# Optimizing the energy consumption and operational availability of point heaters using weather forecasts

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## Abstract

During the winter season point heaters in the network of the Deutsche Bahn consume as much electric energy as a large city. They are controlled using locally measured weather conditions. These are limited to the number and type of the installed sensors. In the Project InfraGrid the geographical and chronological context is used to predict the consumption of electric power accurately and to enhance the operational reliability. Weather forecasts can be used to predict the times at which the points have to be heated due to fast changing conditions that would be measured too late by locally installed sensors. InfraGrid will provide a service that enables the manufacturers of point heaters to get location based weather forecasts. This will increase the operative availability of rail crossings and will help to reduce train delays. Additionally these timestamps are based to calculate the electric load forecasts for point heaters. Topological and geographical aspects will aggregate the load of each device. This information enables the supplier to plan the usage of available power stations and optimise energy trading on spot market, which will in turn reduce costs for intra-day trading of energy on spot markets. As another option, the use of turnout heaters to stabilise the energy network comes into reach. This is a key feature in using renewable energy sources.
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# 1 Introduction

The route network of the Deutsche Bahn AG (DB), with its 34,000 km and 72,000 points ("points" in these documents means locations of track bifurcations), is among the largest in Europe. 48.500 points are equipped with facilities for point heating, which thus provides easier operation maintenance in wintery conditions (DB Mobility Logistics AG [1]).

A point heater consumes as much energy as a two-family house, and all locations combined would produce as much as a German city.

The current state of the art technique is the local weather-dependent automatic control of individual plants. In this process, the points are heated depending on locally measured environmental parameters. The determination of the measured parameters is limited by the number and type of locally available sensors. In principle, it is only possible to respond to weather events when the local measuring sensors have captured the weather event.

The objective of the research project InfraGrid is the extension of the data base to location-based weather forecasts. These should be provided for all operating points (e.g. railway stations) with point heaters (see Figure 1).

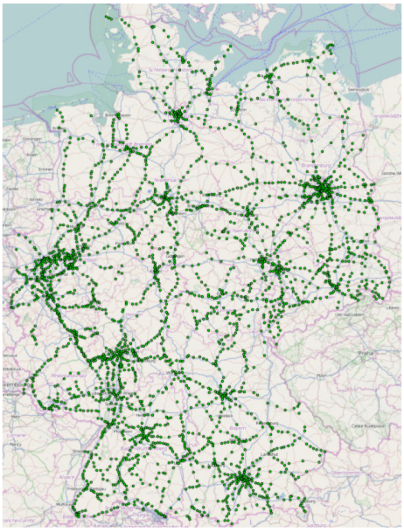

Figure 1: Stations with point heaters.

Using this extended information from the weather forecast, the behaviour of the plants can be predicted more accurately. Therefore, the energy consumption and operational availability of the points can be optimized during the winter months.

In this paper, first the possibilities that arise from this extended context are considered and presented in more detail. Additionally, the recent developments in the project and related data are presented. Furthermore, the previous analyses and their concluding findings are considered.

## 2 Possibilities

By using weather forecasts, there are opportunities that exceed the present possibilities of automatic control by local measuring devices. These arising possibilities can be divided into three areas of action (Weiß [2]):

- Improving operational availability of points
- Reducing cost of energy
- Reducing energy consumption by eliminating unnecessary operation

Operational availability would improve by using time-stamped weather events; the points can be preheated before an arrival of a fast-changing weather event. This prevents icing of the point, and therefore increases the operational availability of points, thereby reducing the risk of train delays.

A reduction of costs is achieved essentially by an improvement of the load forecast of energy consumption, which is caused by the point heaters, and therefore decreases balancing energy costs. The large energy consumption of point heaters requires the prediction of required energy for the next day, so that the energy provider can schedule their resources accordingly. Any deviation of the forecast, up or down, generate costs occurring from the intra-day trading at the energy exchange. A more accurate load forecast reduces these costs.

The communication with the energy provider could also allow the use of point heaters for power network stabilization. This is especially important for the use of renewable energies.

The complete installation of intelligent automatic switching based on meteorological forecast data would result in reduced energy consumption. Therefore switching can be prevented, which are not absolutely necessary on the basis of the environmental conditions.

## 3 Meteorological data

The risk of a point becoming iced is highly dependent on the meteorological conditions that prevail in the environment.

Both the recent weather data, as well as the current weather forecasts can be used. A functional relationship can be determined from past weather data together with its concurrent point behaviour. This functional relationship can be used in combination with weather forecasts to make future predictions.

The Deutscher Wetterdienst (DWD) as the National Meteorological Service provides the corresponding data uniformly throughout Germany. Therefore it operates a network of measuring stations to gather meteorological parameters. The DWD can also provide historical data. Based on the measured data, the DWD calculates different weather forecasts. For the project, the two numerical weather prediction models COSMO-EU and COSMO-DE are used. These differ in spatial and temporal resolution. While COSMO-EU provides a forecast for several days, the forecast period at COSMO-DE is smaller, but the prediction has better spatial resolution (see Baldauf *et al*. [3] and Schulz and Schättler [4]). Both predictions are delivered in the standardized GRIB (Gridded Binary) format of the WMO (World Meteorological Organization), which is based on regular grid points. By bilinear interpolation starting from the grid points, the meteorological parameters are derived for the operating points of the Deutsche Bahn.

### 3.1 Meteorological parameters

The weather forecast models provide a variety of parameters, although not all of them are relevant in the context of point icing. In order to make an appropriate selection, the types of point icing were considered. Icing occurs when the temperature falls below a threshold value, in addition to prevailing wet surroundings. This may be caused by increased humidity or precipitation. Icing can also be caused by excessive snowfall or snow blanks that occur when a snow layer and strong winds exist. Below -20°C lubricant can get sticky and lead to sluggishness.

Therefore these parameters of temperature, precipitation (total precipitation and division into rain, snow and hail), humidity and wind speed are important to be able to simulate and predict the behavior of point heaters.

### 3.2 Supply of the meteorological data

For the provision of meteorological data, the Deutsche Wetterdienst (DWD) uses the standard format GRIB.

The processing of the meteorological parameters is automated. The following steps are performed:

- Downloading the weather data from the server of the National Meteorological Service
- Transforming the nationwide weather data to location-based weather data for all operating points of the Deutsche Bahn through use of interpolation
- Storing the location-based weather data in a database. Because of the large amounts of data and simply structured queries, a non-relational database is used.

The present data in the database are available via a web service (see Figure 2).

The web service provides the ability to query the historical plant data in combination with historical meteorological parameters for every point heating control. The unique identification of the plants is made up of the operating point identifier and a code number.

The web service also provides the short and long-term weather forecasts for all operating points.


Figure 2: WebService InfraGrid.

## 4 State of research

Central to the first section of the project, was the possibility of “improving operational availability.” Additionally, the foundation was laid for further development on the work package “load forecast.” Significant activities were partitioning the information and analysis of the associated data.

### 4.1 Load forecast

A load forecast is supported by a significant relationship between prevailing meteorological conditions and the energy consumption of the point heaters. The device data can be retrieved from the diagnostic system of the DB Netz AG.

As a first step, historical data of point heaters from the last heating season (September 2012 through April 2013) were analyzed. Parts of the data include the meteorological parameters recorded in the diagnostic system (e.g. temperature, whether or not moisture is present, etc.), and the times that the point heaters turn on and off, which are each provided with a time stamp. Thus, it is possible to present the information with a chart, to view the history of the outside and rail temperatures together with the switching times (see Figure 3).

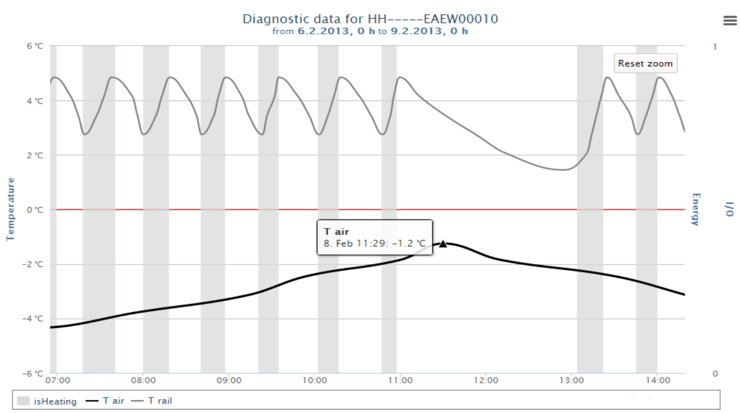


Figure 3: Heating interval of a point heater (light grey), rail (dark grey) and air temperature (black).

Firstly, the percentage of heating time is calculated within a heating interval. A heating interval is defined as the time starting from switching the heater on, through the time it is both tuned off and then up until it is turned on again (see Figure 4). Based on this time interval and the knowledge of the built-in power a load can be calculated.

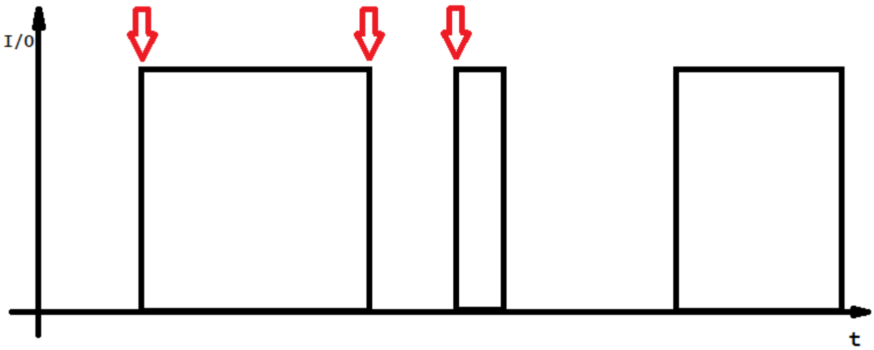


Figure 4: Heating interval, red arrows define the switch-on and switch-off time.

As a simplification, only the meteorological parameters "temperature" and "humidity" are included in the calculation. At first the heating intervals are grouped to "available moisture" and "no moisture present" for the calculation. As a function of temperature, the heating time is calculated as a percentage. The expected correlation between the decreasing temperature and increased heating time can be seen (see Figure 5).

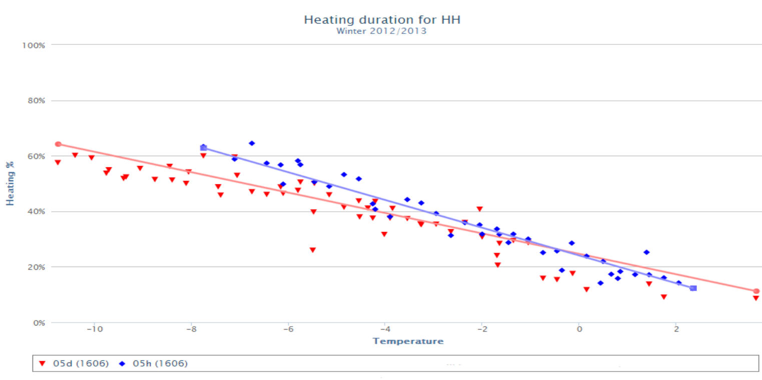


Figure 5: Percentage heating duration of one control (red = dry, blue = humid).

It was examined whether the behavior of the device can be described based on the nominal power of the respective device and the meteorological data.

 
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Unfortunately, the behavior of different devices shows a strong scattering, and so the devices must be considered separately.

Comparing a device to itself in similar weather conditions, there is only a slight variation.

To prove this, the device data was compared grouped by time ranges (see Figure 6).

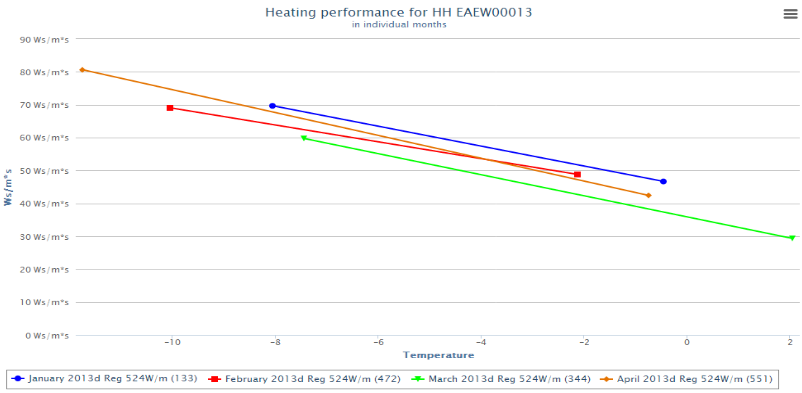


Figure 6: Comparing the heating performance of one control for different months.

## 4.2 Improving the operational availability

To improve the operational availability, it is initially important to determine the scenarios that lead to point icing. The following scenarios have been identified, by Busch [5]:

- precipitation (supercooled) liquid form
- precipitation (not supercooled) liquid form
- snowfall
- snow bank
- temperatures below -20°C
- graupel and hail

For these scenarios, the relevant meteorological parameters can be derived. The forecast of these parameters then can be used to predict an occurrence of the scenarios and preheat the point accordingly. The weather forecasts for the respective locations of the point heaters are analyzed using a decision tree (see Figure 7).

In the reference implementation the weather forecasts are analysed using the decision tree for all operating points. The determined time points for risk of icing can be combined, to form a “switching schedule” for the point heating control.

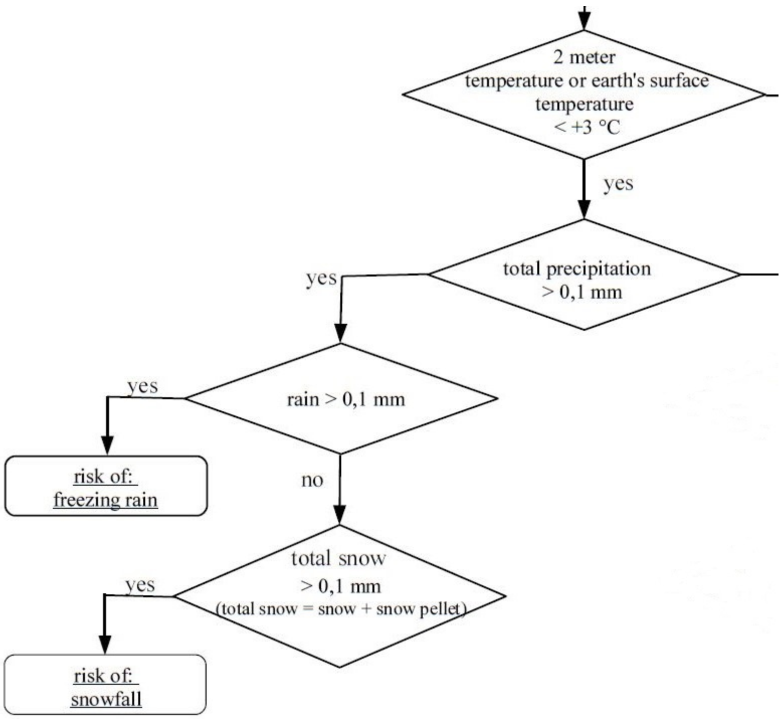


Figure 7: Example clipping of the decision tree.

## 5 Conclusion and outlook

The selection of the meteorological parameters was supported by the development of point icing scenarios. The implemented WebService provides access both to the device data of the point heaters and to the meteorological parameters. It will serve as a central infrastructure for the project.

To ensure the quality of meteorological data, first approaches are implemented to compare the measured values of the point heaters to the corresponding data from the DWD. This way it is possible to determine systematic deviations. The measured values at the respective devices compared to the DWD analysis data deviate systematically. These deviations are device-specific. A correction therefore needs to be calculated for each device.

Reproducible heating behaviour is also device-specific only. This can be explained by microclimatic variations, different software configurations of the control systems and different mounting of the measuring sensors. These parameters cannot be determined and thus cannot be included in a general model. A load forecast for a complete station aggregating many point heaters is only accurate if the behaviour of all individual point heaters can be determined from historical data.

The selection of the meteorological parameters must be obtained through a plausibility check during the next phases of the project. Based on that, the reference implementation to improve the operational availability will be tested with current diagnostic data. Then, the quality of the emerging "short-time-on-switching-schedule" can be determined. The reference implementation created will be developed further by the point heating manufacturers taking part in the project.

The same is true for the algorithms for load forecasting. During future steps of the project an interface should be created to transfer this load forecast to the energy supplier. Based on that, a two-way communication would be conceivable that allows the energy provider to report back time points of possible peak loads. In response, the switching-on of the point heaters might then be adapted to these times in order to reduce the load.

A visualization provides transparency about the decisions made by the system (see Figure 8). It allows the user to verify the calculated switching-on times of the system at stations based on the visualized meteorological parameters.

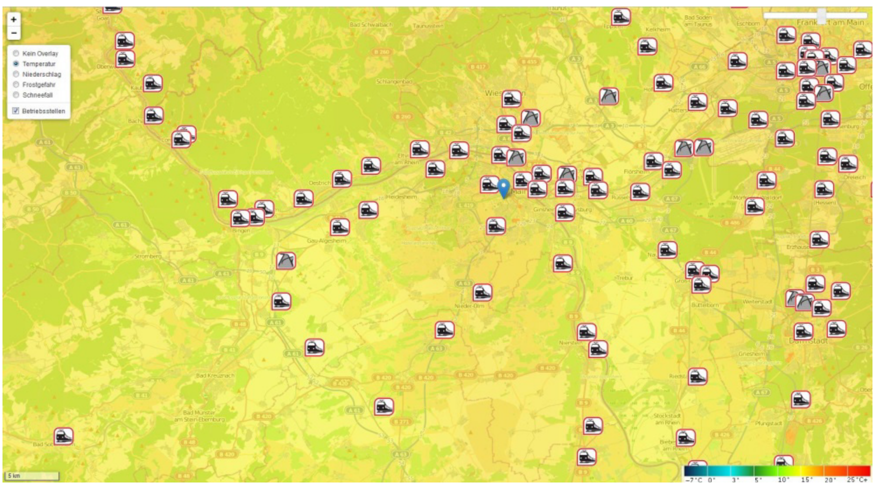


Figure 8: Visualization of stations in combination with an area-measured representation of the temperature.

The developed prototype will be extended to the advanced functionalities in the further course of the project.

The visualization can serve as foundation for communication with those responsible within DB Netz AG. Based on this, further discussions on the detailed requirements and further development of the platform are initiated.

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