ENGINE COORDINATION ACTION

Summary of the Workshop 5
Electricity generation from Enhanced Geothermal System
14-16 September 2006, Strasbourg (France)

1. Introduction

Presently the overall capacity of electricity generation systems based on geothermal energy installed within European countries is 1.13 GW (EU 0.8 GW). These geothermal power plants contribute with approx. 7.1 TWh/a (EU 6.0 TWh/a) to the European electricity supply. The by far biggest share of this electricity generation (about 98 %) results from high enthalpy fields which can only be exploited at specific locations with promising geological conditions. Only to a very small extend low enthalpy resources are presently used. But these low enthalpy resources have by far the biggest electricity generation potential throughout Europe and worldwide.

However, techniques for exploiting low enthalpy resources for the production of electricity are currently only partially established. Firstly there is the challenge to lock up the deep underground to achieve flow rates at temperatures high enough to realise an economic viable project. Secondly the surface technology (i.e. power plant technology) needs to be further developed and optimised in order to achieve high efficiency rates with low investment costs and thus low electricity generation costs.

In the past, different technical approaches to convert low temperature heat into electricity have been developed. Some systems are available on the market, others are still in a demonstration phase and others only exist as system studies (i.e. on paper) so far. The overall goal of these development efforts was and is to achieve the highest possible efficiency rates taking the given thermodynamic constraints into consideration. Therefore for the use of low enthalpy resources mostly binary cycles are chosen. These cycles have on one hand the advantage of the turbine not getting in touch with the brine in case of e.g. too aggressive brines; on the other hand – and even more important – binary cycles are able to convert low temperature heat (i.e. even temperatures below 100 °C) into electricity. However, a simple conclusion about the most promising binary cycle respectively power plant technology can not be drawn based only on the criteria “efficiency”. Additionally a wide range of further aspects has to be taken into consideration. In general thermodynamic aspects need to be seen together with technical feasibility and availability as well as economic, environmental and social aspects related to the site specific conditions.

On this background the aim of the EU-funded ENGINE-workshop was to analyse and assess possibilities and limitations of the currently available power plant technology using the energy retrieved from low enthalpy geothermal sources. To get an overall view representatives of research and industry as well as project operators and planners have been brought together and presented their individual view. Besides some partly controversial conducted discussions, the basis for fruitful exchange of information and experiences was thus created. The slides of the presentations are available under http://engine.brgm.fr/.

Besides the R&E-needs irrespective of a specific cycle or power plant (e.g. material selection for sealing, turbine parts, heat exchangers etc., optimising of the working fluids) the main findings and discussion results of the workshop can be summarised as follows to give an impression of the overall picture.

2. ORC or Kalina Cycle?

Geothermal electricity generation from low enthalpy resources is realised in binary plants. Thereby the heat of the brine is transferred via heat exchanger to a working fluid, which evaporates already at low temperatures (e.g. organic substances). Currently two types of binary cycles suitable for the frame conditions given in geothermal power plants for low enthalpy resources are available on the market: the Organic Rankine Cycle (ORC) (i.e. a conventional Rankine cycle running with a specific working fluid evaporating below 100 °C) and the Kalina cycle (i.e. also basically a Rankine cycle being fed with a working fluid consisting of a mixture of two substances like e.g. ammonia and water). To use of such a mixture as working fluid has the advantage that the heat can be transferred more efficiently between the brine and the power plant cycle; this reduces possible losses. Therefore the Kalina cycle promises higher efficiency rates within a certain temperature window and hence might be advantageous at temperatures below 130 to 140 °C. But the use of a mixture of two substances with a varying mixing ratio within the working fluid streams is only possible with a more ambitious and expensive technology compared to the use of only one substance. This is one of the reasons why there is only one Kalina cycle in operation within a geothermal power plant so far. In contrast there are numerous Organic Rankine Cycles under operation worldwide. Apart from these differences between the two cycles “ORC” and “Kalina cycle” these cycles do have more in common than being contrary. Each cycle has for a certain application at a specific spot specific pros and cons. But both cycles also show a significant optimisation potential in terms of the design of the working fluid, the cycle and turbine designs as well as the cooling system. Therefore the question is not to choose an ORC or a Kalina cycle. Rather the optimisation task is to find the right cycle for the reservoir characteristics and the other project specific demands given at a certain site.

3. Axial or radial turbines?

The turbine used within an ORC or a Kalina cycle is in most cases an axial inflow type. This is derived from the conventional water steam turbine industry where axial turbines are state of technology due to their promising performance within the respective application (i.e. for the use in big e.g. coal fired power plants). The design parameters of the turbine however within cycles driven by low enthalpy resources can vary decisively compared to a “classic” turbine used within a water steam cycle (e.g. enthalpy drop, stream and rotor velocity). Therefore investigations have shown that radial inflow turbines can lead under specific conditions to higher efficiencies. Considering the importance of optimising the efficiency of such cycles under the conditions defined by the geothermal reservoir without raising the overall complexity of a cycle radial turbines could be a promising opportunity. Therefore the question is not to use axial or radial turbines. The point is to choose the turbine type promising the highest efficiencies at lowest risks – without any ideology and predefined opinions.

4. Air or water cooling?

The working fluid of the ORC or Kalina cycle could be cooled down with cooling systems driven by air or water. Air cooled plants have the disadvantage to face seasonal changes in cooling temperatures. Therefore such systems can often not guarantee maximum power from the plant throughout the year. Additionally the running fans need electricity and space; also noise emissions need to be considered at a location close to populated areas. In contrast water cooled plants in most cases can realise lower and over the year more constant condensation temperatures and pressures. They therefore allow for a larger enthalpy drop in the turbine and thus slightly higher efficiencies. However the mass flow of water in the demanded quality required by the water based cooling system needs to be provided considering legal obligations e.g. of the temperature level and the available amount. This can also culminate in high provision costs due to power demand for pumps and e.g. water conditioning systems. Therefore - at a certain location - the question about air or water cooling is not really the most important one because in most cases a location specific compromise has to be found anyway. If e.g. enough water is cost efficient available in most cases a water cooling system will be implemented due to economic reasons. But often this is not the case. Then there is only the chance to go for an air cooling system or even a combined system.

5. Fancy or proven technology?

Fancy (“high efficiency – high risk”) or proven (“low efficiency – low risk”) technology is a matter of the viewpoint respectively of the philosophy. Aiming for low risks one can get good and reliable power plant technology on the market characterised often by relatively low efficiencies; this is e.g. the case for a standard power plant based on an ORC. Accepting a slightly higher risk one will find on the market cycles which promise considerably higher overall efficiencies with the disadvantage that these cycles do exist so far maybe only as a demonstration plant or even only on paper. Therefore the question is not to go for fancy or proven technology. The question is what technological risk a project can / will accept for the profit the project strives for.

This question is in most cases not answered by the project developer; rather the bank or the investor providing the credits decides what risk might be taken. Due the fact that the risk finding the reservoir conditions needed for an economic viable project is in most cases quite high most projects go for a proven and well known power plant technology with a high availability in order to minimise the existing risk. This attitude makes it very difficult for new and innovative technologies to break into the market. Therefore fund raising of public money for demonstration projects is often an important step in order to prove technical feasibility of new technologies to allow them the market access.

6. Power or CHP?

Converting low enthalpy resources to electricity produces considerable amounts of waste heat because of necessarily low thermal efficiencies due to the – according to Carnot – given thermodynamic constraints. The logical consequence – regarding the relatively high investments of geothermal power production from low enthalpy resources – is therefore to try to additionally sell this heat on the local heat market and realise combined heat and power (CHP) projects like i.e. in Húsavik, Iceland, or in Neustadt-Glewe, Germany. In order to further optimise this economic win-win-situation under the given economic and political frame conditions it might be even more promising to run a geothermal CHP plant heat leaded instead of aiming for the highest power output. In Unterhaching, Germany, for example, running the system with the overall installed electrical capacity for maximising the electricity output is the strategy for the summer, whereas during the winter supplying the demanded heat - even by reducing the electricity generation - has priority. Therefore the goal should always be to find a way to sell the heat locally respectively to identify a location where a heat demand is given to improve the economic performance of a geothermal power plant especially for low enthalpy resources.

7. Lessons learned

The available know-how from existing geothermal power plants – regardless if with ORC or Kalina cycle, with axial or radial turbine, with water or air cooled, if power or CHP, with fancy or proven technology – shows that electricity production from low enthalpy resources in Europe is still a fairly young technology which lacks further experience. This is the case for the development of geothermal resources (i.e. the underground part) as well as power plant systems (i.e. the part on the surface). Nevertheless there are quite a lot of projects planned and considerably more experience will be available in the years to come. On this background the lessons learned so far can be summarised as follows.

- Optimisation was mainly thought to be a question of thermodynamics. But regarding geothermal projects this is only one part of the whole picture, in which technical and economic aspects as well as the site specific frame conditions need to be included in order to provide high availability and economic feasible power plants. Therefore the simple discussion about the pros and cons of ORC vs. Kalina cycle, of air vs. water cooling, of fancy vs. proven technology and of power vs. CHP in terms of a further development of geothermal energy use will not lead to any results. The main task of project developers instead is to identify the site specific conditions and clarify the perception of risks which can be taken.

Thereupon the project as total needs to be optimised aiming for economic feasibility free of predefined opinions.

- New and innovative technology is always connected with technical and financial risks (“No risk, no fun!”). This is also the case for systems generating electricity from geothermal resources in general and for low temperature power plants in particular. But with an increasing technical effort (and higher costs) and innovative ideas the efficiency (and thus the income) of a power plant cycle can be improved. Before being able to break into the market these technologies need to be proved which is generally not possible on a purely commercial basis. Here the government is asked to support the market access of such new and innovative technologies which are definitely needed for further establishing geothermal electricity production in Europe.
- Another approach to promote geothermal electricity production from low enthalpy resources – and also evidence that promoting geothermal energy use needs open minded project developing – was stated as a combination with other sources of energy (like e.g. biogas plants). New concepts of combining different energy options supplying heat on different temperature levels can result in a higher overall efficiency and thus profitability and hence be decisive for realising geothermal based electricity production.

Low enthalpy resources for geothermal energy production show the potential to contribute substantially within the energy system (i.e. within the heat and electricity market) throughout Europe. Thereby it is necessary to develop this technology to contribute for a more sustainable energy system in the future. On this background the goal is to successfully develop (i.e. technologically promising, economically viable, environmentally benign and socially acceptable) geothermal power plants. Project development and optimisation is hence a task of having a look on the overall picture.

References

Kaltschmitt M. & Le Bel L. (eds.) 2006, Proceedings of the Engine Workshop 5 "Electricity generation from Enhanced Geothermal Systems", 14-16 September 2006, Strasbourg, France. ISBN 978-2-7159-0992-2. Orleans, BRGM Editions. Collection Actes/Proceedings. ISSN 1773-6161.