USING COMMUNITIES OF SUMMER HOUSES AS A WINTER TIME DEMAND-RESPONSE RESOURCE

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ABSTRACT

This paper presents the HYTTEFLEX concept tested out in the DeVID project. End-user flexibility of cottages during winter has been investigated. HYTTEFLEX uses a group of such residences as a source for local demand-response operations. The concept developed is built on top of an existing Home Automation System (HAS) and a business model that provide commercial home support.

INTRODUCTION

DeVID (Demonstration and Verification of Intelligent Distribution Grids) is a national research and demonstration project in Norway that explores the potential of smart grid technologies in two different parts of the country. One of the work packages is dedicated to exploration of user flexibility. Motivational factors, recruitment processes, technical solutions and other aspects important for business development related to demand side management (DSM) have been studied. We have tried to establish how individuals and households can be engaged in *demand-response* (DR) regimes on terms that are permissible in an industrial and business related sense. A preliminary report on customer recruitment has already been published [1]. Similarly the project has published accounts on the use of tariffs as an instrument to unleash latent flexibility in regular households [2,3]. Our basic assumption is that regional differences require customized approaches. Local conditions and climate, demography, people's experience with the energy supply and local patriotism are among the factors that can influence how people in a region will respond and adapt to a DR regime. Another idea has been to look for ways to integrate DSM with other services to create viable business models. In this discourse we will present and discuss a particular part of DeVID's research

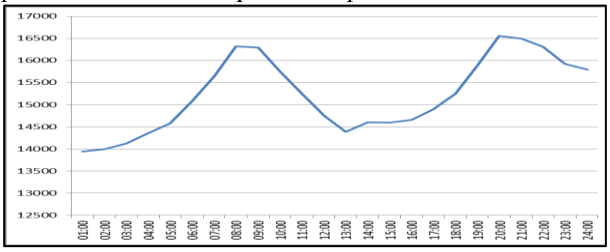

Figure 1 Load profile during a winter day. Y-axis in kW.

where the flexibility potential offered by communities of non-permanent households in an area south-east of Oslo called Hvaler has been investigated. Holiday houses in Norway can be very well equipped and maintain standards that match that of permanent households. Regardless of size, architecture, building material and standard we will refer here to all kinds of non-permanent lodgings of this kind at Hvaler as "cottages".

HVALER REGION IN NORWAY

Hvaler municipality is situated on an archipelago of islands and has only 2600 permanent residences. It is supplied with a 50kV radial. The approximate maximum capacity is 23 MW. During winter, space heating accounts for most of the consumption. Grid loads are strongly, negatively correlated with the outdoor temperature (-0,85) as a consequence of this. A typical load profile for a winter day is shown in Figure 1. Since 2011 a first generation of smart meters (AMS) with hourly measurements was introduced at Hvaler. Hvaler is a popular recreational area during the summer and the population soars. 4600 cottages located in the area accounts for much of this increase. Most cottages are left vacant during the period from November to early March. Some are used on occasional weekends and at Christmas. Our investigations have shown that even vacant cottages consume energy during the winter. The purpose is basically to maintain basic utilities and secure the property against frost and burglary. The graph in Figure 2 shows the average hourly consumption for permanent and non-permanent households at Hvaler during a winter day and on an ordinary summer day. Cottages typically

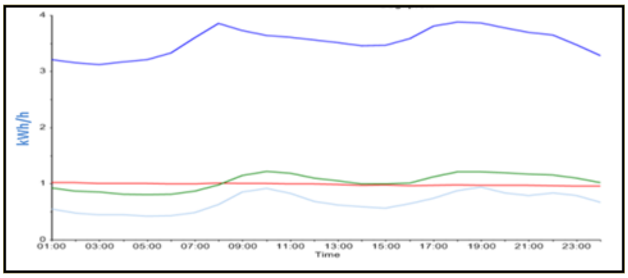

Figure 2 Average consumption profile (kWh/h) for ordinary households and cottages on a winter day (-6C) (dark blue and red line respectively) and a summer day (18C), green and light blue line. Y-axis shows kWh/h.

demand an average load of app. 1 kWh/h during cold days.

HYTTEFLEX

Despite moderate consumption in winter, cottages at Hvaler promised a significant DR-potential due to its sheer number. Moreover, the private intrusion aspect is less acute than for ordinary households. External control over vacant cottages is unlikely to conflict with daily chores. Moreover the use of HAS to remotely monitor a property of this kind has become popular. A widespread brand offers a HAS that is especially designed for remote control of non-permanent residences. It has become very popular and sold more than 30.000 units in Norway alone. We will here refer to this system brand only as "HM". The company behind HM offers a suit of hardware including a gateway that can be connected to the mobile tele-network. A cloud service enables their customers to download software to their mobile phone, tablet or PC. This software allows them to monitor and adjust indoor temperatures and turn on and off appliances. In addition, HM will send messages to the user whenever a violation of user specified defaults occur. This could be due to outages, exceedance of user specified temperature limits or burglary. The interesting thing about HM is that customers pay for the hardware and is charged an annual fee of about €120 to benefit from the associated service. The basic value proposition is that cottage owners can ensure security of their residence while away. There is less need for on-site inspections. Moreover, comfortable temperatures can be achieved prior to next visit. Boilers can be turned on by pressing an icon on the smart phone. The business model behind HM supports, rather than challenges life style essentials. It was therefore interesting to create a piggy-back solution to the HM platform and try to augment the existing business model with a DSM proposition. Consequently HYTTEFLEX was defined and a set of objectives specified: *1.Investigate the flexibility potential represented by cottages at Hvaler during winter and design a DR method to exploit this. 2. Explore the possibility for integrating this method with HM 3. Explore the potential for extending a viable business model with a demand-response service that supports #1 and #2 above.*

METHOD OF APPROACH

Figure 3 shows the overall architecture of HYTTEFLEX. The system consists of two main parts. One is the AMS which communicates with each meter across a GSM connection. The other is the HM HAS system which is controlled by the supplier behind HM. This also uses a GSM link. The Energy Management System (iEMS) that hosts the HYTTEFLEX application receives the meter values and emits the signals which control the heaters and boilers used for DR. HS is a 6-channeled system which allows independent operation of up to 6 zones or rooms. The user can monitor the status of each device through the standard application offered as part of the HM suite. He or she can specify two main modes, *Home* and *Away,* for HS. In order to avoid conflicts and risk undermining the basic value proposition behind the HS system it was decided to let HYTTEFLEX take control only when the user had set the system in *Away* mode. DR schedules were defined in the control center and passed on to the iEMS by means of web services. The HYTTEFLEX application would then pass on control signals based on this instruction set. In return the devices placed in the cottages would send a stream of temperature data and operational status (per minute) back to the iEMS. These time series could then be combined with the meter values obtained.

HM applies plug-in sockets to support and control electric devices. The whole installation process is based on a do-it-yourself concept. However, once hardware is installed and registered, services will be available. Only two types of actuating devices were used in HYTTEFLEX, on/off elements and thermostat controlled heaters. The latter was most common. Temperature sensors could be connected to the same channels and monitor the state in the zone that the system controlled.

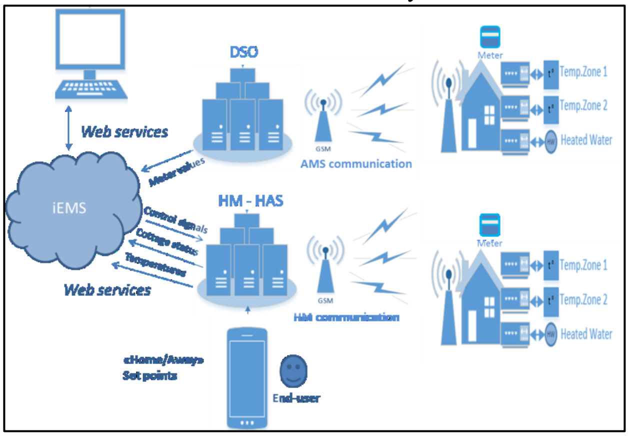

Figure 3 The HYTTEFLEX architecture

Most people operate with an indoor temperature of about 22C when at home (see Figure 4). For cottages that are used only at weekends we found that people would lower the set points a few degrees when away. Temperature levels of 14-18C are common. Insurance considerations suggest indoor temperatures not lower than 4C to avoid frozen pipes and hoses. This is what we call the temperature floor. Cottages abandoned for the winter season will typically have set points for heaters adjusted to this level or very close. Decoupling would rapidly allow the temperature to fall below the floor. In that case frost problems are imminent. In order to avoid this, HYTTEFLEX would ramp-up temperature levels before disconnection. In the cases reported here the ramp-

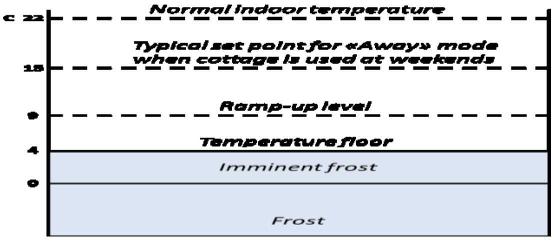

Figure 4 Different temperature levels to monitor

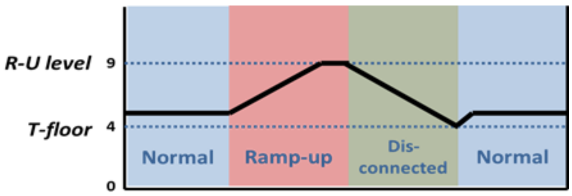

Figure 5 Depiction of operational states and how a temperature buffer is created before disconnection.

up level was set to 9C. The idea was to use the room and the surrounding construction as a thermal buffer and thus allow disconnection without frost issues. The concept is schematically illustrated in Figure 5 where the control states are colored differently and a typical temperature curve has been plotted for each state. If temperatures fell to 4C during the disconnected period the DR procedure would be terminated and the user specified temperature level resumed. The temperature levels could be monitored closely, thus providing transparency to any possible degradation of the demand reduction during decoupling. As meter values were only available through the AMS every 24 hours, real time monitoring of consumption was not possible. HM had no support for power monitoring. Simple predictions were introduced to estimate daily load profiles for the local grid for the day and week ahead. It proved useful and standard control scripts could be produced. This was announced to the users in advance. This outlook also gave increased confidence in the DR tests among users.

RESULTS

Altogether more than 30 cottage owners were engaged in HYTTEFLEX at some time. 18 cottages in this group have given us the chance to persistently test the HYTTEFLEX over a long period. Up to this point we have gathered data from almost 250 test weeks under different winter and spring conditions. The early winter months of 2014 were exceptionally mild. During the period January 1 to June 1 the average temperature at Hvaler was 4,2C higher than the year before. This did have an impact on the experiment. However, the end of year came with below zero temperatures. For a string of days temperatures fell as low as -9C. Additional tests could then be run. Figure 6 shows the operational profile for one test site (Cottage A) on a winter day with average outdoor temperature of 2,7C and some wind in the

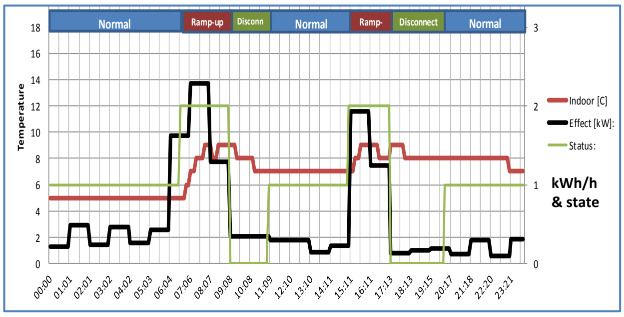

Figure 6 Cottage A: The black line shows the average hourly load and the red line the actual indoor temperature measured for different states on winter day in 2014

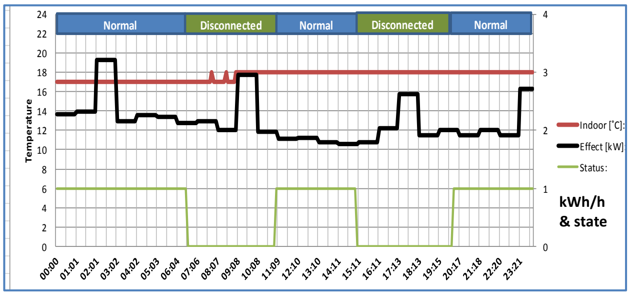

Figure 7 Cottage B is used during weekends and a higher temperature level is maintained during the week. Independent back-up heater maintains temperature level.

morning and evening (7-10m/s). The abandoned residence was prepared for frost control. Minimum temperature set by the user was 5C. The red line in the graph illustrates this well for the morning hours. The green line shows the state of control. State 1 implies “normal” state. State 0 implies that the heater is disconnected by HYTTEFLEX. State 2 implies a “ramp-up”. Until 6:30 on this day the basic HM system maintains control. We can see how normal thermostat control shuts the heater element on and off. This is reflected by the black line indicating the average hourly load recorded by the meter. Under “normal” operations this varies between 200Wh/h and 460Wh/h. When all the heaters are fully engaged they draw 2600W. However, at 2,7C full power is only engaged 16,5% of the time during normal operation. Observe from the graph that HYTTEFLEX takes control after 6:30. The temperature upshot caused by State 2 is clearly shown. The added load is reflected by the black curve. Two heaters are engaged in steps. Once the red temperature line reaches 9C we can see that the load levels out too. The morning peak in the grid is building rapidly on this day at 9:00. HYTTEFLEX then shuts off the electric heaters (green line = 0). There is no way the local thermostat can activate the heating element. For the shut-down period any contributing load from the controlled heaters are banned. This is also indicated by the black line. At 11 o’clock HYTTEFLEX yields control to HM once more (State 1). An interesting thing to note is how the ramped-up temperature extends the shut-down period even when

State 1 is resumed. This is due to thermal inertia of the indoor space and the building structure. The house works as a thermal buffer. During the afternoon on the same day the same procedure is repeated. From 15:00 – 17:00 the temperature is increased. From 17:00 to 20:00 HYTTEFLEX disconnects again. With an outdoor temperature of about 3C during the following night it took 10 hours before indoor temperature fell back to 5C. Consequently the ramp-up caused a very extensive disconnection, although only 3 hours were actually enforced. Figure 7 shows a similar situation on the same day for another cottage (B). This cottage is used at weekends. The temperature level on a week day is set to 18C. 1500W is fully controlled by HYTTEFLEX. Since set-point is higher than 9C ramp-up is not activated. However, Figure 7 shows no temperature change during disconnection. After contact with the cottage owner it was established that a back-up heater, not controlled by HYTTEFLEX, was introduced as a security measure. More cases of this were found. As illustrated for both Cottage A and B heating elements may already be inert when temperature levels in a room is close to set-point. No immediate reduction will then be observed when power is shut off. But power may never be resumed during the shut-down period. In the case of Cottage A 2600W is inhibited during State 0 (decoupling). The net reward measured in kWh/h depends on several factors. The most important being the specified set-point relative to the outdoor temperature. The difference determines the thermal gradient across the outer walls. A steeper gradient will generally demand a longer period of heater engagement. The meter value will thus show a higher average load per hour [kWh/h]. Average peak load reduction thus increases accordingly. But during State 0, when indoor temperature falls, the thermal buffer is gradually depleted. The steeper the temperature gradient across the walls the more rapidly the indoor temperature will fall, and the less time it will take before the floor is hit. When this happens and problems of frost are imminent the load reduction potential is lost entirely. Disconnection will produce a rapid drop in temperature that will force reengagement of the heater. A combination of a very low set-point and a very low outdoor temperature will, at some point, make disconnection impossible. This is shown in Figure 8 (set point = 7C). This shows a string of records for a week when significant temperature changes were experienced. The average hourly load increases with lower temperatures, suggesting a greater load reduction potential as it gets colder. But the small thermal buffer will decline very rapidly and diminish the time possible for disconnection. Figure 8 indicates a situation when this happens at -8,5C. No practical contribution to peak shedding will be achieved. At -7C disconnection time can only be achieved 1/10 of the hour. Figure 9 shows this phenomenon for multiple cottages. 9C. More records will be needed to achieve better curve fitting, but the

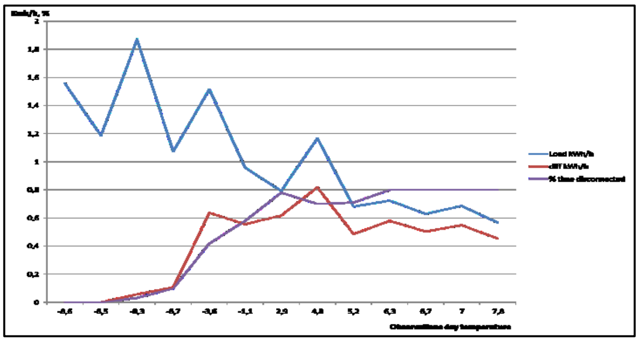

Figure 8 Blue line shows hourly load [kWh/h] for different temperatures. Purple line shows disconnection time/ hour (%). Red line shows load reduction in kWh/h.

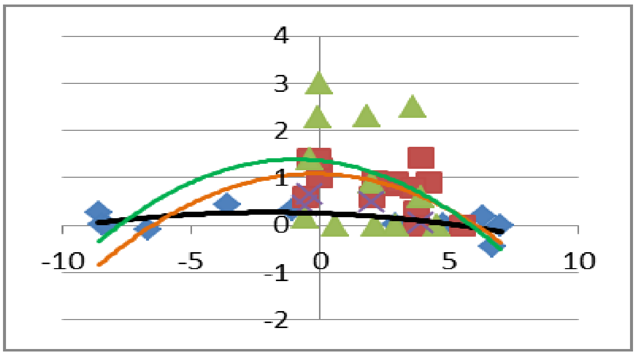

Figure 9 Plots and fitted curves for unleashed flexibility for groups of cottages, each with a different set-point.

tendency matches the results shown for Cottage A in Figure 8. There exists a temperature interval with a distinct maximum value for load reduction. Its magnitude depends on the set-point specified. Additional samples on frosty days are required to obtain more detailed insight into this. For the outdoor temperature interval -1 to +10C we have sufficient records to firmly establish reductions (see Table 1) for the full test group. For this temperature interval we achieved an average of 480 Wh/h.

	Min	Max	Average
Hourly (Wh/h)	180	1100	480
Max power per unit (W)	1500	4100	2300

Table 1 Max power controlled and net hourly power reductions achieved for the HYTTEFLEX test group

CONCLUSIVE DISCUSSION

The flexibility potential

The research documented here indicates that communities of non-inhabited cottages can be used as a resource for reducing peak loads in the grid. The flexibility potential is real and can be unleashed by means of a remotely operated HAS. However, the reduced volume is highly dependent on the outdoor temperature and what temperature level the cottage owner wants to maintain indoor while away. Two different categories of users came forward. The first group consists of those who abandoned the house for the entire season. They wished to conserve a minimum temperature to avoid frost damage. The second group used their cottages during weekends throughout the winter. They allowed an indoor temperature level of 14-20C between weekend visits. A DR approach that seeks to unleash flexibility associated with space heating must observe the dependency on the set temperature chosen and the outdoor temperature. The greater the difference between these two the more peak power can be reduced, but then only for shorter periods. On very cold days, cottages with low set-points will require a significant temperature increase before intervention in order to create sufficient thermal buffering to allow disconnection. The cost of this could be an issue. Average load reduction will usually be lower than max power of the heaters that are controlled. But the control will inhibit this capacity during disconnection which could be useful in special cases i.e. after outages or in emergencies. With the results obtained here an average reduction of 2,2MWh/h could be achieved if 10% of the cottages at Hvaler were involved. The maximum of 6,9MW of instant loads could be managed for various extraordinary operations that require peak control. There are many recreational areas with housing communities similar to the one described here. They can be found along the coast and in mountain areas across Scandinavia and other places in Europe. In Norway alone there are approximately 450.000 cottages and cabins. Although consumption varies, both peak loads and consumption increase. The potential aggregated flexibility will increase accordingly. Based on the figures established here this potential in Norway alone could be as high as 0,2GW. Unlike households were people live permanently, DR in non-permanent residences will not challenge daily life. These houses remain vacant during extensive periods with otherwise high demand and when DR is attractive. The Hvaler case also emphasizes another important thing. Different regions, especially in rural areas, demand specific considerations, but also offer particular solutions. It is important to look for those.

Integration and business model extension

As depicted in Figure 3 the DR concept proposed was successfully integrated with HM, a HAS system that supports an existing and viable business model. Approximately 30% of the active participants invested their own money to take part. They found the HM suite very useful and accepted the extension offered by HYTTEFLEX. Many more were willing to do so, but forfeited due to several reasons: **a) Mild weather b) Late decisions stalled action c) HM's plug-in solution could not work d) Initial technical problems with HYTTEFLEX**. The lack of urgency due to higher than normal temperatures made people postpone their final commitment. According to the vendor general HM sales fell 30% during same period. Returning to an abandoned summer residence during the darkest winter represented an inconvenience and discouraged others. Installation was postponed. Other owners realized late that all heaters in their cottage were permanently connected. Plug-in solutions were not feasible without major interference. All of these reasons for failed deals pertain, however, to general sales and procurement issues that must be resolved according to regular business principles. They do not demote the concept of DR as an add-on to a HAS like the HM system. In spite of concerns related to technical failure which like, in the case of Cottage B, led some to use back-up systems, HYTTEFLEX was still accepted as an interesting extension to the regular HM offer. What is essential is that a system like HYTTEFLEX should take full control of the primary loads in the vacant cottage, keeping in mind that high-priority energy use like washing machines and TV watching is non-existent and no source of conflict.

Need for improvements

Increasing the set of records for low temperatures is currently a priority. In the longer term real-time power readings of each device will improve the concept. This, in turn, call for a greater integration of services than we were able to achieve with HM. It is also our opinion that more effort should be invested in the installation phase to secure proper and reliable set-up. Plug-in sockets cannot be recommended as a lasting solution. It is susceptible to initial failure and subsequent tampering. Ramp-up costs must be taken into account too. With the energy prices in our case ramp-up costs were negligible, especially compared to the potential value of the curtailment of loads in the local grid.

ACKNOWLEDGEMENTS

This research was supported by the Norwegian Research Council and the DeVID industrial consortium headed by NTE and FEAS. We are also grateful for DEFA's generous support and cooperation.

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