REPORT

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Application to Forskningsstiftelsen “Omställning till hållbara och smarta el-, fjärrvärme och transportsystem”

RISE Research Institutes of Sweden AB
Measurement Science and Technology - Electric Power Systems

Performed by

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Summary

The overall objective of the project is to study what role district heating systems (DHS) can play in electricity and grid service markets by modelling the decision-making processes of district heating companies (DHC) in terms of investment, planning and operations of their units. The research objectives of this project are to develop operational and scheduling models of district heating systems to simulate their participation in electricity and grid service markets, and study the impact of this participation on investments in future sector coupling units.

Such models have multiple values. They can be used by DHC to simulate their own system to analyse the profitability of participating in electricity and grid service markets, or to perform investment analysis. The models that are envisioned in this project can also be used for policy analysis to investigate what roles DHS can be expected to play in the electricity system and how design parameters of electricity and grid service markets impact the participation of DHS.

The specific objectives of the project are as follows. First, an overview of the electricity markets and grid service markets will be performed to identify what role DHS can play in different markets. This will include an analysis of other actors on these markets and the conditions under which DHS compete with these actors. Second, scheduling and operation strategies for the production and heat storage units will be devised to enable participation of DHS in these markets and services. Third, incomes from these markets and services will be estimated to investigate whether it is economically profitable to start participating in these markets. Four, an inventory of production units relevant for DHC that couple heat and electricity systems (including biobased combined heat and power plants, heat pumps and electric boilers) will be performed. Five, investment studies will be performed to study the profitability of strengthening the coupling between the heat and electricity systems by investing in these units. Finally, the project will promote knowledge exchange both between DHC themselves and between DHC and grid owners by organizing workshops.

In addition to the above-mentioned workshops, industry partners will be involved continuously throughout the project in an agile way. This will allow us to focus on the aspects that matter the most for the project partners.

Background and state-of-the-art:

The Paris agreement (United Nations Climate Change, 2015), the European Green Deal (European Commission, 2019) and the national Swedish climate targets (Swedish Government, 2017) call for an ambitious energy transition in the coming decades. Sweden is to have zero net emissions 2045 at the latest and 100 % renewable electricity production by 2040 (Swedish Government, 2017). Electrification of industries and transport will play an essential role at achieving the climate targets. For Sweden alone domestic electricity use may increase from today’s 140 TWh to between 180 and 220 TWh (Svenska kraftnät, 2018).

District heating can play key roles in meeting the challenges associated with the energy transition.

First, the massive electrification will lead to additional local grid and production capacity challenges where the existing electric grids do not have enough capacity to transfer the required amount of electricity. This is already happening in several Swedish metropolitan areas (Energimarknadsinspektionen, 2020) and can have large consequences on employment, housing, infrastructure and economic growth (Stockholms handelskammare, 2020). In this respect, district heating systems can remedy the issue by both decreasing the need for electricity for heating and providing local electricity generation in combined heat and power (CHP) plants. Furthermore, sector coupling units in district heating systems such as CHP plants, heat pumps and electric boilers can contribute with flexibility in heat and local

electricity networks (Energiföretagen, 2020). Therefore, there is a need to investigate how further integration of district heating systems with the electrical grids and markets will impact operation and planning of such systems.

Second, the transition to a production mix based on renewable intermittent generation will create a larger need for grid services including frequency-regulation services. While sector coupling units do not typically participate in grid service markets today, studies have shown that it is technical possible to do so and that these units have a role to play in these markets in the future (Energiforsk, 2015), (Solvina AB, 2014). Once again, this requires investigating how further integration of district heating systems with the electrical grids and markets will impact operation and planning of these units.

The European, Nordic and Swedish electricity and grid service markets will undergo large changes in the coming years. In the day-ahead market, the flowbased capacity allocation method will be introduced in place of the current net transmission capacity method. Intraday auctions will be introduced to complement the current continuous intraday market. The settlement period will change from 1 hour to 15 minutes (Svenska kraftnät, 2019). A new Nordic balancing model will be introduced and entail many changes to the current Nordic balancing setup (Nordic transmission system operators, 2020). New markets have recently been introduced (such as the market for fast-frequency reserves introduced in 2020) and more will come (such new products for frequency-containment and frequency-restoration reserves). Therefore, a deeper coupling between the district heating and electricity systems entail a need for district heating companies to better understand the current and future markets on the electricity side in which they can participate.

It is in many cases not profitable to invest in sector coupling units instead of heat-only units (Energiföretagen, 2020). If district heating systems are to play a role in the future electricity and grid service markets, there needs to be stronger economic incitement to drive investments in these sector coupling units, for example by diversifying the participation in different electricity markets. Hence, in addition to the impact on operation and planning of the units themselves, there is a need to evaluate the profitability of participating in electricity and grid service markets.

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Idea, proposed solution and scope:

Idea

The idea of the project is to develop models of district heating systems to investigate what roles they can play in different electricity and grid service markets, and whether the market conditions give correct price signals to fulfil these roles. Specifically, the project aims at answering the following questions:

- What electricity markets and grid service markets are relevant for DHC to participate in?
- How can DHC schedule and operate their existing production and heat storage units to participate in these markets?
- What income can DHC make from participating in these markets?
- Looking farther ahead, what sector coupling technologies will be available for DHC to invest in?
- Will it be profitable for DHC to invest in such sector-coupling technologies instead of investing in heat-only units?

The research value of this project is in developing generic models of DHS that can be used to simulate operation and scheduling of units of any DHS. These models can in turn be used to evaluate the extent to which DHS can participate in different electricity and grid service markets. The extent of their participation will condition the profitability of investing in sector coupling units such as combined heat-and-power plants. Altogether, the analysis will determine what roles DHS can play on electricity and grid service markets now and in the future.

Proposed solution

In a first step, electricity markets and grid service markets relevant to DHC will be identified. A review of the existing and new markets, their rules and designs will be performed. Known changes coming to existing markets will also be reviewed. A review of other actors participating in these markets will be included considering the conditions under which all these actors compete on the different markets.

In a second step, scheduling and operating strategies for DHC to participate in these markets will be designed. Scheduling and operation models will be developed to study the impact of participating in these markets on the production and heat storage units owned by DHC. These models will also be used to evaluate the income generated by participating in these markets. This will allow DHC to quantify the added value in diversifying their participation in different electricity-related markets using their existing units. These models will also be used in investment studies to quantify the income from new units from the electricity and grid service markets, as described below.

Parallel to the work on the above topics, an inventory of relevant investment options for sector-coupling units will be made. Sector-coupling units can for example include biobased combined heat and power plants, biogas-fuelled gas turbines, heat-pumps, electric boilers, and organic Rankine cycle systems. The aim of this inventory is to complement the second step above, in which existing units are considered, by looking at investment options for new units.

Finally, investment studies will investigate in more detail the economic profitability of some of the investment options identified above. This will be done by integrating these new units in existing systems and running the models developed in the second step above to estimate the incomes brought by these new units. These income estimates will be fed into an investment calculator to assess the overall economic profitability.

Scope

The project is limited to the sector coupling between heat and electricity systems and does not directly consider, for example, the transportation system. The latter is, however, indirectly included in the electricity systems since a massive electrification of the transportation system is expected.

Previous studies such as (Energiforsk, 2015) have looked at the interaction between heat and electricity systems on a system level. In this project, we aim at studying how individual district heating companies are impacted by this sector coupling and how sector coupling impacts their individual investment, scheduling and operation decisions. This project will build on the experience and models from two ongoing projects in which RISE participates (RISE Research Institues of Sweden, 2018).

The inventory of investment options will focus on climate neutral units and addons that can enhance the sector coupling between heat and electricity systems for district heating companies. The main focus will be on the following units: biomass and waste-based combined heat-and-power plants, heat pumps, electric boilers, biogas-fuelled gas turbines and organic Rankine cycle turbines. In particular, the following kinds of unit will not be included: pure electricity production units based on renewable energy (such as solar panels), batteries, electrolysers for hydrogen production and fuel cells. Furthermore, since the project is limited to heat and electricity systems, units generating other kinds of products (such as synthetic natural gas and wood chip drying) will not be considered.

Method

Overview of the work packages

A short description of the methodology that will be used in this project in terms of work packages and deliverables can be found below. A more comprehensive description of the work intended in each work package can be found in attachment 1.

- WP 1: Current and future technologies for new units and upgrades
    - The aim of this work package is to make an inventory on potential climate neutral technologies relevant for fostering sector coupling between district heating systems and electricity systems.
    - Total hours: 300 hours
    - Deliverables
        - Deliverable 1.1.1: Portfolio of climate neutral, sector-coupling technologies for district heating companies (dataset and report)
        - Deliverable 1.1.2: Portfolio of investment options for relevant electricity and grid-service markets (dataset)
- WP 2: Revenue streams and scenario creations
    - The aim of this work package is to identify products and market services that sector-coupling technologies introduced in WP 1 can provide in the electricity system and consequently list all the potential heat- and electricity-related revenue streams for district heating companies (DHC). This will take the form of a review of electricity and grid markets as well as the conditions under which different actors participate in these markets. Furthermore, a review of existing forecasts for these products will be performed. Finally, workshops will be organized to promote knowledge exchange between district heating companies (including Vattenfall Värme, the reference group and open to other DHC as well) and grid owners (Svenska kraftnät has declared interest).
    - Total hours: 400 hours
    - Deliverables
        - Deliverable 2.1.1: Review of current and future heat- and electricity-related products and their relevance for district heating companies (report)
        - Deliverable 2.1.2: Potential revenue streams corresponding to each product and accordingly formulating the total revenue for each technology/products option (report)
        - Deliverable 2.2.1: Literature review to list existing forecasts of future prices of market and services that are relevant to sector-coupling technologies identified in WP1 (report)
        - Deliverable 2.2.2: Market and services price time series (dataset)
- WP 3: Operational and scheduling models for sector coupling of district heating systems
    - The aim of this WP is to develop scheduling and operating strategies for production and heat storage units that allow district heating companies to participate in the markets identified as relevant in WP2. These models will be used to evaluate the potential revenues to be made from participating in the markets identified in WP2.
    - Total hours: 800 hours
    - Deliverables:
        - Deliverable 3.1.1: Specifications of the scheduling model (report)

        - Deliverable 3.1.2: Python source code of the scheduling model (source code)
        - Deliverable 3.2.1: Specifications of the operating model (report)
        - Deliverable 3.2.2: Python source code of the operating model (source code)
        - Joint deliverable 3.2.3: Case studies to demonstrate features of the scheduling and operating models (Joint deliverable with task 3.1) (report)
        - Joint deliverable 3.2.4: Evaluation of potential revenues when participating in relevant electricity and grid-service markets (report)
- WP 4: Investment studies
    - The aim of this work package is to establish, carry out and evaluate investment studies in new climate neutral, sector coupling units.
    - Total hours: 300
    - Deliverables
        - Deliverable 4.1.1: A set of relevant investment cases (dataset)
        - Deliverable 4.1.2: Investment studies: results and conclusions (report)
        - Deliverable 4.1.3: Scientific publication presenting the models from WP3 and investment studies from WP4.
- WP 5: Project management
    - The aim of this work package is to ensure effective project management and coordination and ensure high quality and timely delivery of the project results. RISE is going to be the coordinator of the project and will be in charge of the main management tasks over the entire project duration. The project will run for 24 months.
    - Total hours: 150 hours

Description of the project group

The project group consists of actors who complement each other well.

- RISE is responsible for project management, research and development in the project. Several departments within RISE with various complementary competencies and expertise in all relevant areas for the project implementation is part of the project group.
    - Electric power systems: Experts with competence about electricity markets and grid services as well as sector coupling between heat and electricity systems.
    - Energy and Resources: Experts with competence and long experience about biobased energy production and its implementation in different energy systems.
- Vattenfall Värme will be part of the project and will be involved continuously to formulate the needs, identify the research directions of interest, formulate case studies and provide real-life data to use in the case studies The participation of the industrial parties guarantees that the work focuses on relevant cases and issues and that the results obtained can be implemented in future decision-making processes.
- Reference group: A reference group will be formed at the start of the project. It will consist of the financing party (Göteborg Energi) and possibly additional industrial partners. The reference group will be part of defining the work more specifically at the start of the project and will meet regularly throughout the project to follow up

and give feedback on the work. The members of the reference group will also be welcome to become more involved in some of the tasks, for example by sharing data, if they wish to do so.

In addition, Svenska kraftnät has declared interest to participate in the WP2 workshops together with district heating companies to exchange knowledge about current and coming markets and which ones are relevant for district heating companies.

Usefulness for Göteborg Energi:

Göteborg Energi owns and operates district heating and electricity networks. This project will investigate the coupling between these two systems from the perspective of district heating companies (DHC) participating in electricity and grid service markets. More specifically, a review of the current and future markets on the electricity side in which DHC can participate will be made. Scheduling and operation models will be developed to simulate the participation in these markets with existing production and storage units. This can be used by Göteborg Energi to evaluate both the profitability of diversifying its participation in these markets and the impact of doing so in terms of how the production and storage units are operated.

In addition to studying how to bring added value to the existing fleet of units, the project will also look in investment options for new sector-coupling units or upgrades to existing units such as biobased CHP plants, biogas-fuelled gas turbines, heat pumps, electric boilers and organic Rankine cycle units that can interact in both heat and electricity systems. Investment calculations will be performed based on multiple scenarios for prices in the different relevant electricity markets as well as heat billing prices and heat demands. This can be used by Göteborg Energi to investigate what future technology options will be of interest in a future energy system where for example patterns in electricity prices look very different compared to today. Also, by integrating the previously developed scheduling and operation models into the investment calculations, Göteborg Energi can evaluate how scheduling and operation strategies impact the overall profitability of investments.

Finally, the toolbox made of the operation, scheduling and investment models will be made available at the end of the project, and therefore can be used by Göteborg Energi after the project to continue exploring the research questions above.

Communication

Projektet syftar till att analysera tekniska och ekonomiska möjligheter för fjärrvärmebolag att stärka kopplingen med elsystemet genom att delta i flera elmarknader. Detta kan möjliggöra ett bättre utnyttjande av befintliga anläggningar samt stärka kraftvärmens roll i framtidens energisystem.