Operational Cost Optimization by Building Internal Capacity

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ABSTRACT

For a long time design and construction of steam gathering systems were contracted services. Institutional inertia and bureaucracies of public companies like Kenya Electricity Generating Company PLC make the process of outsourcing those services a prolonged process involving tendering and the assignments were carried out mainly by international firms at very high costs. Following several capacity building initiatives like specialized trainings for staff and procurement of specific design software, internal capacity was built to a level of undertaking such design and construction tasks. This paper reviews a case of operational cost optimization by utilizing internal capacity and resources to connect a make-up well to one of the undergenerating wellhead power plants. KWG-15 is one of the 15 wellhead units installed by Green Energy Group (GEG) in Olkaria geothermal field. The production properties of OW-39 originally connected to KWG-15 were not optimal for the plant to generate full load. The plant was generating 1.8MW, about 30% of its installed capacity of 5.5MW with frequent well collapses that led to total outages of the plant. This had become a source of major revenue loss to the company. It was essential to connect another well with suitable production characteristics to boost up the plant generation. OW-39D drilled about 240 meters from the plant had the appropriate production characteristics. Construction activities to connect the well commenced in May 2018 and in September 2018 the project was successfully commissioned bringing the plant output up to 5.1MW. The total cost of the project was USD 129,632.59. The project cost was cut down by more than 70% compared to what would be expected had the project been designed by a consultant and executed by a contractor.

1. INTRODUCTION

KWG-15 is designed to give 5.5MW gross output although the contractual output is 5.0MW. The plant was initially operating on steam from well OW-39. The plant achieved an average of 3.0MW during the performance test carried out soon after being newly installed by the contractor (GEG) in December 2016. The test results showed that the plant was receiving inadequate steam hence could not attain full load. On this account it was recognized that there was need to connect additional steam to the plant to boost generation. KWG-15 was under defects notification period for one year (2017) and modifications to the plant system were avoided during that period which contributed to the delay in connecting additional steam in terms of a make-up well. Since commissioning of the plant in Dec 2016 the plant performance continued to deteriorate and by early 2018 the plant generation had gone down to 1.8MW.

OW-39D located on the lower well pad adjacent to the plant had successfully been discharge tested in January 2017. The output data for that well was analyzed and found suitable for operation of KWG-15 at full capacity. It was thus considered prudent to connect it to that plant due to its good power potential of about 6.5MW at 20 Bara and close proximity. Previously steamline design and construction works of this nature was a wholly outsourced scope. However, over time the company had been supporting and sponsoring capacity building initiatives to undertake such jobs within. This project was a major test case to assess the staff competencies and evaluate the economic merits of implementing such tasks internally.

The total cost of the project was USD 129,632.59. To demonstrate the economic benefits of using the readily available internal resources reference is made to a similar project implemented in 2013 of connecting OW-35 make up well to OW-35A separator. The pipeline had been designed by SKM (now Jacobs). The construction contract was competitively procured and the award was to a local contractor (Spry Engineering) at a cost of USD 1.02M. The pipeline from OW-39D to KWG-15 was approximately half the length and it is therefore reasoned that a construction contractor would have charged about USD 510,000 exclusive of the consultancy fees. Therefore the in-house connection of OW-39D to KWG-15 granted the company the benefit of cutting down the project cost by more than 75% compared to what would be expected had the project been designed by a consultant and executed by a contractor.

2. IMPLEMENTATION STRATEGY AND DESIGN METHODOLOGY

The project involved connecting a well to an existing plant. The scope of work entailed review of data especially test results for the new well and review of the design documents for the existing plant (KWG-15) all the way to design, construction and commissioning of the power plant. Details of the various design activities are described below;

2.1 OW-39D well discharge test results

After drilling the well was tested using Russel James method and different lip pressure (Pc) pipes were utilized to regulate the well throttle conditions hence operating the well at different wellhead pressures (WHP) and the results are summarized in the table below;

Table 1: OW-39D discharge test

OW-39D discharge test results								
Date	**Lip Pipe**	**WHP**	**Pc**	**Mass**	**Enthalpy**	**Brine**	**Steam**	**Power(MW)**
27.01.2017	6"	6.45	2.66	53.4	2675	dry	51.5	7.2
28.01.2017	6"	6.45	2.59	52.1	2675	dry	50.2	7.0
29.01.2017	6"	6.45	2.59	52.1	2675	dry	50.2	7.0
30.01.2017	6"	6.32	2.59	52.1	2675	0.01	50.2	7.0
04.02.2017	5"	8.52	3.49	48.8	2673	0.05	47.0	6.5
05.02.2017	5"	8.52	3.49	48.8	2673	0.05	47.0	6.5
06.02.2017	5"	8.52	3.49	48.8	2673	0.05	47.0	6.5
07.02.2017	5"	8.45	3.42	47.8	2673	0.05	46.1	6.4
13.02.2017	4"	12.31	5.63	49.6	2663	0.27	47.5	6.6
14.02.2017	4"	12.25	5.56	49	2662	0.27	47	6.5
15.02.2017	4"	12.25	5.63	49.7	2657	0.39	47.5	6.6
16.02.2017	4"	12.31	5.63	49.6	2662	0.27	47.5	6.6
24.02.2017	3"	20.04	9.56	50.8	2567	2.4	46.4	6.4
25.02.2017	3"	20.04	9.56	49.2	2641	0.75	46.7	6.5
26.02.2017	3"	19.97	9.56	49.2	2641	0.75	46.7	6.5
27.02.2017	3"	19.97	9.56	49.2	2641	0.75	46.7	6.5

2.2 Survey of area topography and route selection

Pipe route selection plays a major role in designing geothermal pipeline systems. The route depends to a large extent on the terrain. Basic best practices for optimal route selection takes into account factors such as discussed below:

a. The pipe route should be as reasonably short as possible to keep the project cost down.

b. Areas that are not easily accessible due to obstacles such as gorges or steep hills are avoided and level or moderately sloped terrain is preferred as it makes it easy to install the pipeline.

c. Environmental impacts should be kept at minimum and rehabilitation done to restore the areas affected

Site visits were done jointly by Steam field and GIS teams to identify possible routes that meet the criteria described above.

2.3 Pressure drop calculation and selection of pipe size

Steam flow through the pipeline encounters pressure drop due to the effects of friction drag between the fluid and pipe wall. The higher the pipe roughness the higher the pressure drop. High flow velocities result in larger pressure drop and erosion across a section of pipe. It is recommended to keep the steam velocity at less than 40m/s. In order to keep the fluid velocities low, large diameter pipes are picked but this choice is constrained by economic considerations since large diameter pipes cost more. Fittings such as bends and tees result in an increase in pressure drop and therefore unnecessary fittings are avoided in design of fluid systems. Calculation of pressure losses through pipe fittings is carried out using the K-value method. K is the resistance coefficient of the pipeline fitting.

2.4 Calculation of required pipe thickness

According to ASME B31.1, the minimum thickness of pipe wall required for the design pressure shall not be less than that determined by the equation below;

$$t_n \geq t_m = \frac{PD_0}{2(SE+Py)} + A$$

Where

t_n = Nominal pipe thickness, commercial pipe thickness available (mm)

t_m = Required pipe thickness (mm)

P = Design pressure (MPa)

D_0 = Outer diameter of pipe (mm)

S = Allowable stress of material at design temperature (MPa)

E = Weld joint efficiency factor

y = temperature dependent coefficient 0.4 for steel with T<482°C

A = Corrosion allowance (mm)

The design pressure shall not be less than the pressure inside the pipe at the most severe conditions expected during service. Hence, the pressure drop during operations is neglected and the pressure gained due to elevation changes is added to its initial pressure as the design pressure.

Due to process and operational reasons the steam line is broken into two pressure class sections. During well start up the section between the master valve and the working valve is pressurized to the tune of shut in pressure (70bara) through the pressure balance line. This is due to an operational requirement that master valves should be operated when the pressure is balanced both upstream and downstream and in non-flow conditions to avoid wear of the gate. As such the design and selection of the pipe schedules and flange classes for this section has to match the requirement to sufficiently contain the high pressure. The steam line section between the working valve and the turbine is normally subjected to the system operating pressure. The system pressure is selected to match turbine inlet pressure. The turbine and the pipeline are protected from overpressure damages by pressure controllers that vent excess steam through the silencer and by rapture discs designed to operate at a specific pressure and depressurize the line. The designed turbine inlet pressure for wellhead KWG-15 is 13.0 bara but the set point can be varied up to 14 bara. The design pressure used for this section of the pipe is 20bara.

2.5 Design of flanged joints – flanges, gaskets, bolts and valve classes

A flanged joint is composed of separate and independent, although inter-related components – flanges, gaskets and bolts. Proper controls must be exercised in the selection and application for all the elements to attain a joint that has acceptable leak tightness.

Pressure-temperature ratings are maximum allowable working gauge pressures at particular temperatures. ASME B16.5 design standard gives ratings for pipe flanges and flanged fittings as a function of temperature.

For the section between the master valve and working valve whose maximum expected service pressure is 70 bara (shut in), class 600 flanges and valves with a working pressure and temperature of 79.6bara and 300◦C respectively were selected. Between the working valve and the turbine Class 300 flanges and valves with a working pressure and temperature of 41.9bara and 250◦C respectively were selected.

2.6 Pipe stress modeling and results

Pipe stress analysis predicts stresses in piping and loads on equipment resulting from thermal gradients, sustained weight of the pipe and the medium being transported, pressure and occasional loads like wind and earthquakes. Software such as Autopipe aid in stress modelling for load combinations of the cases described above. A complete model provides the designer with the following outputs;

a The spacing of the supports including anchors and spring load supports.

b The forces acting on each support in the X, Y and Z direction. These are the forces that are used in the design of the pipe foundations.

c The pipe shoe movement due to thermal expansion. This determines the gaps to be left for the shoe movement either to the right, left, forward or backwards.

2.7 Pipe supports design

Forces acting on the foundations are derived from the Autopipe stress model. Pipe foundations can either be shallow footing type or deep pile type. Shallow foundations utilizing concrete column and footing was used for this design. The loose non-bearing soil was excavated down to a load bearing bottom to prevent settlement of the foundation during service. The footing is typically a large surface area pad to provide adequate safety against overturning and sliding. Deep concrete piles could be used where the soil bearing capacity near the surface is too low. In those cases deep foundation piles are used to transfer loads to a stronger layer, which may be located at a significant depth below the ground surface. The load is transferred through skin friction to the ground. Installation of this type of foundation requires availability of an excavation rig on site because the depth could be up to 6m and beyond. Footing type of foundations is therefore cost effective for small projects like OW-39D connection. The range of the forces acting on the pipe line is between 25KN to 39KN. In a bid to simplify and speed up the construction process, a standard pipe foundation was adopted for all the pipe supports. The foundation concrete mix design and dimensions was based on the highest forces drawn from the model.

3. CONSTRUCTION WORKS

The scope of works entailed laying a 240 meter long DN 250 line for carrying steam at a high pressure and temperature. One of the key activities was welding works since the pipe joints had to be defect free. All the welders participating in the project had previously been trained, tested and qualified.

4. QUALITY CONTROL AND INSPECTION RESULTS AND COMMISSIONING

Quality control and assurance was for both the civil works and mechanical works. Test cubes for each concrete batch were taken and tested for 7 days and 28 days strength. All welded joints were radiographically inspected for any defects.

The commissioning procedure followed the standard operating procedure for carrying out a cold start for a two phase uphill flowing well. However since this was a new line additional steps were included specifically about;

a. Pre-commissioning checklist

b. Flushing procedure

c. Tie-in process

d. Target bar testing

e. Plant start up

4. ENVIRONMENTAL AND SAFETY ASPECTS

There were no significant environmental impacts emanating from the project since the line was constructed mainly on two existing well pads. Only a short length of the pipe passed through a slope and since the soil is the loose volcanic type the section was at risk of soil erosion which could expose the pipe foundations. However gabions were installed and grass planted to stabilize the ground and slow down the storm water in case of heavy rains.

The colour of the cladding material used in the insulation of the pipeline is jungle green which blends well with the surrounding vegetation. This mitigates the visual impact of the project.

Due to the safety awareness carried out by safety champions within the project team and constant sensitization of inherent occupational hazards as well as enforcement of proper use of personal protective equipment, there was no recorded major or minor accident or incident throughout the entire period of the project.

5. CONSOLIDATED PROJECT COST AND BENEFIT ANALYSIS

The total cost of the project comprises of the cost of materials and the cost of variable allowances for the staff. The project had a strict timeline - completion and commissioning was to be achieved by mid-September 2018. To beat the deadline, approval had been sought and granted to incur overtime to avoid delays in the set commissioning time. The staff variable allowances as a result of overtime work were concentrated with in the months of August and September when most of the activities were on overdrive. KenGen had also enlisted Aztech contractor to provide labour for all civil works within the Olkaria Geothermal area through a framework contract. Aztech undertook foundation excavation, reinforcement bars cutting and bending, formwork preparation, concrete casting and fencing. The cost of other project materials is drawn directly from the quotations provided by the suppliers. The total cost of the project is summarized in the table below;

Table 2: Consolidated project cost

Description	**Amount Ksh**	**Amount USD**
Mechanical work materials cost	5,557,058.94	55,570.59
Civil work materials	2,628,700.00	26,287.00
Civil works contractual services (Aztech Enterprises)	715,000.00	7,150.00
Staff overtime costs	4,062,500.00	40,625.00
Grand Total Project Cost (KES)	**12,963,258.94**	**129,632.59**

This cost is about 30% of similar but outsourced projects carried out in the past. This is a clear demonstration of the value of cost effectiveness made possible by use of readily available internal resources to carry out such tasks since the design and construction costs are brought down by huge margins. Additional key benefit is the speed of execution since the long periods between tendering, evaluation, award and commencement of work are eliminated.

6. CONLUSIONS AND RECOMMENDATIONS

The company has supported efforts to build internal capacity in terms of design capability, workmanship skill for the construction team and quality control and assurance. The successful completion of this project demonstrated the benefits of timeliness and cost effectiveness by readily having in-house preparedness to undertake such urgent tasks. The major slowdown in the project progress was occasioned by procurement delays especially for civil works materials. With that lesson learnt strategic purchases of materials for earmarked projects will be budgeted for and procured in good time before the commencement of the project.

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