GEORG

GEOTHERMAL RESEARCH GROUP

ANNEX I
Project Plan

Efficient Maintenance Management of Geothermal Power Plants

Project ID:	11-04-005
Coordinator:	Rúnar Unnþórsson, University of Iceland
Start date:	April / 2012
Duration:	3 years / 36 months
Partners:	University of Iceland, Innovation Center Iceland, Reykjavik Energy, HS Orka, Landsvirkjun.

1 Project description

General description of the project, clarify what the intended work involves and specify the need or importance for this work in connection with geothermal energy.

General description of the project:

Geothermal power plants (GPP) can make substantial savings given an effective maintenance management for their equipment. The problem is, however, that all systems requiring maintenance are unique. This might be because of the age of their components, the working environment, how they are applied, and in what context.

For this reason preventive maintenance (PM), also known as calendar-based maintenance, is rarely efficient. In fact, standard preventive maintenance programs from manufacturers may lead to too frequent maintenance operations, which are costly and may also increase the risk of failure due to improper assembly.

Over the years, Icelandic geothermal power plants have developed in-house maintenance management methods relying on equipment maintenance manuals as guidelines. Some of the developed methods are modifications of preventive maintenance procedures, e.g. increased maintenance intervals. Many of the developed methods are condition based, e.g. using the pressure difference between inlet and outlet of a heat exchanger to determine when to descale it. Corrective maintenance is also used for unexpected failure and some systems are allowed to operate until failure, e.g. fans for the cooling towers.

In this project maintenance procedures used at Reykjavik Energy, HS Orka and Landsvirkjun for the steam and geothermal fluid equipment – from borehole to injection well – will be documented and formalized. The possible failures for each piece of equipment in the plant will be determined along with the possible causes and the required maintenance actions, i.e. Failure Mode and Effect Analysis (FMEA) of the equipment will be carried out. The aim is to gather real performance data from the computerized management maintenance systems (CMMS), used by the geothermal power plants, and use it for analyzing and comparing the maintenance methods. From the analysis it is anticipated that new and more efficient maintenance procedures will be either identified or developed. The expected outcome of the project are efficient maintenance management procedures for the geothermal power plants.

The need and importance for this work:

At the Icelandic geothermal power plants there exists a significant amount of undocumented knowledge about maintaining the equipment in the power plants. This knowledge is very valuable. In fact the operational and maintenance management of the Icelandic power plants is among the most efficient in the world. This fact has attracted foreign investors to invest in Icelandic geothermal energy companies.

The aim of the project is to capture the knowledge and formalize it. This has not been done before but, by doing so it can be systematically analyzed and improved using engineering methods.

An aging workforce and a lack of new entrants is a pressing issue for the geothermal industry. Due to the fact that the aging workforce holds a vast amount of undocumented knowledge the training of new entrants may become a problem few years from now.

By documenting, formalizing, analyzing and possibly improving the extensive and partially undocumented knowledge and procedures for maintaining geothermal power plants the knowledge will be preserved, the training of new entrants will be easier and implementation will possibly improve the maintenance of the power plants.

Furthermore, the outcome of this project can be used for further studies into the maintenance management of geothermal power plants.

1.1 Objectives and GEORG WP relevance

Specify the main objectives of the project and explain the relevance it has to GEORG WP. Please also explain how the project will help GEORG achieving its main objectives

The main objectives of the project are to carry out FMEA (Failure Mode and Effect Analysis) of the steam and geothermal fluid equipment – from borehole to injection well and attempt to answer the following questions:

1. What maintenance procedures are being used at the Icelandic Geothermal power plants?
2. Can the procedures be combined and formalized?
3. What maintenance procedures are most effective according to real data (DMM)?
4. Can the real data be used to improve the maintenance procedures?

The project directly addresses two objectices of WP 5 – Research and Technology Development. The two objectives are:

1. To research new technologies and improvements in geothermal power production
   By researching the maintenance procedures used in Icelandic Geothermal Power plants the project will help GEORG achieve improvements in both operation and maintenance of the power production.

2. To develop new methods for maintenance procedures in geothermal machinery.
   The project revolves about documenting, analyzing the maintenance procedures used in Icelandic Geothermal Power Plants. Furthermore, the project aims at using real maintenance data to develop new improved procedures.

2 Work plan and time schedule:

Provide a short work plan broken down into subtasks which should follow the logical phases of the implementation of the project. A timeline should be presented as well as list of deliverables and milestones. Please keep in mind the submission of progress- and annual reports to GEORG, while planning the deliverables and milestones.

Subtask	Start	Finish	Deliverable/Milestone
Literature research.	01.08.2012	01.05.2014	Background chapter of Ph.D. thesis.
Documentation of maintenance procedures.	01.10.2012	01.07.2013	Internal document summarizing the Icelandic maintenance procedures. Conference paper.
Failure Mode and Effect Analysis (FMEA)	01.03.2013	01.10.2013	FMEA Conference paper or preferably a journal paper specialized on the geothermal steam and fluid equipment.
Real performance data	01.09.2013	01.11.2013	Data available for analysis

Formalization of maintenance procedures	01.09.2013	01.04.2013	Conference paper or preferably a journal paper presenting the maintenance procedures as one systematic whole.
Analysis & modeling	01.04.2014	01.01.2015	Conference paper or preferably a journal paper describing the results from comparing the maintenance methods and possibly new more efficient maintenance approaches.
Summarizing.	01.11.2014	01.08.2015	The project results will be summarized in a technical report, a book chapter or preferably a Ph.D. thesis

3 Project Management

Make a short description of the applicants involved in the project, inform about the resources that will be assigned to the project. Also specify in clear and simple manner who is resposible for what and how that will be managed.

The main work in the project will be carried out by a Ph.D student (if not available a graduate student may be hired to work on specific tasks) who has a strong background in mathematical methods for solving partial differential equations. The work will be supervised by the applicants. The following is a short description of the applicants and their contributions to the project:

Rúnar Unnþórsson is an assistant professor at the Department of industrial engineering, mechanical engineering and computer science, University of Iceland. Rúnar is a mechanical engineer specialized in condition monitoring, with emphasis on non-destructive testing and evaluation using acoustic emissions. Rúnar will contribute to the project as supervisor with emphasis on coordination of the project work and progress.

Magnús Þór Jónsson is a professor at the Department of industrial engineering, mechanical engineering and computer science, University of Iceland. Magnús is a mechanical engineer specialized in model based analysis, optimization, reliability and condition based maintenance. He will contribute to the project as supervisor with emphasis on condition measurements and modeling.

Sigrun N. Karlsdottir received her B.S. degree in Mechanical and Industrial Engineering in 2003 from University of Iceland and her M.S. and Ph.D. degree from University of Michigan in 2005 and December 2007. She currently works as a research scientist and a project manager at Innovation Center Iceland (ICI) in the Department of Materials, Energy and Biotechnology. Her research interests include corrosion and environmental assisted cracking of metals, corrosion, scaling and materials selection in geothermal environment, ceramic processing and characterization, failure analysis, and oxidation of ultra high temperature ceramics. Sigrun will contribute to the work done in phase 1 through 7 by giving information and guidance regarding corrosion, scaling and materials performance in geothermal environment. She will also contribute to work in phase 3 (FMEA) regarding failure analysis which she specializes in.

Guðmundur Hagalín Guðmundsson is the operation manager of the power plant department at Reykjavik Energy. Guðmundur has an extensive knowledge and experience of power plant maintenance. Guðmundur will contribute to the project by sharing his knowledge and also by providing access to other employees at Reykjavik Energy. This is important for documentation of knowledge and procedures as well as for verification of the results.

Hreinn Halldórsson is the maintenance manager of HS Orka power plant at Svartsengi. Hreinn will contribute to the project by sharing his knowledge and also by providing access to other employees at HS Orka. This is important for documentation of knowledge and procedures as well as for verification of the results.

Þrándur Rögnvaldsson is a maintenance manager at Landsvirkjun. Þrándur will contribute to the project by sharing his knowledge and also by providing access to other employees at Landsvirkjun.

4 Budget overview

Insert the "Costs" spreadsheet from the application documents. Explain the basic cost structure of the project. If it's assumed informative an additional budget summary can be included here, that, however, should not exclude the standard forms. Please justify, in simple terms, how the criterias of chapter 6, Section I in the „Proposal & Award Policies & Procedures Guide" are fulfilled.

Cost item		Requested funding		Other financing		Total
2012/2013	Salaries					11,850
	Operational expenses					0
	Travel expenses					100
	Total 2012/2013:	5,725	48%	6,225	52%	11,950
2013/2014	Salaries					11,850
	Operational expenses					0
	Travel expenses					900
	Total 2013/2014:	6,125	48%	6,625	52%	12,750
2014/2015	Salaries					12,300
	Operational expenses					0
	Travel expenses					800
	Total 2014/2015:	6,025	46%	7,075	54%	13,100
Grand Total		**17,875**	**47%**	**19,925**	**53%**	**37,800**

The grant from GEORG will be used mainly to pay salaries for the Ph.D student working on the project – or if not available then the salaries of a graduation student working on specific tasks. Part of the grant will be used to pay for travel expenses and conference fees which are necessary for the publication of conference papers and also publication fees of journal papers. Lastly, part of the grant will also be used to pay ICI partly for its participation as it cannot contribute 100% to the project. (BOOKS, Articles, etc?)

*Regarding the criterias of Chapter 6. Scientific and Technical Merit (**A**) is fulfilled by the project because it is the first attempt at documenting, structuring and formalizing the maintenance procedures in Icelandic Power Plants. Because real maintenance data will be analysed there is likely that scientific knowledge will be improved – at least technical.*

*The Innovation and Entrepreneurship (**B**) is fulfilled because the approach is innovative (has never been attempted) and aims at the development of new services and methods. The project has also the potential to bring Iceland into international collaboration. Furthermore it is known that the icelandic power plants are run and maintained efficiently, hence the results of the project will promote Iceland as a source of geothermal expertise.*

*The project fulfills the Education / Dissemination critera (**C**)by having conference and journal papers as milestones and also because the majority of the work will be carried out by a Ph.D. student.*

*Regarding the manageral criteria (**D**)then the team consists of 3 real experts in managing geothermal power plants and 3 academic experts. The managing group is strong and is likely to deliver the results promised. The project can be used to encourage cooperation with foreign experts outside of GEORG.*

The project budget is fairly credible. The weakest point in the project budget is the assumed cofinancing obtained from other funds. The cofinancing may fall both ways and cannot be guaranteed. Nonetheless, the project will not fail if the cofinancing goals will not be fully met. If cards are played right then the project has the potential of attracting larger funding sources since operations and maintenance management of geothermal power plants is getting more and more attention.