Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

Connecting a new geothermal field to an established power plant: Expansion of production at Hellisheiði

Gunnlaugur Brjánn Haraldsson[1], Gunnar Gunnarsson[2], Kolbrún Ragna Ragnarsdóttir[1]

[1]ON Power, Bæjarháls 1, 110 Reykjavík, Iceland, [2]OR-Reykjavík Energy, Bæjarháls 1, 110 Reykjavík, Iceland

gunnlaugur.brjann.haraldsson@on.is

Keywords: Steam field expansion, case study, Hellisheidi, pipeline

ABSTRACT

Hellisheiði power plant, SW Iceland, was commissioned in 2006 and it reached full electric capacity in 2011. In 2012 and 2013, it became evident that the original production filed was not be sufficient to be able to maintain the powerplant's full capacity in the long run. The Hverahlíð geothermal field is located around 5 km away from the Hellisheiði power plant. Originally, there were plans of building a separate 90 MWe power plant there. However, to maintain production capacity at Hellisheiði the Hverahlíð field was instead connected to the Hellisheiði power plant, resulting in the longest steam pipeline that has been built in Iceland. In this paper the challenges of connecting the Hverahlíð field are described.

A separation station was constructed at the Hverahlíð site as well as two pipelines, one for geothermal brine and the other for steam. For the steam a DN1000 pipe was selected with a transport capacity of 100kg/s at the pressure of 8-10 bar. For the geothermal brine a DN600 pipe with a transport capacity of 220 kg/s at 206°C. One of the main challenges was that the pipes needed to cross one of the busiest highways in Iceland. Due to the proximity of the pipes to the highway, efforts were made to minimize their visual impact as well as the impact on the surrounding flora/environment.

The pipes were built in 2014 and 2015 and commissioned in early 2016. Since then, drilling in Hverahlíð has been very successful and plans have been made to construct a second set of pipelines from the field to provide steam and brine for the power plant. Hence, extending lifetime of the Hellisheiði power plant and providing flexibility in operation.

1. INTRODUCTION

Hellisheiði Power Plant is located in the southern part of the Hengill area, SW-Iceland. It is a co-generation, heat and electrical power plant with an installed capacity of 303 MWe and 210 MWth. With the current layout of the power plant, electric production is at full capacity but it is planned to increase head production up to 400 MWth when the project is fully developed.

The electric production in the Hellisheiði power plant was developed at a very fast pace. The first turbine units were commissioned in 2006 and the last ones in 2011. Because of this fast pace, most decisions related to the production capacity of the project were made before appropriate data from newly drilled wells had been analysed and before production data became available. Thus, the estimates on the size and the production capacity of the Hellisheiði were mainly based on green field estimated.

Soon after the electric production had reached its final size it became evident that the production capacity of the Hellisheiði field was lower than anticipated. Therefore, new resources were needed to maintain production capacity. New wells in the northern part of the field showed that the size of the geothermal reservoir was significantly smaller than original conceptual models postulated. Decline in production capacity showed similar results, around 20 MWe annually in the years 2014 and 2015.

As early as 2013, it was obvious that it was necessary to enlarge the available geothermal resources of the Hellisheiði power plant, see Figure 1. Re-injection had already been established to support the pressure in the reservoir, but that was not enough to maintain the production rate therefore undeveloped hot formations had to be found. One such formation is the Gráuhnúkar field (see Figure 1) on the southern edge of the Hellisheiði field. That area had already been drilled into and high temperature (>300°C) had been measured in wells there. However, these wells were drilled as re-injection wells and had already been connected to the re-injection system of the power plant. Another interesting formation was located in Hverahlíð (see Figure 1), South-East of the Hellisheiði power plant.

The Hverahlíð field was originally planned as a separate project. The plan was to build a 90 MWe geothermal electrical power plant there. Five wells had already been drilled in the Hverahlíð area in 2013 and it was estimated that at least 45 MWe could be produced from the field. Feasibility studies revealed that that it would be technically and economically possible to connect the Hverahlíð field to the Hellisheiði power plant. Thus, it was decided to put Hverahlíð as a separate project on ice and use the area as a make-up field for the Hellisheiði Power plant.

The pipeline connecting the Hverahlíð field to the Hellisheiði power plant was built in 2014 and 2015. The steam and water phase are separated in a separation station that was built in the Hverahlíð field and transported in separate pipes towards the Hellisheiði power plant. Wells that have been drilled in Hverahlíð since 2016 have been highly successful and the and as of now the capacity of the pipeline is fully used. It has been decided to increase the capacity of the steam supply system by adding another pipe.

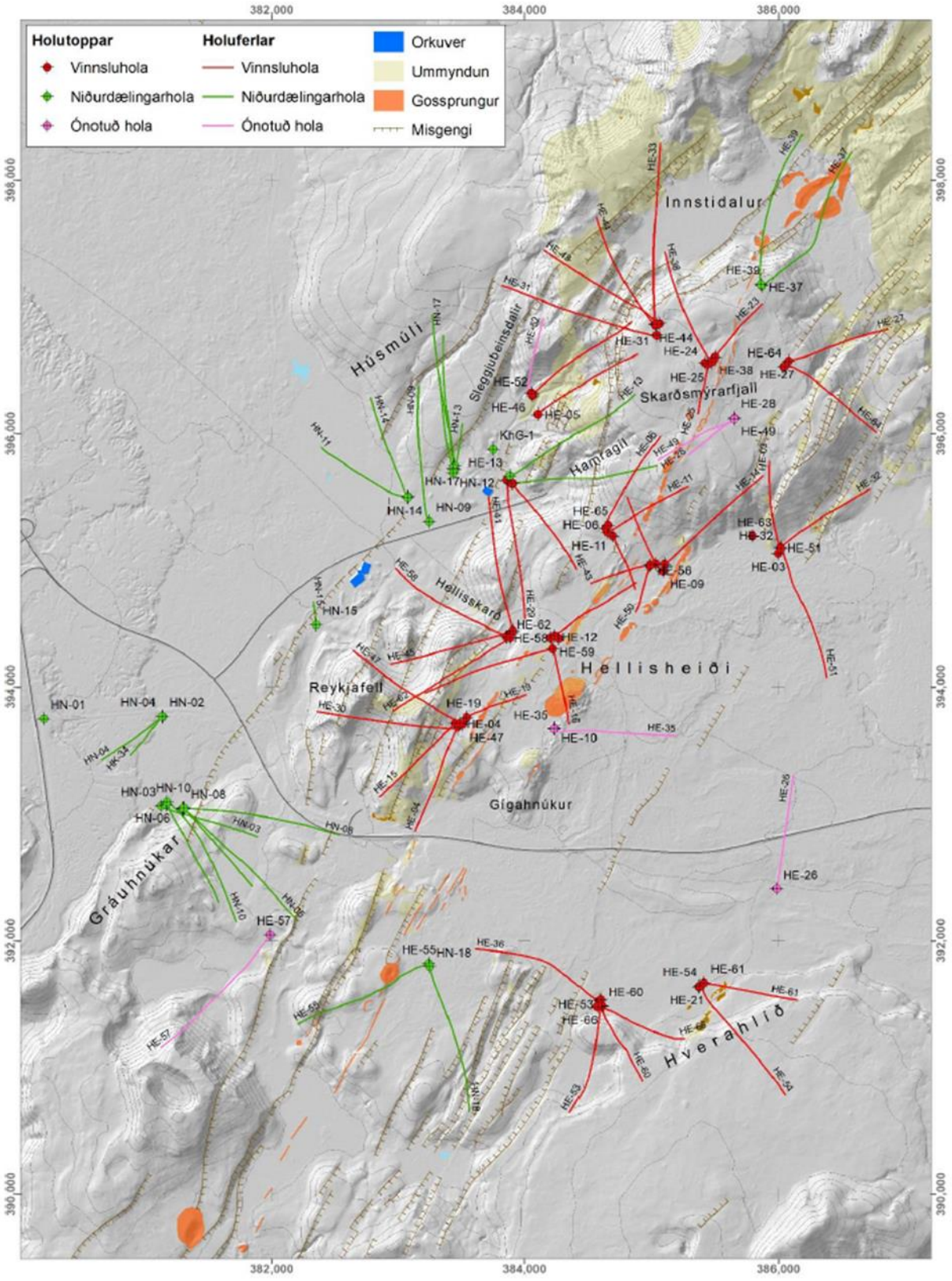

Figure 1: Geothermal fields for Hellisheiði power plant; Hellisheiði, Gráuhnúkar and Hverahlíð

2. DECISION AND PREPARATION OF THE PIPELINES

2.1 Decision to build the pipeline

The original plan was to develop a 90MWe power plant in Hverahlíð to meet the increasing demand for electricity. During this time, operators had difficulties in maintaining full production capacity of Hellisheiði power plant. It became evident that the resource in from which the Hellisheiði power plant utilizes would not be able to sustain full production as planned. The management of OR, which was the developer of the geothermal fields in the area, were faced with a complicated decision making. Firstly, it was very unlikely that the Hverahlíð power plant would be developed as in independent project, even though 5 production wells had been

drilled and yielded up to 90kg/s. Secondly, declining production capacity of Hellisheiði power plant was becoming evident, making it difficult to fulfill the company's commitments. Therefore, it was decided to examine the possibility of connecting the Hverahlíð filed with a pipeline to Hellisheiði power plant. Upon closer inspection, it became clear that this was both technically possible and economically feasible to build a 5 km long pipeline to connect Hverahlíð field to the Hellisheiði power plant, see Figure 2. The decision to build the pipe was officially made at a board meeting in 2013, and then preparations began.

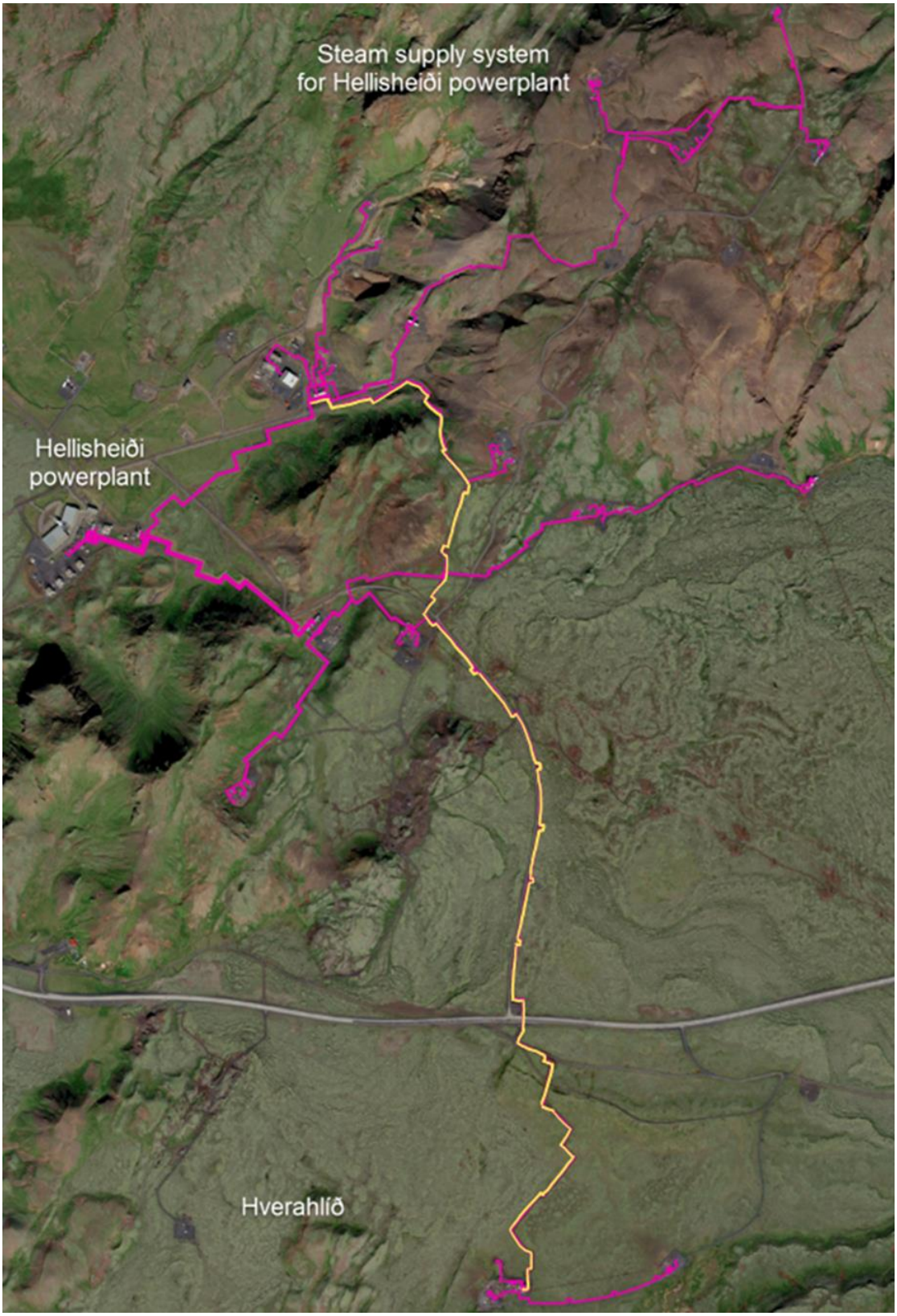

Figure 2: The steam supply system for the Hellisheiði power plant. The yellow line showing the steam pipe connecting the Hverahlíð to Hellisheiði power plant.

2.2 Regulators and stakeholders

To ensure the progress of the project, it had to go through a complex permitting process where different stakeholders can have a significant influence on the granting of permits. Therefore, a great emphasis was put on presenting the project in detail to regulators and stakeholders. They were invited to an introductory event where a computer model of the pipeline was presented so that interested parties could clearly see the scope of the project [1].

2.3 The Design challenges and criteria

The chemical composition and the enthalpy of the geothermal fluid from the wells defines some of the design criteria of the steam gathering system. Precipitation of silica is always a challenge and the pressure has to be kept above a certain limit, so called opal saturation limit, to prevent scaling. The opal saturation limits of the geothermal fluid in Hverahlíð field meant that fluid had to be kept above 15 bar-g.

It was necessary to install steam separators in Hverahlíð as part of the piped route is sloping upwards, which can cause a lot of problems for two-phase flow. Thus, the steam and separation water can be transported through two separated pipes. The disadvantage is that two pipes are needed instead of one and the separated water (brine) must be pumped to prevent boiling in the pipe where it crosses elevated terrain. Helliheiði power plant is designed to operate in the PN16 pressure class, while Hverahlíð steam gathering system is in the PN25 pressure class. Therefore, the pressure must be reduced to PN16 via control valves located after the separator in Hverahlíð.

The steam pipe was supposed to transport 90-100 kg/s, while the separated water pipe was supposed to be able to transport 220 kg/s of 206°C hot separated water. During this period, more than 5000 m of DN1000 pipe material was in already in stock that was fulfilled the design standards. The pipe was insulated with 100 mm rock wool and aluminum clad. The pipe stands on steel foundations at intervals of 18-20 m. The foundations are composed of a steel slide, that is welded to the pipe, which slides on steel rollers to reduce resistance when thermal expansion in the pipe occurs.

3. THE CONSTRUCTION PHASE

The pipelines were fully designed and put out to tender in July 2014. The lowest bid was 99% of the budget and a contract was signed to LNS-Saga in September 2014. Construction began in the same month. Between 50-80 people worked on this project throughout the construction phase. In the owner’s team there were 5 to 6 people in project management and supervision. Starting the project in September meant that the work on the construction would have to be carried out during winter, which was one of the big risk factors of the project. To mitigate this risk construction was started in places where it was considered likely that the work could be carried out during winter with the aim of completing the construction by the end of year 2015.

Construction started slowly, the weather was unusually good until the middle of December when one of the heaviest winter seen in Iceland for over 20 years began. By the end of January 2015, approx. 20 snowstorms had hit the country with associated difficulties. Due to the weather that winter the work was delayed but with the joined effort of the owner and the contractor, it was possible to put the pipeline into operation in early February 2016. Commissioning was very challenging as winter had returned and the pipe was partly buried in snow when that process began. Pressure testing a pipe of this size was also a very challenging task. The pipe was pressure tested with steam at 15.5 bar-g. Large operations like these are usually planned when the weather conditions are optimal and the surrounding area of the pipe is closed off to outside traffic. However, this was not possible as it was during winter and the pipe crosses one of Iceland's main highways, which cannot easily be closed.

4. RESULTS

The pipeline was officially commissioned in February 2016. It took about 600 days to complete the work, which involved 450,000 working hours, without lost-time accidents. The total construction cost was 2,633,000,000 ISK, the cost estimate was 2,484,000,000 ISK and the lowest bid was 2,465,000,000 ISK. The project was on schedule, on budget and completed without a lost-time accident, making it a great success.

The pipeline immediately performed as expected, but there were minor difficulties with the steam control valve, which had to be fully open to maintain full capacity. It would have been desirable to have excess capacity to have better control of the steam flow. This was later solved by replacing the control valves.

The goal of harnessing more additional geothermal resources in order to maintain the production capacity of Hellisheiði power plant was achieved. Moreover, it was possible to decrease production in the overloaded original production field of the power plant. An additional benefit is the flexibility of being able to operate both fields simultaneously.

5. DISCUSSION

The pipeline has now been successfully operated for 7 years. Drilling of make-up wells began in 2017 in Hverahlíð and three additional wells have now been drilled with the aim of expanding the area further. This area is one of the most productive geothermal fields in Iceland. In order to transport more energy from this area, the preparation for a second steam pipeline from Hverahlíð to Hellisheiði power plant has already begun. It is also being evaluated to replace the control valves with a back pressure steam turbine to lower the pressure for Helliheiði power plant for better utilization of the steam.

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