

KenGen's Wellhead Technology Experience & Business Insight

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ABSTRACT

Today, geothermal energy is known as one of the most reliable alternative renewable energy source and has been proved to be technically and economically feasible. Geothermal electricity is generated from geothermal energy. Several modes of technology are used to convert the geothermal energy into electricity but the paper will focus on wellhead generation technology.

Kenya has been focusing on the generation of power to meet its acute power shortage and ever rising demand. Traditionally KenGen has used conventional power plants which involve months of well drilling and years of central power plant construction. The wellhead technology seeks to take advantage the idle time between completion of drilling and the start and finish of the central power plant construction. It yields an overlapping concept that harvests the capped steam as soon as it is available for immediate power and revenue generation prior to the central power plant completion. KenGen being the country's leading power producer has embraced the use of wellhead generators in geothermal thus realizing early power generation.

Wellhead Technology has a modular approach which connects wells with outputs of up to 15MW. The modular approach allows for a combination of wells using short streamlines instead of the traditional long lines which are very costly and take much longer to construct. The modules form clusters which generate power through the convectional mode of steam running turbines. The power is then directly fed into the grid. As a result, wellhead technology has enabled KenGen gain an edge over the following challenges:

- ✓ Immediate power supply to address its rising demand.
- ✓ Due to its low capital cost and immediate utilization the company has been able to borrow capital and repay almost immediately unlike the traditional mode that takes close to a year before the repayment plan kicks off. This minimizes interest gains on loan.
- ✓ Reduced cost of power generation i.e. steam fields.
- ✓ Power plant portability which taps into isolated and remote areas.
- ✓ Higher revenue collection from the attractive wellhead feed-in tariff as compared to the conventional PPAs.
- ✓ Modular approach enhances access to small value loans thus appealing to small and medium scale investors.

This paper seeks to address the wellhead (early generation) concept and KenGen's experience in deploying this revolutionary technology.

1. INTRODUCTION

KenGen has pioneered a new technology in geothermal power generation by installing two wellhead generator units at Olkaria and Eburru. The wellhead units generate 5MW and 2.5MW of electricity respectively. The technology involves tapping steam from wells, which are undergoing

tests, or are awaiting connection to permanent plants so as to benefit from early generation. This move by the largest electric power generator comes at a time when the country is experiencing an increased demand for electricity.

Rapid economic growth and industrialization has created the need for accelerated drilling of geothermal wells in order to tap geothermal power potential and avoid over-reliance on the erratic hydroelectric power. Long droughts have slashed the capacity of main dams, forcing shutdowns and leading to reliance on costly diesel-powered generators, which have in turn pushed up energy bills.

With the success of the Olkaria and Eburru wellhead power generating units, KenGen now intends to install more units with an expected yield of 70MW. Other geothermal areas targeted with this new technology include Menengai and Longonot. Through this move, KenGen has gone on record as being the first company in Africa to embrace this new technology and therefore moved a step away from traditional methods to achieve the same results. An important point to note is that permanent power plants take between 24 and 36 months to construct and commission.

2. AN OVERVIEW ON PLANNING OF GEOTHERMAL PROJECTS WITH A CASE STUDY ON OLKARIA, KENYA

The planning of geothermal development in Kenya comprises of the following stages:

- a) Review of existing information of a prospect;
- b) Detailed surface exploration;
- c) Exploration drilling and well testing;
- d) Appraisal drilling and well testing;
- e) Feasibility studies;
- f) Production drilling, power plant design and environmental impact assessment;
- g) Power station construction and commissioning;
- h) Reservoir management and further development; and
- i) Shutdown and abandonment.

The development programme from project identification to power station commissioning takes about 8 years but can be reduced to 5 years if finances are readily available. From the experience of development at Olkaria, it has been learnt that:

- i. Timely financing of the projects is very critical;
- ii. Some of the exploration wells can be used in running pilot plants to generate some power while decisions for further development are being considered;
- iii. Staged development has an advantage of making early use of the existing wells, thus reducing early expenditure and generating revenue to take the project forward and build confidence in the resource;
- iv. Appraisal drilling should not be stepped out too far apart from the discovery exploration well. Such step-out wells might destroy confidence in the prospect by being unproductive; and
- v. Planning for competent staff is a very critical, yet often ignored, aspect of a good geothermal development strategy.

2.1 Kengen Pioneers Wellhead Power Generation Systems

2.1.1 Drilling Logistics

- Drilling of geothermal wells takes between 50 to 70 days at depths of between 1.8 and 3.0km.
- After drilling, the exploration wells are fully tested. Permeability tests are conducted soon after capping the well.
- A suite of down-hole temperature and pressure measurements follow this when the well is heating up from the cooling experienced during drilling.

Good wells recover quickly and within one month they develop enough wellhead pressure to discharge on their own. Other wells may require assistance to start discharge by compressing and releasing several times. Discharge tests take a minimum of three months and a maximum of 1 year to determine the full characteristics and long-term behavior of the well. During discharge tests, steam and brine measurements are made to determine the amount of steam available. Chemical analysis data of steam and brine is useful during exploitation and also for defining the reservoir characteristics.

The current method is to pass the geothermal fluid through a pipe, measure the total flow and direct the fluid to a wellhead separator to separate the steam from the water. The water fraction is measured and the difference between the total mass flow and the water gives the steam fraction.



Figure 29: Photo showing OW-38B discharging into the atmosphere. The well has a discharge capacity of 18MW



Figure 2: OW 44 series discharging. The wells discharge a combined capacity of 20MW

Normal well testing in its entirety wastes resources. In most cases, wells are discharged over long periods to assess their response to exploitation as the resource is drawn down without tangible production.

2.1.2 Case Studies

Through the use of this new technology, KenGen will test the wells while routing the steam through the generators, which will supply power to the grid. This approach will enable the country meet its energy demands within as short a time as 70 days of commencing well drilling.

It is no longer economical to drill all the wells needed to supply a permanent power station before financing is sought or returns are realized from the wells. In the event that a well is adjacent to a new well that is being drilled, power from the first well can be used to supply the next well to be drilled, thus reducing diesel usage at the drilling rigs. The balance can then be sent to the grid.

It is estimated that a drilling rig consumes approximately 350,000litres of diesel from the start to completion of a geothermal well. Conversion of the cost at 82KShs to the dollar yields about 426,829.3 US dollars. By connecting these wells to wellhead generators, more than a quarter of drilling and base camp facility costs can be saved. In addition delays in procurement of diesel fuel will be eliminated hence reducing the drilling period significantly. The diesel generators and auxiliary power supply units to the rig require routine maintenance - they require changing of oil and oil filters as well as fuel filters. It is also the case that labor required for maintenance comes with both cost and time implications to the drilling process. The use of portable wellhead generators therefore eliminates the use of diesel hence encouraging use of alternative green energy which is environmental friendly, cheaper and clean.

With this in mind, each completed well will start contributing to the grid; and could as well do this for the next four to six years it takes to complete all wells and build the main power plant. In essence, geothermal wellhead generators achieve environmental friendliness, facilitate early generation of power using renewable resources and provide an early revenue stream that can be used to drill more wells or contribute to financing of the main power plant.

2.1.3 Effect on the Ecosystem

The standard method of well testing that is currently used discharges steam into the atmosphere. This affects the environment because the temperature of the immediate environment is raised above normal conditions and may result in a change of the eco-system.

Encouraging the use of wellhead generators minimizes this effect as the steam will pass through the generators with the steam pressure and temperature dropping and will ultimately be condensed into a liquid, forming a closed loop with very little or no atmospheric venting.

2.1.4 Design Features

The wellhead design has a modular design based on standard manufactured components. Being flash based, the wellhead generator is suitable for temperatures above 190°C. The plant can operate independently for each well or be

organized into power farms to provide a similar power output to large traditional geothermal power plants. The wellhead generator plant is delivered in 40-foot ISO containers on-site, and the standardization of key components allows for quick installation. The first power online can be expected within 12 months after ordering.

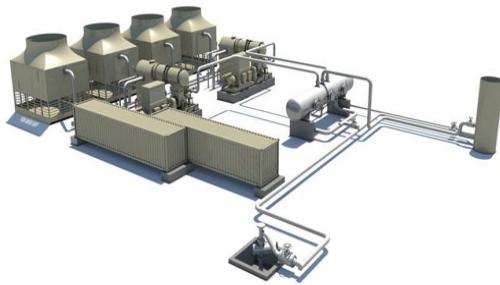


Figure 3: Schematic representation of the 2.5MW Olkaria geothermal wellhead generator

This solution has been developed to counter both the long-term delays in supply of power online and prohibitive investments costs associated with the deployment of traditional geothermal power plants. The wellhead generator delivers power online from the completion of the first well, providing for step-by-step utilization of the geothermal field, without waiting until a critical mass of productive steam wells are drilled.

2.1.5 Key Benefits

- a) *Early return on investment:* This technology represents a significant advantage over the deployment of traditional power plants enabling the early supply of electricity and access to revenues earlier in the investment cycle
- b) *Optimal energy utilization:* The independent well-head power plant enables optimum power to be produced from each individual well regardless of their differing outputs and characteristics. The concept negates the needs of traditional power plants for well redundancy or an excess steam buffer to cater for well failures and allows all wells to be utilized. The wellheads modular design also makes it possible to generate electricity from remote wells that are outside the topographical reach of large traditional plants.
- c) *Rapid deployment:* The wellhead's modular design, based on standard manufactured components, allows for significantly reduced lead times and early power online. Delivery of power online can be reduced to within 12 months of ordering the first wellhead generator power plant. Thereafter rapid deployment, at a rate of one wellhead generator plant per month, can be achieved.
- d) *Lower risk with modular flexibility:* The wellhead generator modular power plant is delivered in 40-foot ISO containers and each module is ready made at the factory allowing for quick installation. It is designed to operate independently for each well, but can be organized into power farms to provide a similar power output to large traditional geothermal power plants.

e) *Maximized return on investment:* In the event of a well failure, the wellhead generator is designed to be decommissioned, transported and redeployed on a second well, maximizing the return on investment. Equally important, is the fact that the failed well can be returned to its original state thus preserving the environment.

f) *Reduced cost per megawatt:* The wellhead generators' modular design based on standard manufactured components enables a highly competitive capital price and allows for easy maintenance and access to spare parts.

g) *Flexibility and adjustability in power generation:* Focusing on the characteristics of each well independently, the wellhead generator is able to adjust turbines to achieve a high level of power output efficiency, driving down electricity production costs.

h) *Ease of operation and maintenance:* The wellhead generator also deploys an advanced control system providing real-time operational data, allowing for early remedial action and preventative maintenance thus avoiding unnecessary downtime.

2.2 Eburru 2.5MW Geothermal Wellhead Power Station

The Eburru Wellhead Geothermal Power Plant has been commissioned and is now generating up to 2.52 MW for the Kenya Electricity Generating Co. (KenGen). This is a major milestone for KenGen, as it is its first geothermal wellhead power plant in commercial operation.



Figure 4: Photo of the recently commissioned Eburru wellhead power plant

Eburru is located approximately 2 hours outside of the capital, Nairobi, in Kenya's Great Rift Valley. The Eburru geothermal field is on the flanks of the Ol Doinyo Eburru Volcano and is situated 11km northwest of Lake Naivasha. The project is unique because, for the first time, KenGen engineers carried out implementation work without the assistance of external consultants. Civicon served as the general contractor, responsible for construction of the plant. During the month of January, GDA engineers worked closely with KenGen engineers and operators and Civicon construction crews to complete the commissioning and performance testing. The plant was first synchronized to the

grid on January 23rd. The performance testing was completed just six days later on January 29th.

GDA designed the plant and the steam field, and supplied all of the major equipment. This included an Elliott GYR steam turbine, Kato generator, Lufkin gearbox, Graham condenser and vacuum pump, Goulds cooling water pumps, and a Cooling Tower Depot single-cell fiberglass tower. GDA also manufactured auxiliary equipment in-house to minimize installation time, including the lube oil system, turbine control valve assembly, compressed air system, fire pump skid, emergency power system, and plant control system. The equipment and materials were shipped from the US to Kenya in 11 shipping containers one month ahead of schedule.

2.3 Olkaria 5MW Geothermal Wellhead Power Plant

KenGen has partnered with the Green Energy Group (GEG) in constructing the 5MW Olkaria geothermal wellhead power plant. The highly experienced executive team at GEG has assembled a team commanding a wealth of experience within the design, engineering, project management and operation of geothermal plants and is supported by a Board of Directors drawn from both investment banking and the engineering sector.



Figure 5: Photo of the 2.5MW Olkaria wellhead generator

3. CONCLUSION

A 50-70 MW geothermal power plant takes about 2 years to construct and commission. This phase includes the following:

- Steam gathering and brine re-injection system;
- Power house, electromechanical equipment, cooling towers and blow-down re-injection system;
- Sub-stations and transmission line; and
- **Commissioning.**

Transmission lines can be an issue particularly if the way leave acquisition is not handled in good time and professionally. This is because transmission lines can be fairly long and traverse very many land ownerships. Land compensation may be required in some parts while in others outright purchase may be the solution. **Power lines**, just like power stations require an environmental impact assessment to be conducted.

It is in the light therefore, that we advocate for cheaper and faster ways to tap electricity from our wells and utilize them in order to realize significant economic gains. This can only come from an innovative option like the use of small power plants (wellhead plants) which can be rapidly deployed, have lower risk with modular flexibility; and are designed to be decommissioned, transported and redeployed on a second well in the event of a well failure, thus maximizing the return on investment. Equally, they offer a reduced cost per megawatt and are easier to operate and maintain.

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