamination by hydrogen sulphide (H2S) of the copper conductors. The nominal capacity of the generators is 35,000 KVA with a power factor of 0.85. The voltage output of the generator is 13.8 kV, which is connected to the national grid of 115 kV through a step-up transformer located at the substation (Figure 6).

The third unit of the plant is a 35 MWe double flash unit supplied by Fuji and went into commercial operation in 1980. Unlike the other two units, this one uses a lower steam pressure (1.5 bar-a) in addition to the medium pressure steam. The low pressure steam is obtained from a double process of separation of geothermal fluid. To carry out this process, water is headed to a two - low pressure separators (flashers) where low pressure steam is obtained and sent to the collector, then to the last stages of the turbine. With this arrangement, the output of the plant was increased by 15%.

2.3 Mechanical equipment installed in Ahuachapan power plant

2.3.1 Turbine and auxiliaries

The turbine is one of the most important parts of the equipment of a geothermal plant and also one of the most expensive (Figure 7). According to records, the turbine is the equipment where it needs more time to do the job of overhaul. Some of the main parts of the turbine are: rotor, stationary blades, main oil pump, auxiliary oil pump, outer casing, inner casing, coupling bolts, turning gear, overpressure rupture disks, condenser, bearings, gaskets, oil sealing, storage tank, steam strainer, barometric pipe and over speed safety device.

FIGURE 7: Machinery room in Ahuachapan power plant

2.3.2 Cooling system

The cooling water system is composed of the cooling tower, the main circulation water pumps, the cooling pumps and the system of auxiliary pumps.

Mechanical work in the cooling tower during the overhaul includes the inspection of the system of fan gear box, which are dismantled to verify internal conditions.

2.3.3 Gas extraction system

It is designed to operate with two steam-jet ejectors, the steam for this system is taken directly from the main steam line. There are another two steam-jet ejectors mainly used as a back up system.

At present, the normal operation of the non-condensable gas extraction system is done with a vacuum pump and the ejector system described above as standby.

Some of the main parts of the old gas extraction system are four steam-jet ejectors and two auxiliary water pumps, valves. The new system is composed by one ejector, valves, vacuum pump, reducer gear box, and lubrication water pump.

2.3.4 Generator

Normally, the disassembly and internal inspection of this equipment is necessary after every four years of continuous operation. It is the responsibility of mechanical area the disassembling and inspection of all mechanical components, while the electrical aspects like insulation condition assessment, cleaning and testing are the responsibilities of the electrical area. When the electrical inspection is finished the mechanical area starts the re-assembling.

A summary of the main components in the process is shown in Table 1. Only the major components under each system are presented.

TABLE 1: Information about the systems, equipments and components

Main systems	Main equipments	Main components
Steam conduction and transmission (gathering system)	Wellhead, separator station, steam transmission and water transmission	Master valves, flow control valve, two-phase pipeline Separator vessel, pressure relief device, level control Steam pipe, condensate drains, steam pressure, controllers, steam driers, steam flow meters Hot water pipeline, hot water pressure relieves. Humidity separators
Turbine and auxiliaries	Inlet devices steam turbine oil system	Steam strainer, emergency and governor valves Rotor, nozzles, diaphragms, bearings, casing, packing gland seals Oil pumps, servomotors, oil pipes.
Cooling system	Cooling towers and water pumps condenser	Fans, motors, gear reducers, structure, fills, cold water ponds, strainers Large hot well pumps and motors, auxiliary pumps Condenser heat exchangers, nozzles, gas cooling
Gas extraction system	Steam jet ejector and vacuum pump	Control valves, isolating valves, nozzles, intercoolers Vacuum pump and motor, water seal pump and motor gear reducer box.
Generator and electrical	Generator, transformers and protection	Rotor, stator, exciter, bearings, coolers Step up transformers, station transformers Relays, switchgears,

3. TYPES OF MAINTENANCE IN AHUACHAPAN POWER PLANT

The types of maintenance in the power plant are preventive, predictive and corrective maintenance.

3.1 Preventive maintenance

For the preventive maintenance, this type of management system is based on computerized/manual, written/updated procedures, and audited. Written programs of routine activities are developed, and a computerized maintenance management software (MAXIMO) is usually applied. It has the objective of providing information necessary at a suitable moment to realise the activities for maintenance (Figure 8). The program can be done following the recommendations given by the machinery manufacturer and furthermore, the experience gained by the maintenance and operation personnel. This also facilitates the gathering of information to determine which parts of the equipment demand more man-hours and money.

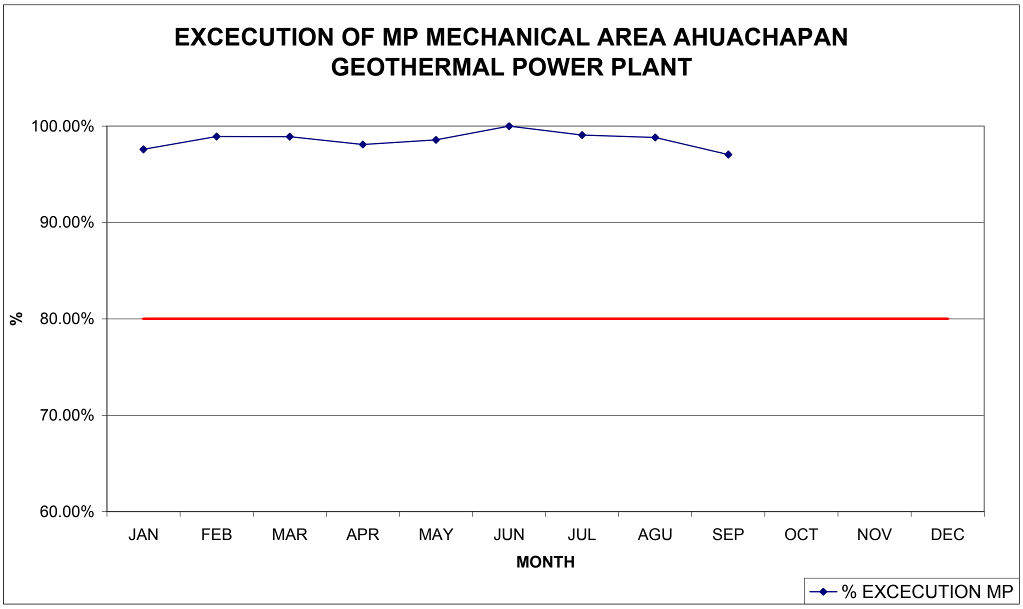


FIGURE 8: Control about MP in Ahuachapan power plant

It is also possible to obtain information on the amount of work orders for preventive, corrective and predictive maintenance.

3.2 Predictive maintenance

The common maintenance procedures carried out under the predictive maintenance include vibration analysis, thermography, ultrasonic and oil analysis. Table 2 gives a summary of the predictive maintenance and their applications. The first four are the common procedures and are described in detail.

TABLE 2: Advantages and disadvantages of the preventive maintenance

No	Predictive Maintenance	Applications
1	Vibration analysis	Misalignment, out of balance weights, wear of bearings etc
2	Thermography analysis	Overloading, excessive friction or wear, abnormal electric resistance
3	Oil analysis	Contamination, breakdown of lubrication properties, signs of wear
4	Current measurement	Electric overloads, faulty bearings, current leakage
5	Visual inspection	General defects that can be detected by human senses of sight, hearing and feeling
6	Insulation tests	Check status of electric insulation
7	Power rate	Bearing failures, damaged turbine blades, vacuum loss
8	Voltage measurement	Brush failure, excitation faulty, insulation failure

Vibration analysis: Software for vibrations analysis is used in predictive routines. In the main water circulation pumps, equipment is inserted to obtain vibrations without having to execute routines of measurement with portable equipment. This facilitates the information on the conditions of operation of the pumps. This equipment is considered important for the good operation of the generating units. With this, it is possible to observe in the control room the magnitudes of vibrations of the pumps as well as the graphs for further analysis (Figure 9).

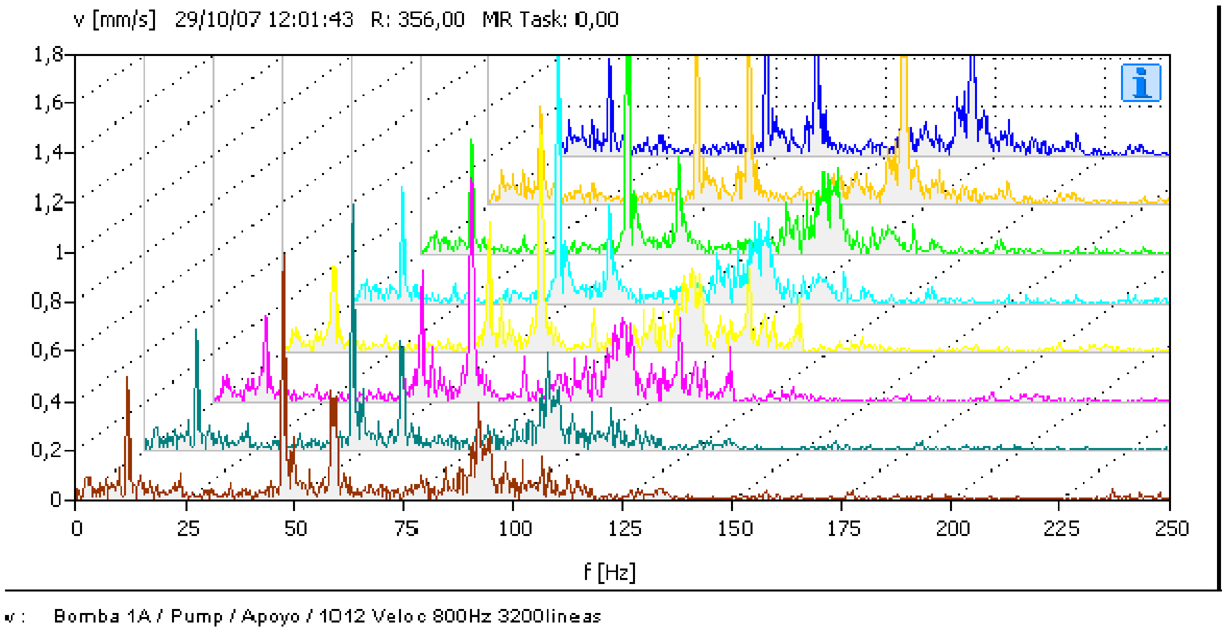


FIGURE 9: Operation condition register

3.3 Corrective maintenance

Through the MAXIMO software, it is possible to get statistics of corrective maintenance, for example in October and November 2010, there were less than 2% monthly of corrective maintenance (Figure 10).

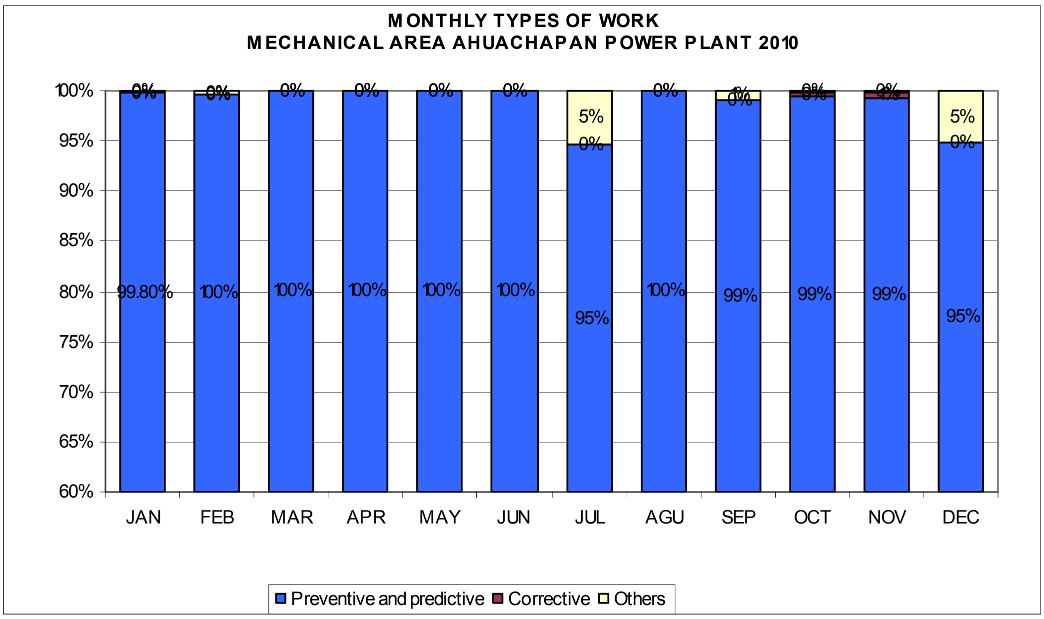


FIGURE 10: Control on types work order

4. OVERHAUL IN AHUACHAPAN GEOTHERMAL POWER PLANT

4.1 General information

The overhaul of a unit is carried out every two years of continuous operation. This maintenance usually takes four to six weeks to complete, depending on which unit is to be maintained. For this type of maintenance, it is necessary to optimize the time and cost, the time because when one geothermal unit is shut down, the electrical system in El Salvador requires putting online thermal plants, thus the electricity produced by these plants is considerably more expensive (Lopez, 2006).

When the Ahuachapan power plant undergoes overhaul in any unit, it is necessary to prepare the working tools , possible spare parts and the temporary personnel to be hired during the programmed time to carry out the work.

Due to the provisions of the energy system of the country, it is necessary to schedule overhauls so that the power system operator (UT) can guarantee the supply of energy by scheduling the maintenance of the electrical power plants. UT evaluates if it is possible to authorize it or not; which depends on the generating conditions of the hydroelectric plants, otherwise high contribution of thermal production would be required, which could cause the high price of electricity.

4.2 Manpower for overhaul in mechanical area

The organization chart of mechanical area is shown in Figure 11 for permanent workers only. In the power plant, for overhaul, it is necessary to hire personnel with the required skills to carry out the work. The number of people to be hired depends of the scope that is defined for the maintenance and of the determined time to develop it. Programming is undertaken with the participation of the involved personnel. With the different areas, generally operational ranges are discussed, for example in the cooling tower, the mechanical area is required to disassemble the fan gear boxes for inspection and the group responsible of the electrical part is required to disassemble the motor for inspection. Occasionally, the personnel in charge of the tower, is required to make changes in wood materials and should have a very good coordination to avoid conflict between workers and the subsequent delay.

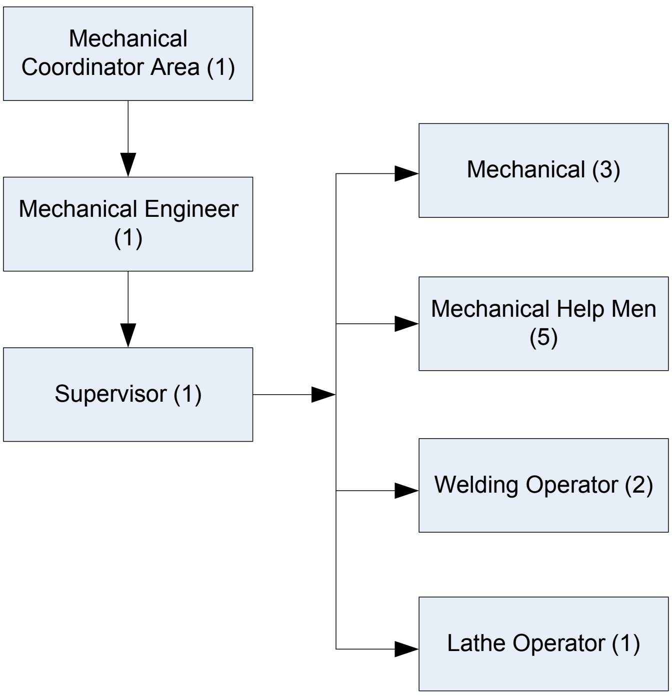


FIGURE 11: Chart of mechanical area Ahuachapan

Thus, it is important to define the program of maintenance to establish a clear view of the objectives and the time to execute it. After designing this guide, it is possible to determine the optimum number of personnel to be contracted for the work.

After considering the first aspect that consists of assuring the availability of important spare parts, personnel has to evaluate the tools to use, since some of them are considered special and the procurement time can be long, so if they are not prepared in advance, delays in the maintenance schedule could occur.

Another important aspect in relation to the tools is to verify their good working condition since when using damaged tools, a high risk of accident for the personnel and the equipment in maintenance is assumed. For this reason, a tool in bad condition is necessary to be replaced to assure its good operation.

The following step is the elaboration of the work program (shown in appendix 1). Through this, it is possible to determine the number of personnel necessary for the work. It is also important to find ways in which the activities can be carried out in a parallel manner with the aim of reducing the working time. Thus this program should be discussed with the people in charge of the other work areas, since this can produce some delays (Lopez, 2006).

In Figure 12, it can be observed the time required to realize an overhaul operation in each system. As can be seen, more time is spent to overhaul the turbine.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. Procedure for maintenance to reduce the working time and the cost during the overhaul period has been elaborated. It includes good planning and discussion with the involved personnel, the condition of working tools, maintenance management software and work programs.

In Figure 12, it is possible to see which turbine requires more time during the inspection program.

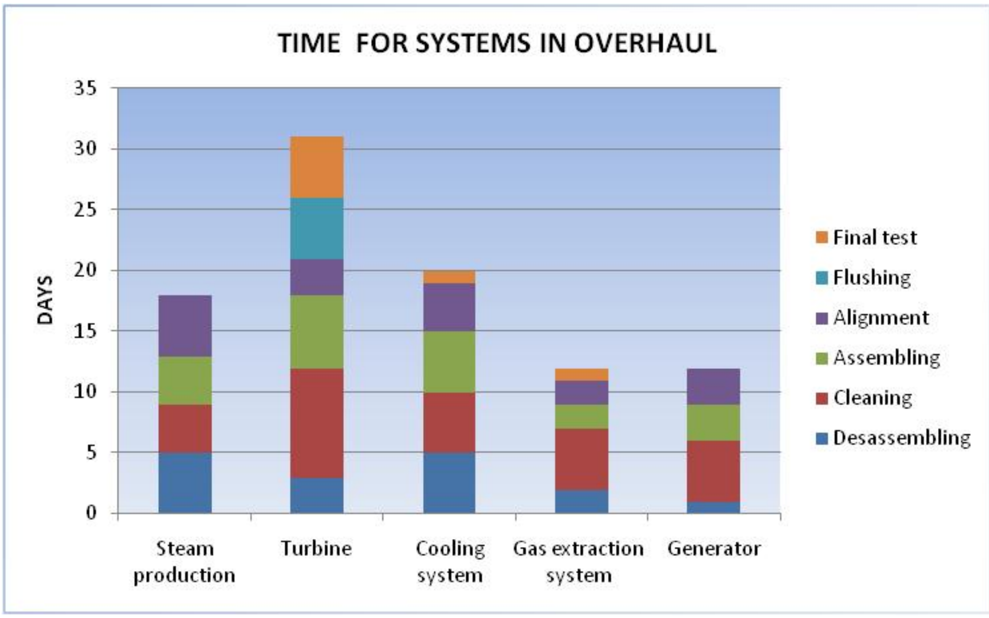


FIGURE 12: Register of time for systems in overhaul

2. Due to the provisions of the energy system of the country, it is necessary to schedule overhauls so that the power system operator (UT) can guarantee the supply of energy by scheduling the maintenance of the electrical power plants, to avoid the high cost of electricity if more thermal generation is required.

7.2 Recommendations

According to Figure 12, the main problem is the cleaning of turbine parts as it is currently done manually. It is recommended to change this manual method to mechanical method in order to reduce the time to five days.

It should also be considered that the use of these techniques can obtain a reduction of five days less during overhaul, which could provide lots of benefit for Ahuachapan geothermal power plant.

REFERENCES

Amaya, J, 2004: *Document preparation for company of insurances mainly risk*. LaGeo, Geothermal power plant Ahuachapan, internal report (in English).

López G., 2006: *Informe de Revision Mayor U1*. LaGeo, Geothermal Power Plant Ahuachapan, internal report (in Spanish).

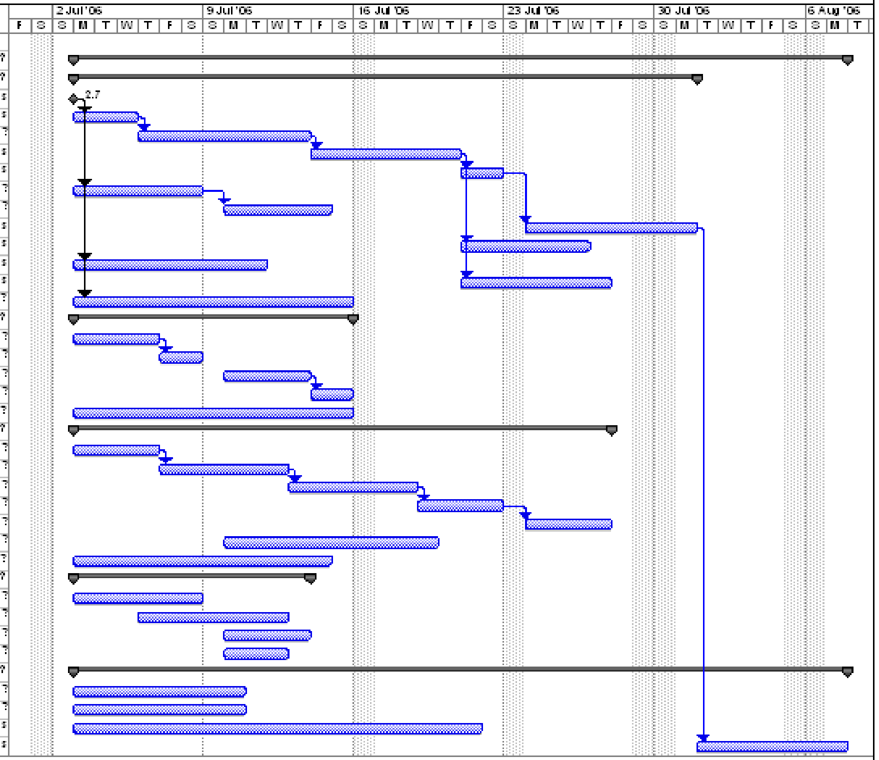
Superintendencia general de electricidad y telecommunicaciones (SIGET), 2010. Website: www.siget.gob.sv.

Unidad de transacciones (UT), 2010. Website: www.ut.com.sv.

APPENDIX: Program for overhaul in Ahuachapan power plant (El Salvador)

PROGRAM FOR OVERHAUL OF AHUACHAPAN

ID	Nombre de tarea	Duration
1		
2	Overhaul U1	30 days?
3	WORK TURBINE	26 days?
4	STOP TURBINE	0 days
5	DESASSEMBLING OF THE TURBINE	3 days
6	CLEANING OF THE TURBINE	8 days?
7	ASSEMBLING OF THE TURBINE	6 days
8	TURBINE ALIGNMENT	2 days
9	CLEANING OF THE OIL SYSTEM	6 days?
10	CLEANING OF THE COOLING OIL	5 days?
11	FLUSHING	6 days
12	CONDENSER CLEANING	5 days
13	CLEANING OF COOLING GENERATOR	9 days
14	CLEANING OF STRAINER STEAM	6 days
15	INSPECTION OF EMERGENCY AND GOVERNING VA	13 days?
16	WORK IN MAIN CICULATION WATER PUMPS	13 days?
17	DESASSEMBLING AND INSPECTION OF THE CWP 1	4 days?
18	ALIGNMENT OF CWP 1	2 days?
19	DESASSEMBLING AND INSPECTION OF THE CWP 2	4 days?
20	ALIGNMENT OF CWP 1	2 days?
21	INSPECTION OF THE VALVES	13 days?
22	WORK IN COOLING TOWER	23 days?
23	INSPECTION OF GEAR BOX 1	4 days?
24	INSPECTION OF GEAR BOX 2	6 days?
25	INSPECTION OF GEAR BOX 3	5 days?
26	INSPECTION OF GEAR BOX 4	4 days?
27	INSPECTION OF GEAR BOX 5	4 days?
28	CLEANING OF THE HEATING INTERCHANGE SYSTE	9 days?
29	INSPECTION OF THE VACUM PUPM	12 days?
30	INSPECTION OF THE STEAM PIPES	11 days?
31	INSPECTION OF THE THE EJECTOR SYSTEM	6 days?
32	CLEANING OF THE INSTRUMENTATION PIPES	7 days?
33	INSPECTION OF THE WATER SEPARATOR	4 days?
34	INSPECTION OF BELLOWS FROM PAPISTEAM	3 days?
35	INSPECTION OF THE COOLLING WATER CLOSE CIRCU	30 days?
36	INSPECTION OF COOLING WATER PUMPS	8 days?
37	INSPECTION OF THE VALVES	8 days?
38	GENERAL PAINT	18 days
39	TEST AND START	5 days



Project: OVERHAUL UNITS
Date: OCTOBER 2008

Tarea | División | Progreso | Hito | Resumen | Resumen del proyecto | Tareas externas | Hito externo | División

Página 1