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Wellhead Generating Plants: KenGen Experience

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ABSTRACT

Installation of small 2-5 MWe plants on the wellhead was adopted at Olkaria in 2012 as an early generation strategy. The concept has now been expanded to involve more or less permanent units utilizing up to three wells (15 MWe) located on a single well pad. This strategy appeared quite attractive, at least at the beginning, as it was deemed to stimulate the market to invest in small plants and possible joint ventures once the concept is proven. It also assured operators of the field of early revenue pending completion of drilling and construction of power plants of the conventional type/size. Two plants were piloted, one 5 MWe plant at OW-37A in Olkaria east field and another in the virgin Eburru field both operated by KenGen. Portable wellhead units at Olkaria are condensing type and consist of turbo-generator, cooling tower, condenser, gas extraction system, electrical and control system and auxiliary equipment. Unlike conventional geothermal plants, these wellhead generating units have little permanent civil works and have shorter pipelines. They are designed to fit into containers or skid mounted to facilite easy transfer from one well pad to another as candidate well(s) may be abandoned to pave way for more permanent works. This paper discusses the strategy and offers a comparative study on the performance of such plants vis-à-vis conventional size plants operating at Olkaria.

1. INTRODUCTION

Exploration for Geothermal Energy in Kenya started as early as the 1950s. The then Kenya Power Company (KPC) jointly with the Government of Kenya (GoK) and international development partners including UNDP carried out exploration for geothermal energy in many parts of the Kenyan Rift. Several prospective areas were explored and subsequently extensive works were done at the most prospective areas at Olkaria and Eburru Geothermal fields near Naivasha.

In the Olkaria Central Field, several exploration wells were drilled in which wells OW-101 and OW-202 drilled in 1982 and 1996 respectively were productive wells. The wells remained shut-in until 1996 when Oserian Development Company, a flower farming company leased well OW-101 for use in electricity production and greenhouse heating. Later in 2006, Oserian entered into a contract with KenGen to extract steam from well OW-202 for electricity production. In the neighbouring Olkaria West Field, about 10 exploration wells were drilled between 1983 and 1997 with four of them producing steam. The wells remained shut-in until in 2000 when the Government of Kenya leased the wells to Ormat International for power production.

In Olkaria Northwest, 22 production wells were drilled between 1985 and 1993. But it was not until 2003 (ten years later) that a generating plant was installed and commissioned. In the Olkaria Domes Field, 3 exploration wells were drilled in 1999. Two of the wells were productive. Later in 2007, appraisal and production drilling started and as at March 2010, over 100MWe equivalent of steam had been proved. Plans for constructing a power plant at the field have started but it takes at least 3 years to construct and commission the planned power plant. During that period, the available steam will be shut-in instead of generating revenue.

At Eburru Geothermal Field to the North of Olkaria, KenGen carried out exploration in the area and drilled 6 wells between 1989 and 1990. One well was productive but has remained shut-in until recently when a wellhead plant was installed by KenGen.

In 1990, KenGen reservoir engineers proposed the use of mobile wellhead generators for use of generation. The idea did not receive the desired support at then. However, the proposal was revisited in 2000 where a consultant was engaged to do a feasibility study. The feasibility did not support the concept. However, in 2007, KenGen contracted GDA to supply a wellhead generator for its field at Eburru. The unit was commissioned in 2011. In 2008, KenGen entered into a partnership with a developer GEG to carry out a pilot wellhead that would be customized to resource conditions. The pilot went through a series of problems but was successfully commissioned in 2012. The success of the pilot was encouraging and KenGen contractors for supply of 75MW wellheads. The project is ongoing. The success of wellheads has shown that if KenGen had invested in them much earlier, it would have reaped lots of revenue ahead of installation of the main power plant.

This paper shows that a lot of potential revenue is lost by having production wells sitting idle for years and presents the potential of wellhead generators as means to achieve early power and revenue generation for geothermal resources. The paper further discusses the experiences of KenGen in installation of wellhead generators and the potential benefits of investing in wellhead generators.

2. CASE OF LOST GENERATION OPPORTUNITY

To estimate the economic importance of the wellhead generation concept, a look at the lost revenue generation potential is considered over the years that the steam has available but was not in use. It is assumed that if the steam from the wells had been put into use for power generation immediately the steam was acquired, significant amount of revenue could have been generated. It is also assumed that the cost of energy would have remained constant at the current feed in tariff. A conservative availability of 80% and load factor of 90% is assumed. Six cases situations where available steam remained shut-in for considerable period of time are considered in this assessment namely:

i. Olkaria East field where excess steam has been available since connection of makeup wells in 2000 and recent drilling of production wells for Olkaria I AU yielded steam which has been idle awaiting the power plant.

ii. Olkaria North East Field – 70MW of steam that had been acquired by 1993 and which remained idle until 2003 when Olkaria II was commissioned

iii. Olkaria West field where steam had been acquired by 1983 as part of exploration but was not used until 1999 when Ormat leased the wells

iv. Olkaria Central field where exploration wells drilled in the late 80's yielded steam but was not used until it was leased to oserian power plant in 2005

v. Olkaria Domes field where drilling of exploration and appraisal wells between 1999 and 2008 yielded substantial steam and this steam is still awaiting commissioning of Olkaria IV power plant.

vi. Eburru geothermal field where one successful well was drilled in 1989 and the well remained idle until 2011 when the eburru wellhead was commissioned.

At Olkaria East field, excess steam has been available from the time 8 make-up wells (well OW-27 to well OW-34) weredrilled 1993. These make up wells were drilled in the Olkaria East Field in response to steam decline observed at the early years of Olkaria I power plant. When all the makeup wells were connected, it resulted in excess steam which has remained available for over two decades. In 2008, drilling of wells for Olkaria I units 4&5 power plant started. The power plant is currently under construction and this means that some steam wells have remained capped since 2008 awaiting for installation of the plants.

In the Olkaria Central Field, several exploration wells were drilled in which wells OW-101 and OW-202 drilled in 1982 and 1996 respectively were productive wells. The wells remained shut-in until 1996 when Oserian Development Company, a flower farming company leased well OW-101 for use in electricity production and greenhouse heating. Later in 2006, Oserian entered into a contract with KenGen to extract steam from well OW-202 for electricity production. In the neighbouring Olkaria West Field, about 10 exploration wells were drilled between 1983 and 1997 with four of them producing steam. The wells remained shut-in until in 2000 when the Government of Kenya leased the wells to Ormat International for power production.

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In Eburru Geothermal Field to the North of Olkaria, KenGen carried out exploration in the area and drilled 6 wells between 1989 and 1990. One well was productive but has remained shut-in since then.

To estimate lost generation potential, the power potential of the wells or available steam is computed over the years the steam has been shut-in in wells. It is important to establish if the investment would have made economic sense considering the capital needed and the annual O&M costs. A simple economic model is to consider estimate energy sales by assuming a uniform unit sale of US$ cents 8.8 per kWh presented by the feed-in tariff applicable in Kenya and uniform O&M cost of 2% capital cost per year. Ignoring the time value of money, the total cost of project is taken as sum of capital investment and total O&M costs over the years. The revenue is assumed as product of the total energy generated (assuming 90% availability) and a uniform unit cost assumed from the FiT tariff. The result is as illustrated in the table 1.

OLKARIA + EBURRU = $ 1 BILLION LOST REVENUE

IN SHUT-IN PRODUCTION WELLS

= $ 200M WAS SUFFICIENT CAP & OM COST FOR

GETTING WELLHEADS IN THOSE WELLS

Table 1: Estimated lost generation and revenue from shut-in steam

Geothermal Field	Olkaria I make-up steam	Olkaria I wells for units 4&5	Olkaria II	Wells OW-101/102 Olkaria Central field	Well OW-202 Olkaria Central field	Olkaria West	Eburru	**Total**
Power potential (MWe)	30	16	70	1.5	3	15	3	
Year available but not used	2000	2008	1993	1982	1993	1983	1989	
Idle until (year)	2010	2010	2003	2004	2006	2000	2010	
Duration Idle yrs	10	2	10	22	13	17	21	
Lost Generation GWh 80% availability	2,365.20	252.29	5,518.80	260.17	307.48	2,010.42	496.69	**11,211.05**
Capital investment ($1256000/MW)	37,680,000.00	20,096,000.00	87,920,000.00	1,884,000.00	3,768,000.00	18,840,000.00	3,768,000.00	**173,956,000.00**
Annual O&M cost 2% Capital	7,536,000.00	803,840.00	17,584,000.00	828,960.00	979,680.00	6,405,600.00	1,582,560.00	**35,720,640.00**
Capital and O$M cost	45,216,000.00	20,899,840.00	105,504,000.00	2,712,960.00	4,747,680.00	25,245,600.00	5,350,560.00	**209,676,640.00**
Revenue $0.088/kWh	208,137,600.00	22,201,520.00	485,654,400.00	22,894,960.00	27,058,240.00	176,916,960.00	43,708,720.00	**986,572,400.00**

3. THE WELLHEAD GENERATION CONCEPT

3.1 Overview of wellhead generation

In wellhead generation, steam is extracted from the well and converted to electricity at the wellhead. In this way there is little transmission of steam and as such there is no steam field development except for the brine and cooling tower blow-down disposal systems. The power generated can be fed to the local distribution network or can be stepped up and fed to the nearest transmission network. Unlike conventional geothermal plants, wellhead generating units have little permanent civil works. Portable wellhead units are preferably containerized or skid mounted such that they can be easily transported from one well site to another.

Wellhead generators can be Back Pressure, Condensing or Combined Cycle types and consist of turbo-generator, cooling tower, condenser, gas extraction system, electrical and control system and auxiliary equipment.

Wellhead generators concept offers lots of benefits. Under wellhead generation, geothermal development can be fast tracked. The lead time between investment into development of geothermal resource and the time to revenue generation will be substantially shortened from several years to only a couple of months. By reducing the time required for a geothermal resource to generate revenue, geothermal development can be made to self-sustain in that the revenue generated from the fast tracked units can be used for further expansion of the resource. Wellheads also offer the opportunity to maximize resource utilization by ensuring that no steam is wasted or shut in. Further to this wellheads can be uniquely designed to optimize the specific well output curve rather than generalized or averaged over many well outputs across a large well field.

3.2 Objectives of wellhead generating plants

The objectives of wellhead generation include among others;

1. Reduction of time to market: - significant reduction in the time between completion of drilling of a geothermal well to development and subsequent revenue generation from the well or wells in close proximity.

2. Maximum utilization of available steam and avoidance of steam being shut-in for long pending further drilling before developmental/project thresholds are met.
3. Shorter and higher ROI on wells: - By utilizing available steam early, the period for ROI in drilling expenses is shortened considerably. Higher tariffs are possible for the generators as well.

3.3 Advantages of wellhead generators

Technically, wellheads have several advantages over conventional plants. These include, but not limited to the following;

a) Higher Feed-in tariffs are possible for small isolated plants such as wellheads. In Kenya for instance, a lucrative FiT tariff is applicable for these plants.
b) Wellheads have short transmission lines of steam and this result in less losses and lower costs.
c) The energy is transmitted as electricity which is more efficient than transporting steam.
d) Individual characteristics of well can be fully utilized by selecting the plant for the most optimum point on the output curve. In this way, the most optimum output of a well is utilized.
e) Ease of maintenance (small individual plant can be shut for maintenance).
f) Flexibility (can move from one well to another) and dynamic – units may be modified to match changes in well characteristics.
g) Cost effective – minimum civil works needed small transport costs.
h) Competitive to attract financiers. In most cases, financiers prefer to fund small cost project which are typically short term projects with early and high returns as opposed to long term, high cost projects.

3.4 Disadvantages of wellhead generators

Despite the above enumerated advantages, wellheads also have their share of setbacks which include the below listed:

a) Geothermal wellhead generators are a new technology and therefore the equipment are still expensive and spares may be limited.
b) The fact that wellheads will be installed at the well pad means that there will be many of them and this presence challenges to operations and maintenance team.
c) From an environmental standpoint, equipment dotted over large areas could elevate visual impacts as opposed to centralized power plants. Furthermore, management of brine and effluents from the plants can be complicated.
d) The small units can have high operating costs compared to central unit. Transmission of power is cumbersome since many transformers and transmission networks are required.

4. THE WELLHEAD GENERATION PLANTS AT OLKARIA

4.1 Wellhead generators typical layout and components

The wellhead generators currently installed at Olkaria are of condensing steam turbine cycles. The plants consist of steam system consisting piping horizontal separator, silencer and pressure control system, single flow condensing turbines, shell and tube condensers, steam jet gas ejectors for extraction of NCG and forced draught counter-flow cooling towers. The entire control system is containerized. All the foundation structures are made portable except a section of turbine foundation. A schematic layout is shown in Figure 1 below.

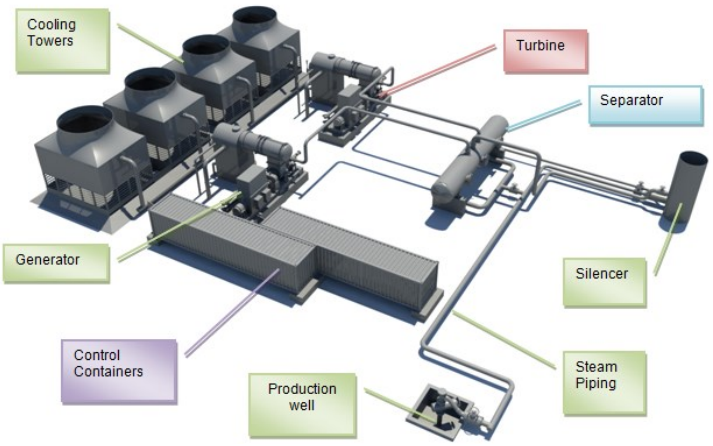


Figure 1: Field layout of C64 wellhead units at Olkaria. (Courtesy of GEG and KenGen).

4.2 Present Status of installation of Wellhead Generators at Olkaria

In 2008, KenGen entered into a partnership with GEG to conceptualize, design, procure and install a pilot wellhead generator that would be customized to each well's resource condition. The pilot plant had a capacity of 5MW. After several challenges, the pilot was successfully commissioned in 2012 and has been in successful operation to date registering high availability of >98%.

In 2009, KenGen engaged GDA to supply and install a 2.3MW wellhead plant for its Eburru field. The plant was successfully commissioned in 2011. Pilot 5MW wellhead unit in successful commercial Operation since February 2012.

- Rating 2x2.75MW turbine generators,
- Current output 3.3MW
- SSC_t 2.46 kg/s/Mw (GEG, 2012)

In 2010, KenGen awarded GEG the tender to supply, install and commissioned wellhead units with total 75MW output at selected wells at Olkaria. The project kicked off in 2012 and the first 12.8MW units were commissioned in March 2014. First 2 units under the 75MW wellheads project of KenGen (Well pad OW-43) commissioned in March 2014.

- Units installed: 2xC64
- Rating 2x6.4MW = 12.8MW
- Maximum load so far: 13.6MW
- SSC_t 2.56 kg/s/Mw (Odongo, 2014)

Additional wellhead generators beyond the 75MW contract are being considered. See Table 2.

Table 2: Plans for wellhead installations by KenGen in the 75MW project.

Wellhead project	Capacity	Status	Commissioned/planned
Eburru	2.3	Operational	2011
Pilot	5	Operational	2012
75MW Portion I	12.8	Operational	Jan 2014
75MW Portion II	12.8	Under commissioning	May 2014
75MW Portion III	15	In progress	June 2014
75MW Portion IV	20	Not commenced	Unknown

4.3 KenGen Lessons and Experiences

Challenges

In this project, a number of unique challenges were encountered during its implementation. However, like in may geothermal projects these give thrust to creativity and innovativeness. Delays are however inevitable incase unforeseen challenges are encountered.

i. New Technology
   - Wellhead concept was a new technology.
   - Initial or design mistakes were encountered
   - No established manufacturers – large manufacturers not willing to venture into small plants

ii. Suspicion of the project
   - Extended suspicion from the government agencies especially after the pilot plant initially failed to run
   - Repeated audits carried out

iii. Project Organization structure
   - The project was not properly defined in the organization structure
   - Formulated as a special project without staffing
   - Split scopes – GEG doing one part, KenGen the other and therefore delays and conflict

iv. Evacuation of power
   - Hundreds of plant trips at the pilot unit due to initial line problems
   - Wellhead at OW-43 delayed due to delay in construction of evacuation line
   - Siting of wells now constrained by availability of evacuation lines

Lessons learnt

i. Do not fear to take risks
   - Risks are inherent part of projects
   - Manage the risks

ii. A proper audit of contractors and manufacturers capability is critical
   - Avoid surprises
   - Know what they can deliver

iii. Clearly Define the Project Structure
   - Clearly define the scopes, roles and responsibilites
   - Avoid mixing scopes

iv. Plan Ahead for Evacuation of power
   - Put this ahead in planning

v. Keep your paper work in order
   - All transactions must be documented

4.4 Possible Improvements of present design

i. Improved Cooling Systems – Conserve Condensate
   - Hybrid type cooling towers
   - Dry cooling towers
   - Bottoming with a binary unit

ii. Improved NCG system
   - Improve plant efficiency
   - Hybrid – steam ejector + vacuum pump
   - Vacuum pump only

iii. Remote operation of wellhead units
   - Reduce operational costs

iv. Portability improvement
   - Improved ease of relocation
   - More containerization

5. CONCLUSION

This report has shown that a lot of opportunities to generate power and revenue during geothermal field development are lost due to acquired steam left idle awaiting future utilization. A simple assessment has shown that KenGen lost a potential of **11,211** GWh by not utilizing steam that was available and letting sitting idle in the wells. This amount translates to approximately **USD ONE-BILLION** in revenue lost over the years the steam was shut-in at the wellhead. Only 20% of these amounts would have been needed as capital and operational costs in that period.

The report has shown that wellhead turbo-generators can be utilized during the field development to generate power and revenue while carrying out field testing, field development, planning and utilize excess steam during plant operation. KenGen has successfully implemented wellhead generators in its Olkaria field. The successful implementation of wellhead generators has confirmed their viability for early generation. Through implementation of wellhead generators, KenGen has gained vital lessons that will serve ongoing and future implementation of wellhead generators.

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