



ANNUAL REPORT YEAR 2013

Efficient maintenance of geothermal power plants

Project ID: GEORG 11-04-005

Coordinator: Rúnar Unnþórsson

Start date: 01.04.2012

Duration: 3 years

Partners: Reykjavik Energy, HS Orka, Landsvirkjun

1 General status of the project

The aim of this project is to investigate, map and formalize the maintenance management of five geothermal power plants. The plants are Hellisheiði, Nesjavellir, Svartsengi, Reykjanes and Krafla. This is done by conducting interviews on site and investigating real data from the DMM software provided by the power companies. The expected outcome is a holistic maintenance management system based on the data and experience given by the power plants. However, only the fluid/steam phase of the power plants is to be investigated. This is due to the fact that electrical components have already been analysed thoroughly and the experience from the Icelandic geothermal power plants is unlikely to shed new light on this equipment. The fluid/steam equipment is however yet to be analysed based on the Icelandic experience, which this project aims to.

This year has been very fruitful with regards to progress and publications. Results have been presented on conferences, both as posters as well as in presentations. Scientific publications have also been published, either in journals or in conference proceedings. Also, two masters theses were published as a direct part of this project. A detailed outline of the published material is presented later in this report.

The Ph.D student Reynir S. Atlason presented two articles at the ASME POWER conference in Boston in July and presented findings from two studies.

Three studies have already been accepted to be published and presented in the ASME POWER 2014 conference to be held in Baltimore in July, 2014.

The upcoming year will likely be as productive as 2013, since the project is well under way and cooperation with the power companies has been successful. It is needless to say that the cooperating power companies have been very open to this project as students have been granted almost unlimited access to data and staff.

In general, the focus of the overall project has been narrowed and clarified even further where the vision of the final outcome has begun to materialise and results have been published in high quality ISI journals, conferences and as poster presentations.

1.1 Major milestones of 2013

- Two M.Sc theses were defended as a part of this project.
- One journal article was published
- Two conference proceedings were published
- A PhD student presented the study and current findings at the ASME POWER conference in Boston, MA.
- Six poster presentations were conducted in 2013. Two on the Arctic Energy Summit, held in Akureyri. Two on Georg Open day and two on the open master's day at the University of Iceland.
- Three articles were submitted to ISI journals, one has been published

- A thorough literature review on the main components of geothermal power plants and the most common problems associated with them was made by Reynir S. Atlason, this work is on-going.

1.2 Project progress/time schedule:

This section will outline the work that is currently being carried out or is scheduled to be conducted throughout this year.

The first months of 2014 were used to submit articles to the ASME Power conference to be held in Baltimore in July. Two articles were also received from review in geothermics, one of which was accepted with minor revision. Upcoming studies include a thorough need analysis in the Icelandic geothermal sector and a comparative study where turbine maintenance will be compared to a medical surgery. The context of these studies is as follows:

1. Thorough need analysis in the Icelandic geothermal sector.

In this study, a Kano Need Analysis will be conducted in the Icelandic geothermal sector to assess which factors are to be implemented in the maintenance management system to be developed. We map which solutions are being used by Icelandic geothermal power plants to address maintenance issues. A Kano model is used to identify which characteristics are preferred by Icelandic geothermal power plants to be implemented in a maintenance tool or software. Visits are conducted to all Icelandic power companies operating geothermal power plants. A questionnaire was developed and used for Kano analytical purposes.

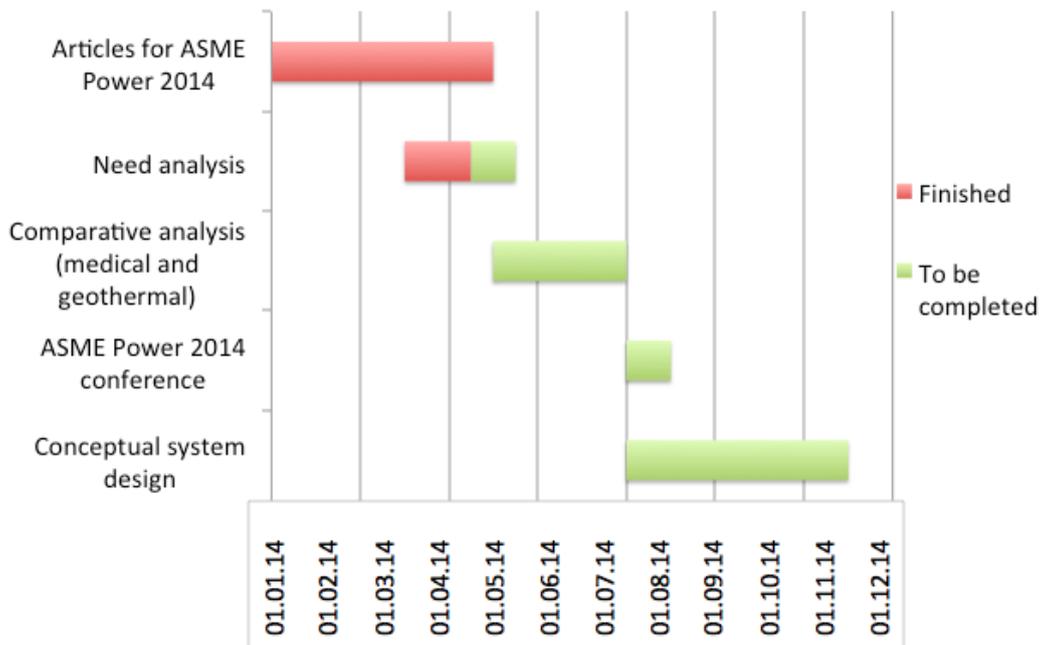
A journal article was submitted – in early May – to a special issue of Energies, focusing on geothermal power.

2. Geothermal turbine maintenance using valvular surgery approach.

This study is a cooperation between Reynir Atlason and Asgeir Masson, a medical doctor at the University hospital of Reykjavik, dpt. Of surgery. In this study, we investigate closely the maintenance protocol for geothermal turbines at the largest geothermal energy utiliser in Iceland, Reykjavik Energy. We subsequently compare the geothermal turbine maintenance protocol to the medical approach to heart valve surgery. Our findings show which factors are absent from the geothermal turbine maintenance protocol and which measures need to be taken to take geothermal turbine maintenance to a surgical level. Reaching such a level will potentially shorten the down time of turbines during maintenance procedures, minimise costs derived from downtime and allow for a better maintenance planning.

The collaborative study between the University of Iceland and the University Hospital is expected to result in a journal publication.

The two studies outlined above will provide a solid basis for the final section of this project, developing and testing a concept for a maintenance management system.



2 Project Management

The project is mainly managed by Rúnar Unnþórsson. Regular meetings with the students have been conducted by the management team where the project is discussed. Rúnar Unnþórsson has also mentored and prepared Reynir S. Atlason for the ASME POWER conference in Boston. In 2014, Guðmundur Valur Oddsson joined the team as a mentor. Both Rúnar and Guðmundur will mentor and advice Reynir for the Power Conference to be held in 2014.

3 Student involvement

In 2013, two masters students were working as a part of this project and one PhD student. Ari Elísson and Almar Gunnarsson are both masters students and Reynir S. Atlason is a PhD student. However, other students were also involved to some extent, Oli Geirsson, a PhD student in mathematics assisted with statistics in “Geothermal Wellhead Maintenance: A Statistical Model Based on Documented Icelandic Experience”. As before, it is projected that Reynir S. Atlason will continue to carry out the main body of work in the coming year.

In July 2013, Reynir S. Atlason went to the ASME POWER conference held in Boston, to present two studies, “Operation and Maintenance in Icelandic Geothermal Power Plants – Structure and Hierarchy.” And “Specified Maintenance Of Steam Turbines In Geothermal Power Plants”. The presentation was quite successful and sparked a lively discussion between the student and the audience.

It is likely that other master’s students will cooperate to some extent on this project in the coming year. Table 1 lists the participants in the project in 2013 and other.

Table 1. Participants in the project in the year 2013/2014

<i>Name</i>	<i>Gender</i>	<i>degree</i>	<i>Contribution (months)</i>
Reynir S. Atlason	Male	MS. Env. and Nat. Resources	12
Almar Gunnarsson	Male	MS student ME	5
Ari Elísson	Male	MS student ME	4
Óli Geirsson	Male	MS Mathematics	1
Rúnar Unnþórsson	Male	PhD Engineering	2,2
Magnús Þór Jónsson	Male	PhD Engineering	0,7
Sæmundur Guðlaugsson/Guðmundur Hagalín (OR) + other staff at OR	Male	Engineers	1,7
Þrándur Rögnvaldsson (LV) + Steinn Ágúst Steinsson + other staff at LV	Male	Engineers	0,9
Hreinn Halldórsson (HS) + other staff at HS	Male	Engineers	0,8

4 Publications and disseminations so far

This section provides a detailed outline of the presentations and publications. Results were published either in ISI journals, Master's theses, conference proceedings or in poster sessions. Note that some posters were presented on more than one occasion, each occasion is therefore listed in the posters section.

So far, one journal article has been published. Another journal article has been accepted with minor revision in *Geothermics*. One article is being reviewed for publication after it was revised for the journal *Geothermics*. Two articles have been accepted to the ASME Power 2014 conference to be held in Baltimore in July and one is currently being reviewed for the same conference.

4.1 Journals

R.S. Atlason & Unthorsson R. "Geothermal Wellhead Maintenance: A Statistical Model Based on Documented Icelandic Experience." *Geothermics* (2014): (Accepted, minor revision)

R.S. Atlason & Unthorsson R. "Turbine Repair at Nesjavellir Geothermal Power Plant: an Icelandic Case Study." Geothermics (2014): Revision Under Review.

R.S. Atlason & Unthorsson R. (2013) New Design Solves Scaling Problems on Geothermal Control Valves. POWER pp. 18-21. ISSN 0032-5929 (2013).

4.2 Masters theses

A. Gunnarsson. (2013). Maintenance of steam turbines at Hellisheiði power plant. M.Sc Thesis. Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, University of Iceland

A. Elisson (2013). Performance Indicators for Maintenance in Geothermal Power Plants. M.Sc Thesis. Faculty of Industrial Engineering, Mechanical Engineering and Computer Science, University of Iceland

4.3 Conference proceedings

R.S. Atlason & Unthorsson R. "Necessity is the mother of invention: The dawn of domestic geothermal turbine repairs in Iceland." ASME 2014 Power Conference. American Society of Mechanical Engineers, Baltimore 2014. (Accepted)

R.S. Atlason & Unthorsson R. "Go with the flow: The evolution of geothermal wellhead maintenance at Hellisheiði power plant." ASME 2014 Power Conference. American Society of Mechanical Engineers, Baltimore 2014. (Accepted)

R.S. Atlason & Unthorsson R. "The Elli geothermal control valve solving scaling problems." ASME 2014 Power Conference. American Society of Mechanical Engineers, Baltimore 2014. (Accepted)

R.S. Atlason & Unthorsson R. (2013, July). Operation and Maintenance in Icelandic Geothermal Power Plants: Structure and Hierarchy. In ASME 2013 Power Conference (pp. V001T05A007-V001T05A007). American Society of Mechanical Engineers.

Gunnarsson, A., Elisson, A., Jonsson, M., & Unthorsson, R. (2013, July). Specified Maintenance of Steam Turbines in Geothermal Power Plants. In ASME 2013 Power Conference (pp. V001T05A005-V001T05A005). American Society of Mechanical Engineers.

4.4 Posters

R.S. Atlason & Unthorsson R. (2013) Asset Management Model for Geothermal Power Plants Based on Icelandic Experience. (Poster presented at Arctic Energy Summit Conference)

R.S. Atlason & Unthorsson R. (2013) Asset Management Model for Geothermal Power Plants Based on Icelandic Experience. (Poster presented on GEORG open day)

A. Elisson, Unthorsson R, Jonsson, M. (2013) Performance Indicators for Monitoring Geothermal Power Plants. (Poster presented on open masters day at the University of Iceland)

A. Gunnarsson, Unthorsson R, Jonsson, M. (2013) Maintenance of Steam Turbines at Hellisheiði Power Plant. (Poster presented on open masters day at the University of Iceland)

A. Gunnarsson, Unthorsson R, Jonsson, M. (2013) Maintenance of Steam Turbines at Hellisheiði Power Plant. (Poster presented on GEORG open day)

A. Gunnarsson, Unnthorsson R, Jonsson, M. (2013) Maintenance of Steam Turbines at Hellisheiði Power Plant. (Poster presented on Arctic Energy Summit.

