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Expansion Work and Experience Gained in Operation of Aluto Langano Geothermal Power Plant

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ABSTRACT

Ethiopia is well endowed with geothermal resources, and current exploration is believed to have studied only a fraction of the ultimate potential. The potential prospective areas are distributing along the Ethiopian Rift Valley system which runs in a northeast direction along the entire length of Ethiopia. To begin to realize this potential, in 1998, the Ethiopian Electric Power Corporation (EEPCO) constructed the Aluto Langano geothermal power plant in Ethiopia located in Rift Valley lakes Region. The ALuto Langano, geothermal pilot plant with a Gross capacity of 8.5MW consisting two Ormat generating units.

Various studies confirmed that up to 100MW electricity can be produced from the Aluto geothermal steam field, which is known to be one of the high temperature prospected areas in the Country. This geothermal resource covers an area of about nine square kilometers.

Expansion work at the Aluto Langano Geothermal power plant, to boost its capacity to 70MW in two phases, was launched on December 27/ 2013 at a cost of over 30 million USD. The project is financed by the government of Japan, World Bank and the government of Ethiopia. In the expansion project, drilling of 24 wells including five reinjection wells, of up to 2,500m deep is planned in a two and half years period.

1. BRIEF DISCUSSION ON ALUTO LANGANO GEOTHERMAL FIELD EXPANSION PROJECT

The study carried out as part of expansion project on geothermal development in the Aluto Langano geothermal field is; to assess the generation capacity that is feasible to exploit in the project area. Considering the geothermal resource availability, determining the necessary number of production wells and reinjection wells, the basic design of fluid collection, and reinjection system, power plant facilities , transmission line and substation facilities, study of social and environmental impact possibly induced by the project and economic and financial evaluation of the whole integrated project.

Generally study of geothermal power development project is divided into two;

i) Underground geothermal resource development

Several development scenarios were carried out to estimate the Aluto Langano underground geothermal resource size. Using Reservoir simulation based on 3-D numerical Reservoir model forecasted a 30 years economic life with a 35MW power development at steam pressure of 10 Bar. To maintain the rated output for 30 years 8 production and 4 reinjection wells with 5 make-up production wells and 2 make-up reinjection wells will be necessary.

At present a directional drilling has been started in the eastern direction of Aluto Power plant to intercept the Wonji Fault.

ii) Surface power generating facilities.

The geothermal power facilities encompasses of geothermal fluid transporting (gathering system), power plant, high voltage transmission line and Substation.

The proposed power plant size and facilities are;

Capacity	35MW gross using single unit
Power plant type	single flashed steam cycle with condensing turbine
Steam condition	10 bara at 179.9 0C saturate at plant inlet
None condensable gas in steam	8wt%

2. INTRODUCTION AND BACKGROUND OF ALUTO LANGANO GEOTHERMAL POWER PLANT

The Aluto Langano geothermal field is located in the Ethiopian main Rift valley, lakes district, some 200km south of the capital Addis Ababa, which is one of the principal sectors of the East African Rift system. In this field a detail geological, geochemical and geophysical surveys carried out during the late 1970's and early of 1980s. The result of the studies indicated that a high temperature underground fluid exists with an evidence of long time residence occupied by high temperature rocks. Six deep exploratory wells were drilled at Aluto out of which four wells were successful to supply a geothermal fluid to the power plant.

The ALuto Langano Geothermal pilot plant was built, commissioned and put into operation in 1998 to realize the existence of this potential under a turnkey contract. The power plant is composed of two generating units; the geothermal Combined Cycle Unit (GCCU), Ormat Energy Converter (OEC) with grows output of 8.5MW. The two high pressure wells LA-3 and LA-6 are feeding the geo fluid to the conventional steam turbine. The exhaust steam coming out of the steam turbine is delivered to a heat exchanger which in turn boils a binary fluid to drive the binary turbine.

After its commissioning, the power plant operated for a relatively short period of time before a number of problems arose that severely affected the availability and power output level, ultimately leading to the shutdown of the power plant. These problems occurred underground, within the surface (fluid handling) equipment, and in the power plant itself. After a number of years, EEPCO issued an international tender to rehabilitate the power plant and put it back into operation.

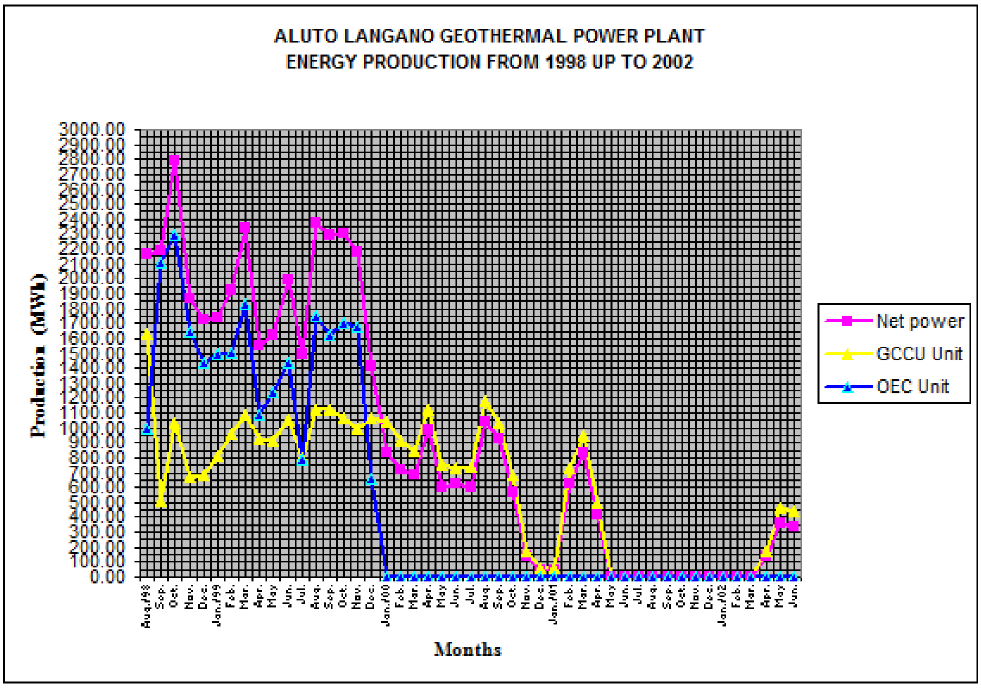

Figure 1: Chart of Energy production up to now

Subsequently, EEPCO engaged the services of a geothermal consultant to do the analysis of the problems and carry out the necessary repairs on the units to put it back into operation. Work presently completed and underway as part of the power plant rehabilitation, include:

- Reconditioning of the GCCU steam turbine is completed and the unit is put back into operation. This included re-engineering of the steam turbine to enable it operate at lower steam pressures, upgrade of the power plant automation system (PLC) and Improving the lubrication system of the steam turbine
- Repair and maintenance (servicing and/ or overhaul) of the wellhead valves is completed
- Flow tests, go-devil runs, and down-hole pressure and temperature measurements to confirm the causes of the output declines were undertaken. The result of the test indicated that the two high pressure wells are in good condition and are currently supplying the geothermal fluid to the GCCU unit.
- Analysis and investigation of corroded OEC heat exchanger tubes to determine the root cause of the failure. The result of the tests indicated brine carry-over, with the trace of chloride, was the root causes of the tube failure. Based on the result obtained it was decided to replace the complete heat exchanger tubes. This work is currently underway.

3. IDENTIFIED PROBLEMS RELATED TO THE STEAM FIELD AND THE POWER PLANT

Some of the identified problems that are related to the steam field and the power plant are:-

1. Solid deposition in the well bore and surface equipment

2. Well output decline

3. Journal bearing failure of the steam turbine

4. worn-out steam turbine shaft from the driving end side

5. Tube leak of the OEC heat exchanger

6. Frequent failure of the cooling fan shaft

3.1 Solid depositions in the well bore and surface equipment

The geothermal reservoir that feeds the well bore contains a variety of dissolved fluid compositions. Liquid- dominated geothermal reservoirs are hydrothermal reservoirs that contain circulating liquids which transport the thermal energy of the hot rock with dissolved minerals near to the surface by natural fluid circulation. The fluid comes from such reservoirs may form scales that deposits in the well bore and fluid carrying surface equipment.

Schematic diagram showing common locations of sold depositions (UNU GTP Merga's Report, 2001)

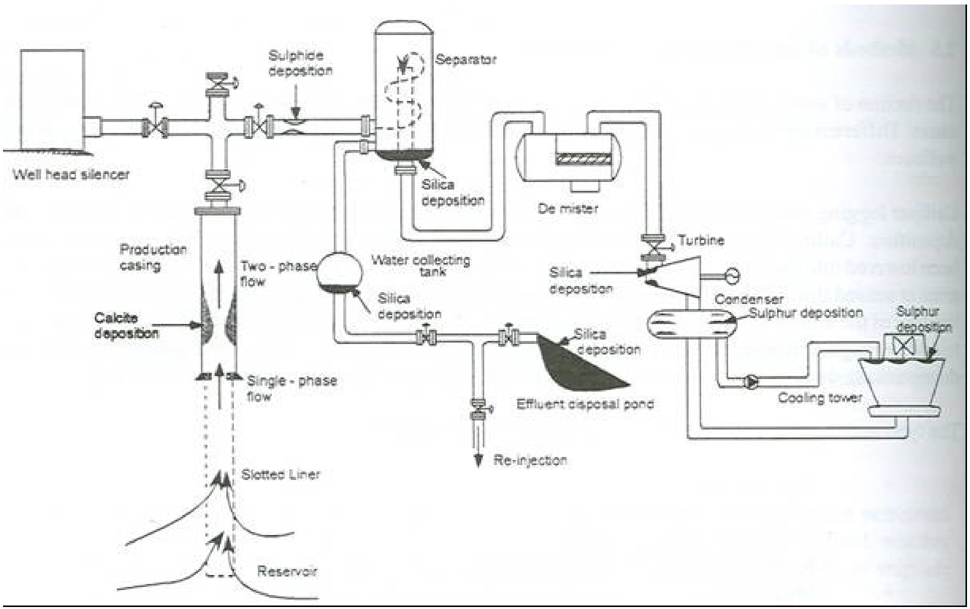

Figure 2: Flow diagram showing common locations of solid depositions

Tests and down-hole logs conducted on the Aluto Langano geothermal field wells indicted that well LA-4 exhibited a calcite scale depositions. This well was drilled in 1983 to a depth of 2062m in the outflow zone of Wonji fault. The logging result of May 2006 indicated that a go-devil of 3" diameter stopped at a depth of 1085m and a 41/2" stopped at a depth of 1050m respectively while logging fragments of white soft pieces, resembling calcium carbonate, were recovered from both go-devils.

The blockage observed in well LA-4 has also significantly reduced the flow from this well. Subsequently, a well work over is recommended to remove the obstruction and bring the well back into normal flow, and this work is currently underway. Confidently within a two to three months time the well work over will be completed and the well will come back into normal operation.

4. RECOMMISSIONING OF THE GEOTHERMAL COMBINED CYCLE UNIT (GCCU)

During early operation following commissioning the GCCU, it was observed that when well LA-6 was opened and the flow from both wells was joined, LA-3 wellhead pressure increased while the flow of LA-3 sharply dropped at a considerable rate. This indicates that when the two wells operate in conjunction, LA-3 was unable to flow sufficient steam, at higher system pressure to maintain the stable flow to the unit.

De-staging of the steam turbine, to enable operation of the GCCU at a lower inlet pressure, was suggested by PB Power in its final report prepared in 2000. According to PB Power, by de-staging the GCCU unit and removing the turbine stages, the design steam inlet pressure would be lowered. This helps to match the stable production pressure of the wells to that of the turbine inlet pressure.

The Predicted performance of the GCCU unit is as follows, including the original design (PB POWER, Report)

Table 1

Steam Pressure inlet (bar) to the demister		**Steam Flow Rate (t/h)**	**Power output**
Design data before destaging	12.0	29.0	4.0
	10.0	24.05	3.25
	7.5	18.1	2.3
	5.0	12.15	1.35
	7.0	26.8	2.9
	6.0	23.0	2.5

With first stage removed	5.0	19.2	2.1
Removal of the first two stages	5.0	29.0	2.6
Actual performance after removal of the first two stages	5.14	~29.0	3.05

Based on this and the actual flow test results conducted by the rehabilitation consultant (GDA), it was recommended to remove the first two stages of the rotor. The modification of the turbine rotor was implemented by shipping it to Conhagen workshop in Texas, USA, as there were no competent & experienced workshops available locally who could do the de-staging. De-staging of the GCCU unit was performed successfully and the unit was put back into normal operation in June 2007.

Figure 3: Aluto Langano Gpp in Operation

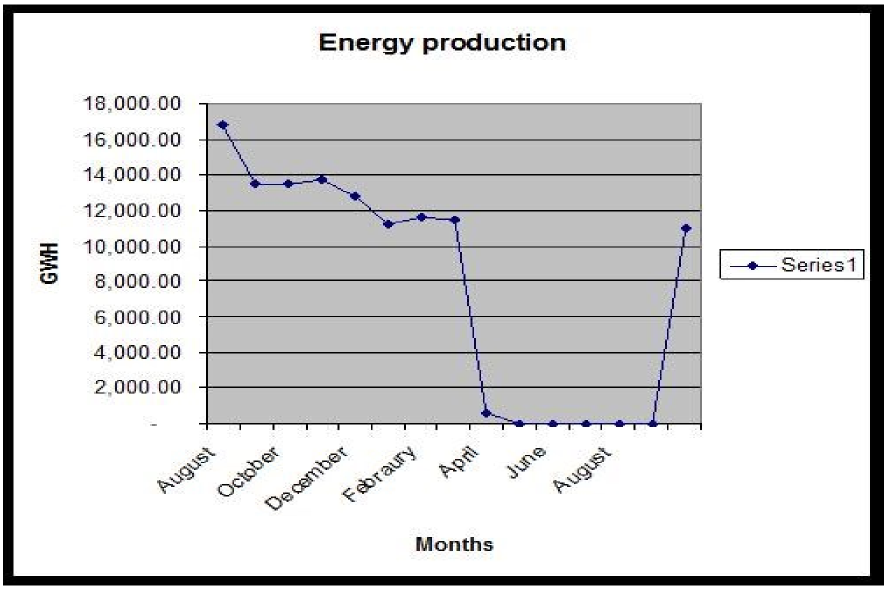

Figure 4: Plot of GCCU unit Energy Production

During the course of its operation after the rehabilitation, routine vibration measurements revealed gradual increase in the vibration levels nearly 9 months after the start of operation. It was later discovered that the root cause of vibration was related to loosening of the inertial masses on the pinion gear of the speed reduction gearbox. From the month of March to August 2008 the unit was taken out of operation due to need to rectify the problems on the Reduction gear box (RG). The purpose of the RG is to couple and reduce speed of the high speed steam turbine to match with that of the synchronous generator.

Extensive investigation on the cause of the problem with the gearbox was carried out and in addition, experience with similar geothermal power plants (such as the Puna, Hawaii plant) indicated that the Pinion gear can be successfully repaired. The gearbox pinion was finally sent to the Ethiopian Airlines workshop for reconditioning. The Ethiopian Airlines reconditioned the RG and carried out dynamic balancing to acceptable industry standards. The RG was finally taken to the power plant, installed and the unit was restarted and put back into operation in August 2008.

5. TUBE LEAK OF THE HEAT EXCHANGER OF THE OEC UNIT

The Ormat Energy Converter (OEC) is an organic turbine that uses N-Pentane as a working fluid. The two medium-enthalpy wells LA-4 and LA-8 are a primary energy source to boil the Organic fluid through the tube and shell heat exchangers. The OEC unit comprises of a one pass vaporizer and four stages of Pre-heaters; the heat exchanger tubes were made of 316L and duplex stainless steel except for the first & second passes of the pre-heater which were made of Carbon steel tubes.

However, after about a year of operation in December 1999, a pentane leak was observed through the non condensable gas (NCG) vent and caused the stoppage of the OEC unit. The results of investigation carried out after the stoppage of the unit indicated that pentane leaked into the geothermal fluid stream due to vaporizer tube failure.

During the recent rehabilitation of the Aluto plant, in order to investigate the root causes of the tube failure, the failed tubes and other relevant materials were sent to a metallurgical testing company in the USA to carry out a failure analysis. The company, Jonas Inc. conducted metallurgical analysis of the tube material and investigation of the compatibility of the chemistry of the geothermal fluid with that of the tube material.

Table 2: Results of tube inspection

Tube	Number of pits per foot on ID	Pit Depths (mm)	Pit Diameter (mm)
1	12	0.2 to 0.9	0.2 to 1
2	23	0.2 to 0.9	0.2 to 1
1	8	0.2 to 0.9	0.2 to 1

The result of Jonas' investigation indicated that localized pitting in the ID of the tube was due to high concentrations of corrosive impurities carried into the heat exchanger by brine carry-over during the initial operation of the plant therefore it concluded that the heat exchanger material was not suited or was not compatible with the chemistry of the Aluto wells. It further indicated that if heat exchangers are operated under their present condition further damage would occur to the heat exchanger tubes. The recommendation was to replace the existing heat exchanger tubes with a more corrosion resistant stainless steel grade 2205 Duplex SS.

6. EXPERIENCE GAINED

1. Experience gained in refurbishment of wellhead master valve and bleed line is much important. Assembly & disassembly of master valves, hydrostatic testing, acquisition of spare parts, use of specialist tools & equipment, local manufacture of some valve parts

2. The knowledge acquired in steam filed resource management and wellhead equipment operation would ultimately be used for Aluto expansion and other geothermal prospects

3. Operating the new procured digital Kuster K-10 tool for down hole pressure and Temperature logging

4. Knowledge acquired in using the wellhead data logger and interpretation of the logged data is remarkable in steam filed operation

5. Experience gained in refurbishment of the Cooling tower fans, specifically, in vertical shaft alignment and correct tensioning of the torque transmitting belt would be used in resolving any problems that may arise to the cooling fans system.

6. Knowledge acquired in rehabilitation of the power plant automation system has familiarized the plant personnel to the operation of the programmable logic control (PLC), Supervisory Control Acquire Data Acquisition (SCADA) system and HMI of the power plant.

7. CONCLUSION

As described above Ethiopia is endowed with considerable amount of geothermal resource potential. But up to now geothermal utilization in the country is only a fraction of the huge resource. The success with the re-commissioning of the Aluto plant will now pave the way for future expansion at Aluto and other prospect areas.

Bringing back into operation of Aluto Langano geothermal power plant has been a first priority for EEPCO due to several reasons including maximizing the return on the capital invested, providing power to the national grid system, and demonstrating that geothermal power (from Aluto site as well as other fields) can reliably meet the electricity demand in Ethiopia for the future.

Development of the Aluto Langano geothermal site to bigger scale is ongoing and the experience gained in operation and maintenance of the Pilot Plant will ultimately be used for the larger scale development.

Close monitoring of the resource (reservoir performance, fluid chemistry & steam quality) and performance of the power plant will ensure the reliable operation of the Pilot plant and also provide useful operational data that can be used for future power plants in the area.

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