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JOINT STUDY OF THERMAL UTILIZATION APPLICATIONS FOR A SMALL- TO MEDIUM-SIZED BWR - UNIVERSITY OF SASKATACHEWAN ACTIVITIES

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Introduction

In 2011 Hitachi Ltd. and the Province of Saskatchewan signed a memorandum of understanding to foster collaboration among the parties regarding nuclear research and development. Subsequently the University of Saskatchewan, Hitachi-GE Nuclear Energy, Ltd. and Hitachi Ltd. reached an agreement to investigate applications of thermal energy from small- and medium-sized nuclear reactors, and flexible intermediate heat exchanger (IHX) systems to efficiently couple the reactor Balance of Plant(BOP) to these thermal utilization applications.[1]

1 The Projects

The research program was made up of six projects investigating different aspect of utilizing thermal energy from an SMR.

- Assess various chemical process industries and Steam-assisted Gravity Drainange (SAGD) applications with waste heat/steam - Mr. Ray Knudsen, P.Eng., LeanOptions Consulting.
- Design and optimization of the IHX for individual or multiple TU applications - Dr. Carey Simonson, P.Eng., Dr. Gaoming Ge, EIT, University of Saskatchewan.
- Design IHX for various Thermal Utilization Applications - Mr. Rajesh Shah, P.Eng., SNC-Lavalin
- Nuclear Power Plant Waste Heat Utilization for Greenhouse Applications - Dr. Karen Tanino, Dr. Huiqing Guo, P.Eng., Mr. M. Shamim Ahamed, University of Saskatchewan.
- Assess various desalination processes integrated with an SMR - Dr. Ajay Dalai, P.Eng., Mr. Kalyana Venkatraman, P.Eng., University of Saskatchewan; Dr. Roger Humphries, P.Eng., AMEC Foster Wheeler.
- Study for using BOP waste heat for District Heating - Dr. Carey Simonson, P.Eng., University of Saskatchewan.

In addition to the projects undertaken by the University of Saskatchewan and partners, Hitachi Limited and Hitachi-GE Nuclear Energy undertook a number of projects to develop conceptual designs of BOP, IHX and safety systems for the DMS BWR. [2]

2 Assess various chemical process industries and SAGD applications with waste heat/steam

The objective of this study was to determine the thermal energy needs of existing heavy industries in Saskatchewan. These are primarily mining, oil and gas extraction, and process industries such as petroleum refining, ethanol production and fertilizer production.

The project researched the relevant industrial and resource extraction process and interviewed industry to characterize the thermal needs of these industries, and to determine the quantity and quality of heat required by the several processes that make up each full production process. The results were analyzed on an aggregate and case-by-case basis to understand both the thermal capacity required and also to provide a summary view of the thermal energy needs of Saskatchewan industry. The project conducted high level financial feasibility analyses of using heat energy in these industries.
The project faced a significant hurdle in the unwillingness of companies to share the details of their processes and energy needs, viewing this information as competitive intelligence. The project team was able to address this by persistence, and by using information from other sources that was representative of these specific industries.

3 Design and optimization of the IHX for individual or multiple TU applications

The objective of this research study was to design and simulate IHX networks to efficiently transfer heat from the BOP to various combinations of thermal utilization applications.[3] The results of this project would provide the parameters necessary for a second IHX project to take additional design steps.

The project needed to overcome a number of hurdles to achieve its objectives. By the nature of the problem, there was a tight relationship between the designs of the BOP-facing heat exchanger being performed by Hitachi and the TU application-facing heat exchanger network being designed in this project. Effective collaboration between the two groups led to an effective solution.
A second obstacle arose from the definition of the project - building a heat exchanger network that can accommodate a wide variety of potential heat loads is extremely challenging, and impossible to optimize for all possible configurations. Further, specific combinations of heat loads must be selected in order to simulate the performance of the system. In collaboration with several other projects, the project team selected a number of configurations that represented installations which might realistically be constructed in Saskatchewan or similar geographies, and which maximized use of the available heat energy.

4 Design IHX for various TU applications

The objective of this study was to investigate the technical and economic feasibility of constructing the IHX design developed by the University of Saskatchewan IHX project. The approach was to translate the high level design created by the U of S team into a concrete design based on available industrial components and to calculate the cost of construction.

This project team worked in close collaboration with the University IHX team, a very gratifying result. The team was able to provide context and construction knowledge to the other IHX team, which was very useful in guiding the conceptual design. Similarly, the University team was able to provide much early information to this team, and to make adaptations in the designs to improve its feasibility. There was also much interaction between the two IHX projects and the project assessing the heat quality and quantity requirements of regional industries.

This project faced a significant staffing challenge, with three project leaders over its course. All participants worked hard to ensure the project succeeded, regardless.

5 Nuclear power plant waste heat utilization for greenhouse applications

The objective of this study was to assess the technical and economic viability of using thermal energy from a nuclear reactor to provide heat to greenhouses used for local vegetable production in cold regions such as Saskatchewan. The project approach was to compare two radically different greenhouse designs: a large facility to support commercial vegetable production, and a small, energy efficient design to provide nutrition to a small Northern community at which imported foodstuffs are extremely expensive.

The project began by evaluating alternative commercial scale greenhouse designs with a focus on effectiveness in high latitudes, including configuration, siting and construction material and details. Simulation studies were conducted to select design parameters to optimize solar gain and heat retention. The design outputs fed an economic model which evaluated the value of the crops produced against the capital and operating costs of the designs. Data from existing greenhouses was used to seed the models.
A similar approach was taken with the energy efficient greenhouse - although in this case data is much harder to access. Various greenhouse designs from the literature were evaluated, and their performance modelled to determine optimal construction parameters. A preliminary economic analysis has been done, with a more detailed analysis using data gathered from existing facilities is proceeding.

6 Assess various desalination processes integrated with an SMR

The intent of this study was to investigate the applicability of nuclear desalination to treat water in Saskatchewan, with a focus on using thermal, rather than electrical energy in the desalination process.[4]

The project began with a survey of water characteristics in the province. Water in the province is typically fresh, brackish or highly saline; the last case is typically associated with the potash and commercial salt industries. The focus of the work was on brackish water remediation.
Based on the water characteristics found by the survey the team evaluated a number of desalination technologies. Because the salinity of most water of interest is low, the project team concluded that reverse osmosis (RO) technology was the most cost effective desalination solution. Cost analysis concluded that this would be cost-competitive with other desalination approaches.
Representative sites were evaluated based on the volume of water such a plant would produce, and the electrical power available.

7 Study for using BOP waste heat for district heating in Saskatchewan

The objective of this study was to evaluate the feasibility of using thermal power from a nuclear reactor to provide district heating in Saskatchewan. District heating is pervasive in Scandinavia,

is it possible that such an approach would also work in geographies and climates like Saskatchewan?

The project quantified the heating requirements of Saskatchewan residential buildings, including both space heating and domestic hot water. The project team developed three representative scenarios in Southern, Central and Northern Saskatchewan, computing both energy requirements and transmission losses in the heating network. Only new construction was considered, as the costs to retrofit existing buildings would be prohibitive. Tours of district heating facilities in three Scandinavian countries were conducted to gather information about operations. Based on these inputs, an economic viability assessment of district heating use was developed.

References

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[3] Gaoming Ge, T. Ikegawa, T. Kerby, K. Nishida, and C.J. Simonson, "Thermo-Economic Performance Evaluation of a Cogeneration Medium-Small Modular Nuclear Reactor Plant", PRTEC-14367, Hawaii's Big Island, USA, 2016 March 13-17.

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