STRATEGIC PLATFORM FOR INNOVATION AND RESEARCH IN INTELLIGENT POWER [IPOWER]

DEFINE INTERFACE BETWEEN VPP AND POWERPLANT (CASE STUDY)

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Abbreviations

GOP – GreenWave Output Protocol
KWh – Kilowatt-hour
UI – User Interface
c – Celsius
IE – id est (that is)
e.g – exempli gratia (for the sake of example)
XML – Extensible Markup Language (XML was designed to transport and store data).
DR – Demand Response
HAN – Home Area Network

1 TABLE OF CONTENTS

2 INTRODUCTION

Consumers are growing increasingly aware of changes to the environment and expressing an increased desire to contribute to conserving resources. As global energy demand is projected to rise to over 35 trillion-kilowatt hours by 2035[1], and utilities are finding it challenging to meet this increasing demand. As a result, consumers, governments, and utilities are seeking ways to reduce consumption and preserve our environment while minimizing the cost of increasing energy prices for consumers.

Utilities also face the challenge of operating in markets with an increasing number of government mandates requiring that consumers get better tools to understand and reduce their energy consumption. Furthermore, governments are now evaluating possible benefits from switching from present flat rate to flexible electricity pricing, which opens up for the opportunity of utilizing a pricing interface as a control scheme for controlling energy consumption.

[1] Fuels Used in Electricity Generation – EIA,

The overall objective of the T1.I.3 task is to develop interface units (VPP) that can aggregate application units and provide a generic interface to the power production side. With this overall goal, GreenWave Reality has invested time and resources in a case study seeking to test and prove the concept of using a generic price interface as a control in the VPP in combination with the GWR Home2cloud platform, which can be applied as the link to the power production side. This report presents a description of the case study solution in iPower WP1 including specifications of the hardware (HW) components used and screen shoots of the developed consumer portal UI.

Furthermore, the case study is carried out in selected private homes.

Overall it is clear that the technology for implementing a DR ecosystem exist. One major barrier going forward is the Business Case, which today in Denmark is lacking the financial incentive for the consumer, DSO and possible aggregator. Replacing the flat rate electricity pricing strategy, which we have today with a flexible electricity pricing is a clear pre-requisite for using a price interface for control.

3 GWR SMARTHOME CASE STUDY

This chapter presents the by GreenWave Reality developed Demand Response algorithm and functionality, describing the solution hardware and developed UI.

The focus is on controlling the heat pump via the GWR home2cloud EMS system. It is meant as a proof of concept for utilizing an energy price interface as control interface to the HP. For the case study GWR has developed a Demand Response algorithm that collects the 24 hours day ahead electricity prices from Nord Pool, and then pushed the pricing information to the in home gateways that are setup to controlling the heat pump (HP). In addition, GWR has developed a user interface (consumer portal UI) allowing the user via a PC browser to set his/her in home comfort temperature and flexibility.

3.1 SYSTEM ARCHITECTURE:

The home in the case study is equipped with HP DR Kit consisting of a the following:

- Gateway
- LS Control Temperature Sensor
- Danfoss Relay
- Aeon Clamp Reader
- UI access via PC
- UI access via App

The Demand Response kits are supplied preconfigured by GWR and is shipped directly to the Case Study End-users. Professional installers are responsible for conducting the installations of the system HW in the home of the end-users. The DR kit installation is initiated with attaching the kit Gateway via standard CAT 5 cable to the Internet Router of the home. An LS Control temperature sensor is placed in the room, which is used the by the family the most (the living room as a example) and will serve as the reference temperature for the rest of the house. An Aeon Labs clamp reader is mounted on the phases (Power Cables) going into the HP (the reader itself is placed outside the HP cabinet). A Danfoss Relay is connected to the HP circuitry, being that actual devise that supplies an EVU ripple signal to shut down the HP. Please see figure 1 below with an overview of the overall system architecture.

In the Heat Pump Menu the HP must be set to “External Control” and the HP “Invert setting” must be activated. This will enable the HP to receive the EVU Ripple signal from the Danfoss Relay and to enable the Demand Response algorithm to shutdown the heat generation of the HP. The system does not control the water boiler within the HP (this is outside the scope of the case study). The reason for this is that the user should always have access to warm water (the ability to shower) at any time. If the user would experience cold water caused by the system, this will only provoke the users with the risk that the system will be uninstall.

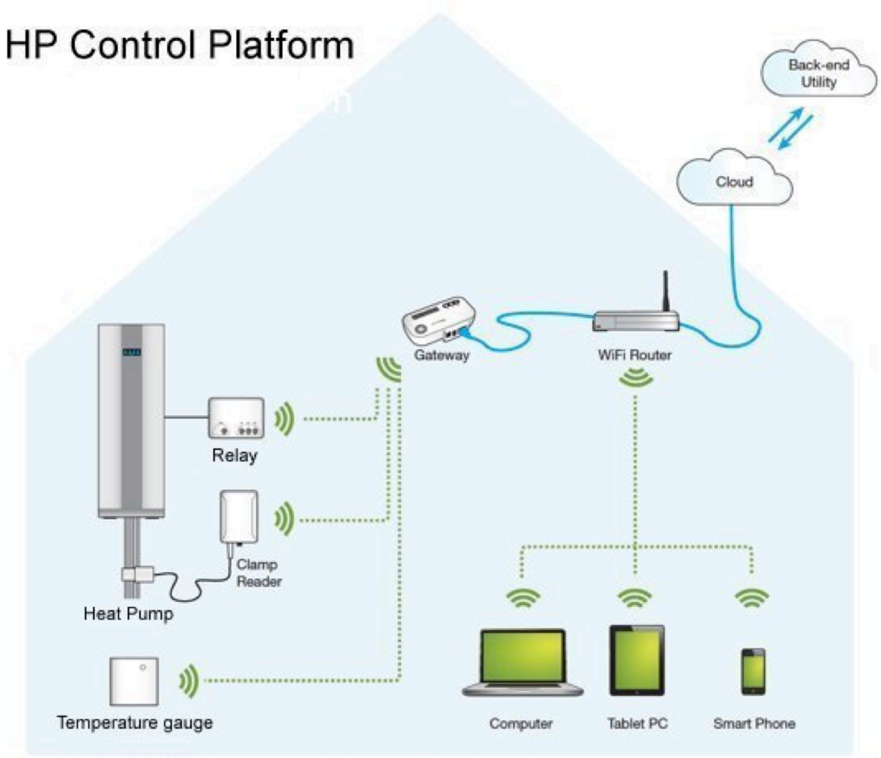


Figure 1. Illustrates an overview of the case study system architecture.

3.2 DEMAND RESPONSE ALGORITHM

The Heat pump control algorithm is developed to respond to the parameters "price" and "temperature within the home". It is Important to emphasize that the intension of the case study is **not** to save energy, however, is focused on moving the energy consumption away from High price periods. For this reason, the algorithm will initialize the HP to close down every-time the "price is high" in combination with the temperature in the home being within the Flexibility temperature range set as by the users (The comfort zone temperature and flexibility is set by the user via UI). Since, the HP does not have a build in memory to remember EVU ripple commands, the algorithm is developed so that it will continuously and in intervals of 10 sec initialize the HP to shut down. When the electricity price turns to low the algorithm then does nothing, resulting in the HP automatically turning itself on after a period of 15 to 20 minutes (no instruction is needed to turn the HP on, the HP turns on automatically).

The developed DR algorithm supports the following Bosch; EDC and IVT Heat pumps equipped with Rego1000 firmware:

- Compress CMO 200, CMO 300
- Compress EHP 6000
- Older model of Compress EHP, also with firmware Rego1000
- EDC model EQC10

GWR has placed the DR algorithm in the Gateway. Consequently, if the Internet connection in the house should temporarily be interrupted, the system will continue to run. In addition, The Gateway has data storage backup of up to 105 days, which data is automatically uploaded to the backend when the Internet connection comes back online. The purpose for this is to prevent loss of data.

General heat pump info:

- When a Bosch heat pump has been initialised to shut down -> it will take about 15 to 20 minutes before the heat pump is able to start up again.
- Technically a Bosch heat pump can be closed down 4 times in 1 hour.

3.2.1 THE GWR PRE-REQUISITES FOR DEVELOPING THE CASE STUDY DEMAND RESPONDS ALGORITHM:

- The Gateway will need to be able to support the following:

1) Parameters 1 Price

   Price changes (day ahead price of kWh) feed derived from Nord Pool -> high price, average price (E.G. 0,10 higher than average price)

   High or Average price

   a. High Price
      i. Price point higher than x.xx
   b. Average Price
      ii. Price point at x.xx

2) Parameters 2

   Flexibility of customer

   Example Customer Optimum Temp is say 20°C

   Flexibility Low or High (User selected)

   i. Low (0,5 degree Celsius up or down from the Optimum Customer set Temp of 20°C (Range 19,5°C low to 20,5°C high Temp)
   ii. Middle (1 degree Celsius up or down from the Optimum Customer set Temp of 20°C (Range 19°C low to 21°C high Temp)
   iii. High (1.5 K up or down from the Optimum Customer set Temp of 20°C (Range 18.5°C low to 21.5°C high Temp)

3) Use Case (High Price)

   Use Case (Heat Pump ON temp below Optimum but not below min range

   a. Based on if the temp was at or below Optimum temp 20c (IE 19c or 18c But **not** at or below 17c) the Gateway would then check the current price look at the Smart Switch
      i. If High Price: Run smart control to Turn OFF due to high price

- Add UI elements
  - Settings to set Optimum temp point
  - Setting to set Flexibility Low or High
  - Setting to set Price level what is acceptable (Price Point) and what is NOT acceptable Price Point (High Price)

  (This must be hidden from the User, the user must not decide an acceptable price point - > this should be determined by price comparing with the Average price).

- GOP Changes (setup of API commands):
  - Set XML for Price Points
  - Set XML for Temp range (IE Min and Optimum Temp Points)
  - Pulling Pricing from NorthPool Spot website

- Gateway Changes:
  - Expand ability to look at 2 Parameters and execute smart control based on above Use Cases

3.3 NORDPOOL SPOT INTEGRATION

The GWR Home2Cloud backend downloads the electricity Spot prices from NordPool Spot website once a day around 13.00 o'clock. The link to nordpool spot is the following: http://www.npspot.com/Market-data1/Elspot/Area-Prices/ALL1/Hourly/
The GWR Home2Cloude backend then pushes the collected electricity spot prices to all the gateways in the system. With this approach all the in-home gateways will have the electricity prices for the next 24 hours until the next update.

3.4 Z-WAVE DEVICES

- Energy Management Gateway

At the heart of the GreenWave Reality Home2Cloude platform is the Energy Management Gateway. The Gateway is the hub that connects the various devices creating a Home Area Network (HAN) that can be monitored and controlled. The Gateway also connects to smart meters or the GreenWave Reality Meter Reader to provide whole home electric and gas readings to consumers, which is then securely forwarded to the cloud-based backend platform. The Gateway is compact in size but has a powerful core processor and simultaneously supports different RF radios including ZigBee, Z-Wave and 6LowPAN, along with other wireless devices for future compatibility.

- Danfoss Relay RXZ-1 (RF relay switching unit)

230VAC powered static controller with binary switch capability, containing 1 power relay

Radio Controlled Room Thermostat Receiver Module	
Supply Voltage	230 Vac ± 15%, 50Hz
Construction	BS EN 60730-2-1, EN 300-220-1
Maximum Ambient Temperature	45°C
Switch Type	RXZ - 1 x SPDT, type 1B
Switch Rating	264 Vac, 3 (1) A (Total current)
IP Rating	IP40
Control Pollution Situation	Degree 2
Max. Range	30 metres
Operational Frequency	868,42 MHz
Software Classification	Class A
Rated Impulse Voltage	2.5kV
Ball Pressure Test	75°C

- AEON Clamp Reader

The Aeon Labs Smart Energy Monitor is a low-cost energy monitor for the entire home. It can wirelessly report immediate wattage and kWh usage to central control point gateways and can be easily and safely be installed by anyone. Consequently, Electricians are not required to install the Aeon Labs Smart Energy Monitor; the customer never needs to handle hot exposed wiring. Current transformer clamps clamp around the AC Mains to detect energy usage for the entire house. The main body is anchored using a back mount, which opens to easily for battery replacement every 1 years.

RF Protocol	Z-Wave
Z-Wave device type	Z-Wave multiple level routing slave
Connection type	Clamp
RF Frequency	921,42Mhz - AU/NZ approved RF for Z-Wave
Application	Indoor/ Outdoor
Operation temperature	minus 10 - plus 40°C
Weight	750g
Operation Range	Up to 30 m when no obstacles
Storage temperature	minus 10 - plus 70 °C, humidity 5-95% (max)
Housing	ABS

- LS Control Temp ES 861.

Z-Wave Temp - is a wireless battery operated highly accurate temperature sensor designed for installation in low energy installation systems based on Z-Wave. The sensor unit may be installed externally. The temperature sensor measures the temperature and transmits the reading wirelessly to a central gateway. The temperature sensor has a very low energy consumption as only important changes in temperature is transmitted. The measuring range is set centrally. The central unit is alerted in case of low battery and the user is prompted to change the battery.

Description	Z-Wave temperature sensor in box grey
Supply	2 Alkaline batteries ≥1.200 mAh - size: AAA
Frequency	RF 868,42 MHz
Size HxWxD	71 x 71 x 25 mm
Measure range 1	internal sensor: 0 - 50 °C
Measure range 2	external sensor: minus 10 - 70°C
Precision sensor	±0,2 °C

3.5 CONSUMER PORTAL UI

An important pre-requisite for engaging end-users in the HP demand response demonstration case study, is the availability of a user friendly UI for interoperability and access to the system. For this reason, GWR has developed a consumer portal (SEAS-NVE branded), giving the end-users access to a unique website via a PC browser or App for iPhone/Android. In addition, a user guide in PDF format has been developed to ease the end-user setup of the system. Below please find the consumer portal UI screens for setting up the system comfort zone/ flexibility incl. user guide comments for easy installation.

Figure 2 shows the introduction UI screen for setting up the HP intelligent control:

The intelligent control unit can help you manage your HP electricity consumption through price signals, and in parallel allows you to contribute to stabilizing the grid when there is high consumption.

Start by clicking on the heat pump icon in the overview and then click the button "Start Up". In addition, to optimizing your energy consumption the intelligent control also includes tools to ensure that your home remains temperature comfortable. The intelligent control unit stops all optimizations, if the temperature in your home drops below one of you minimum temperature settings.

Figure 2. The screen for starting HP intelligent control setup.

Figure 3 shows the comfort zone setting screen, where the end-user must select his/her in-home comfort temperature.

To ensure optimal comfort the intelligent control provides you with the ability to set a minimum temperature for your home. If the temperature drops below this setting, all optimizations will be suspended and your heat pump will operate in normal mode, until the next scheduled optimization.

Set the middle temperature by pressing one of the arrows. Once you have found the minimum temperature you want, press the button "Continue".

Figure 3. The screen for the comfort settings

Even though the end-user enters a ± range comfort temperature, the system only uses the low temperature in the range for control purpose.

The figure 4 shows the flexibility options, which the end-users have the ability of selecting. The end users can chose between the settings: Low, medium and high.

The greater the flexibility you provide, the longer the HP will run at reduced power. The more valuable your contribution will be.

Select the flexibility you want by moving the point on the scale of either Low, Medium or High. Then press "Continue".

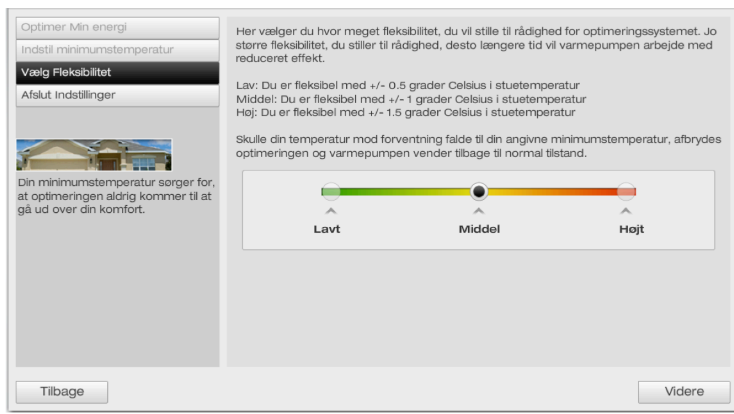


Figure 4. The screen for selecting Flexibility

The screen in figure 5 summarizes the selected settings. If the end-user does not agree with the selected settings then the user can always go back and change the settings.

> The last step in the configuration of the heat pump is to examine and accept the choices that you have made, press the button "Finish", or use the back button to make any corrections before you continue.

Figure 5. Shows the screen exit setup.

Figure 6 shows two screens which give an overview of the HP status and power consumption. Furthermore, the end-user is given the ability to temporarily disable the demand response HP control if there should be a need for immediate heating in the home.

> You should now have optimized your heat pump based on your wants and needs. The intelligent control unit contains lots of information and tools to help you monitor and control your heat pump at home or at any computer with Internet access. Here's a quick introduction:
>
> 1. Personal settings: Here you change your settings.
> 2. Consumption period: Shows how much energy your heat pump has consumed over time. If you click on the image, you will get more details of your heat pump energy consumption.
> 3. Disconnect optimization: Use this to manually override your optimization profile.
> 4. The heat pump Mode: Displays the current temperature in the home as well as heat pump optimization mode.
> 5. Comparative table: Shows the energy consumption over time and with a comparison of the heat pump average consumption.

Figure 6. Shows the HP overview screen (top) and the HP energy consumption comparison graph (bottom).

3.5.1 LAST YEAR ENERGY CONSUMPTION

For cross comparison of current energy consumption with historical data the system allows the end-user to manually updated the consumer portal with last year energy consumption in kWh (figure 7)

Under settings you have the opportunity to fill in your household's total kWh consumption last year, which makes it possible to compare your household energy consumption in households that have a similar size and participating in the project.
Select last year's energy consumption in the left menu.
Type value in kWh and press the Save button.

Figure 7. Shows the screen for entering the last year electricity consumption.

8) For an overview of the electricity consumption in DKK currency, the end-user can manually enter the present flat rate energy price into the portal (figure 8).

By completing your total electricity price per kWh (check price on your electric bill) you can get knowledge about how much electricity your heat pump uses in DKK currency.

Choose “Rate” in the left menu. Enter the kWh price from your electricity bill, then press the Save button.

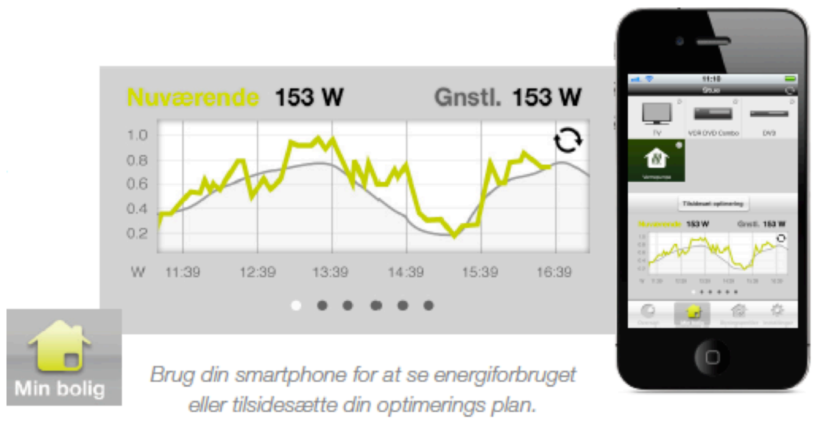
Figure 8. The screen for entering the energy price.

3.5.2 APP UI

GWR has made an App available for the case study end-users, which will run on both iPhone and Android smartphones.

The App can be downloaded from the download center via the App Store and Android market. Search for GreenWave Reality. Select and install the available SEAS-NVE App. In the App settings on the smartphone change the URL to point at https://improsume.greenwavereality.eu/. Then the user can logon via his/her user name and password.

The intelligent control unit smartphone application gives you a fun and easy way to manage your energy on where you are. To get an overview of the heat pump, select the preview button in the lower left corner of the screen and slide your finger from right to left until the heat pump is selected. The overview includes a summary page that shows you your electricity consumption, your heat pump current optimization.



3.6 HP SIZE AND ENERGY CONSUMPTION WHEN CONTROLLED

The HP resellers in Denmark usually assess the size of a HP to a size a little bit less of what is actually needed for a specific house. Consequently, the HP will run 100% optimized in the home and according to its available capacity. Consequently, when the HP is turned off via the GWR DR algorithm the HP will have to work harder to catch up the lost cycles and heat production time. The end result is a higher HP Energy consumption compared to if the HP would run on automatic without being controlled at all. Therefore, the majority of the heat pumps that partake in the case study (within the country of Denmark) will end up consuming a bit more energy when being controlled. Where as the HP such as in Switzerland[2] will not, since the HP resellers in Switzerland generally assess the HP size much larger then the actual need of a specific house, resulting in more available HP flexibility.

[2] Source: EKZ – Utility in Switzerland

3.7 BUILDING UTILIZED FOR THE CASE STUDY

Private homes have started to volunteer to partake in the case study for the period of 1 December 2013 to 30 of April 2014. For more information please see chapter 3.7.1 below.

3.7.1 PRIVATE HOME

A private home in Rødding (Jylland) has agreed to participate in the case study.

The home has a Bosch HP, which has been equipped with the GWR HW. The available Bosch HP has a build in water tank/boiler. For privacy reasons no further information is disclosed about the end-user.

Other private homes have volunteered, however, have not been evaluated as a suitable match for the pilot, due to reasons such as the Heat Pump not being a Bosch model and not equipped with the REGO 1000 HP firmware.

4 CONCLUSIONS

GWR has developed a scalable home2cloud ecosystem, which can be utilised as a platform for DR and control of devices in private homes and small business.

The case study describes that it is possible to use the energy prices as an interface for control of the HP in private homes. The focus has exclusively been on controlling the HP, however, other devices such as ventilation and air conditioning systems and other in-home devices could also potentially be part of this ecosystem.

In addition, the case study also describes that moving energy consumption away from peak periods can be achieved when using a price interface for control. One obstacle when only utilizing a price interface for control is that this may generate new peaks. The reason for this is that all the homes will automatically increase their energy consumption when the price is low. Consequently, for the DR response algorithm to work efficient the price interface should be mixed with other control schemes, however, this topic is outside the scope of the case study.