Final report

1.1 Project details

Project title	Dynapower
Project identification (program abbrev. and file)	
Name of the programme which has funded the project	EUDP
Project managing company/institution (name and address)	CleanCharge Solutions ApS
Project partners	Thiim A/S, DTU Elektro, Københavns Kommune, CleanCharge
CVR (central business register)	29840547
Date for submission	D. 31/5-2016

1.2 Short description of project objective and results

The objective was to test and demonstrate technically, a real smart grid case, where we took into account limited power capacity on a single radial, mix load and the charging of several EV's. The case selected for testing could be achieved with available technology and current players on the market. The goal of demonstrating maturity and scalability of the selected business case was achieved. The chosen fleet of electric vehicles has this exact issue in several of their locations, where they have EV fleets charging with similar charging patterns. The existing grid connection simultaneously supported an existing building electricity usage. We succeeded in reducing load where we could work around the limited power capacity, while also being able to accommodate charging an electric vehicle fleet.
Det var formålet at afprøve og demonstrere teknisk et virkelig smart grid case i forhold til begrænset kapacitet på en enkelt stikledning, blandet effektforbrug og opladning af mange el-biler (EV). Casen bler udvalgt således at afprøvning kan ske med tilgængelig teknologi og aktuelle markedsaktører med henblik på at demonstrere teknisk modenhed og skalerbarhed for en udvalgt business case. Vi fandt problemstillingen i en flåde af elbiler i Købehavns Kommune. Her var vi i stand til at reducere belastningen fra opladning af en elbils flåde, mens vi samtidigt fastholdt bygningens egen forbrug på sit daglige niveau med sin eksisterende forsyningsaftale.

1.3 Executive summary

The challenges for securing the electricity locally for larger fleets of electric vehicles, were solved as a simple solution encompassing a system, which measured power and load, communicated back into a control system, which in turn controlled a grid load by controlling the charging of electric fleet vehicles.

1.4 Project objectives

1.4.1 Objective and background

The project objective was described in the original application as:

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The objective is to test and demonstrate technically a real smart grid case with limited power capacity on a single radial, mix load and charging of several EV's. The case is selected such that the test can be achieved with current players on the market and with the goal of demonstrating maturity and scalability of the technology

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Specifically, the project aimed to use components provided by Thiim and CleanCharge/RWE to demonstrate load control at a parking lot, belonging to the city of Copenhagen, in inner Copenhagen.

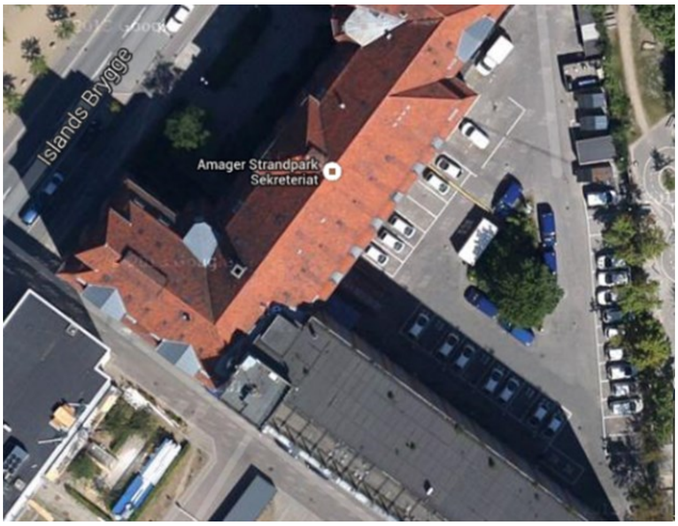

Figure X – main Dynapower test site

The project should then demonstrate that realtime measurements on the buildings consumption could be used as input for a control algorithm capable of limiting EV charging in order to reduce peaks in consumption.

1.4.2 Technology/setup

The technologies available to the project were as follows:

- A number of RWE charging stations supporting a fleet of EVs belonging to the city of Copenhagen.
- A number of RWE charging stations located at the Technical University of Copenhagen, lyngby campus.
- Two smart grid units (SGU) provided by Thiim for electric measurements.
- A backend system provided by RWE to monitor and manage charging stations

The technology developed in the project:

- Software that demonstrates the use of all the available technologies in the application of load control.

In the following figure illustrates the technical setup of the project and how the above technologies were integrated and connected to meet the objective of the project.

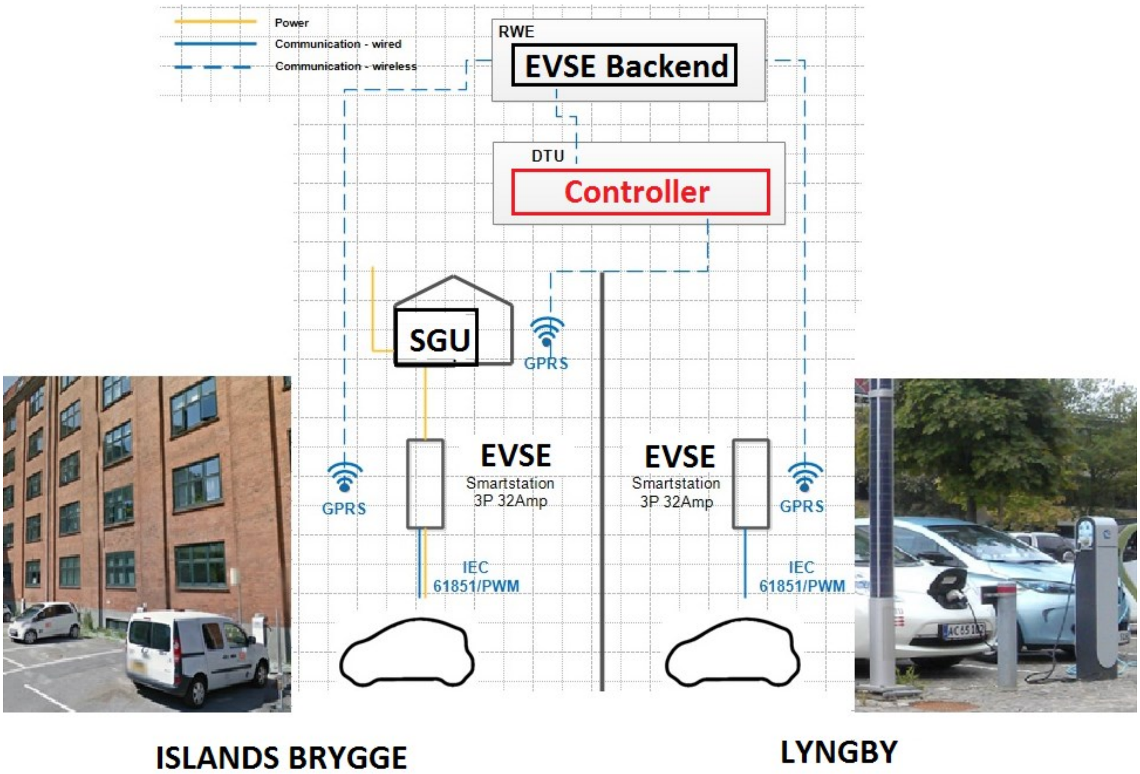

Figure X – Project architecture

In Figure X it is shown how the developed software (red boxes) are used to test the EV charging control both at DTU in lyngby and at the main test site in Copenhagen (Islands Brygge).

The following figure illustrates how the DTU controller communicates with the SGU and RWE.

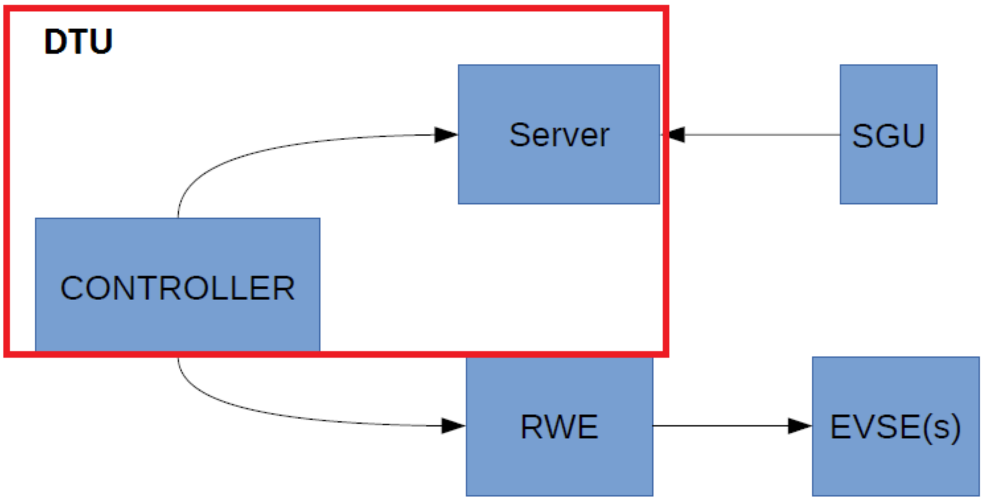

Figure X – Communication

The Lyngby site was used for initial testing before demonstrating at Islands Brygge.

At the Islands brygge site the SGU was installed and was used to monitor the sum consumption of the building.

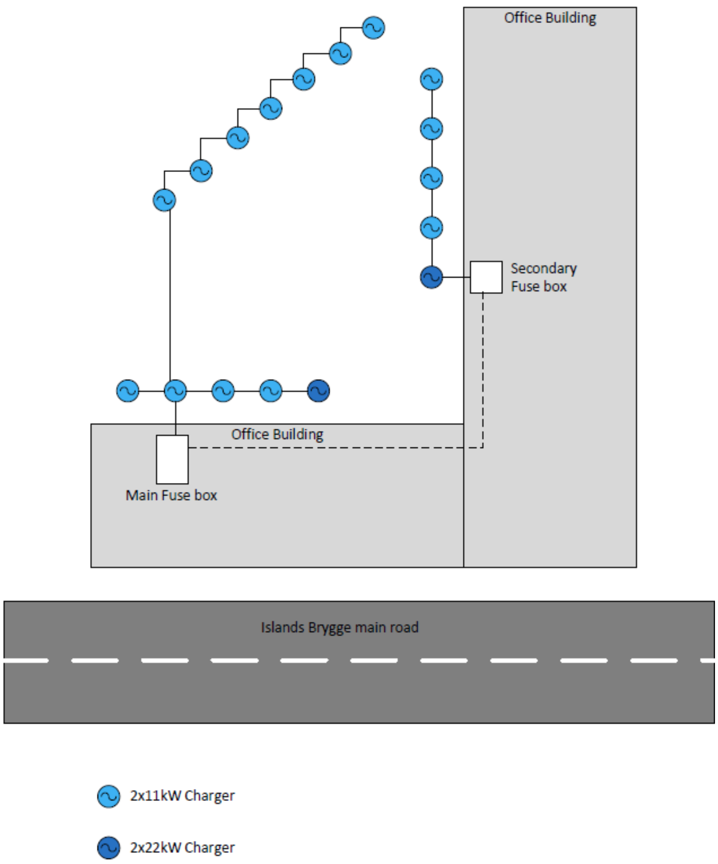

Figure X – Islands brygge chargers, connections and fuses.

The SGU unit was installed next to the main fuse box in the picture above. The SGU measured at two different points:

1) The building consumption including all charging spots
2) The 12 EVSEs connected at the main Fuse box.

Each of the charging outlets had a specific electric vehicle assigned, which followed a pattern of consumption, we could measure and control the load from, based upon the control system set-up via the load measuring SGU unit.

(More detailed description of Islands Brygge setup)

The project partners successfully implemented this architecture, and the technologies, necessary to carry out the demonstration. The implementation, however, took longer than expected due to delays in hardware availability and installation.

1.4.3 Project methodology and phases

The project application initially defined four phases for carrying out the project (1- analysis/design, 2- development, 3-iterative tests, 4-pilot). These phases and associate deadlines were adjusted slightly, and more detail was added, at project startup. The two first phases was renamed and the original iterative test/pilot phases was combined in the new "Operation" phase. Finally a new phase was added for "analysis and documentation".

The following shows a summarized version of the final phases and milestones:

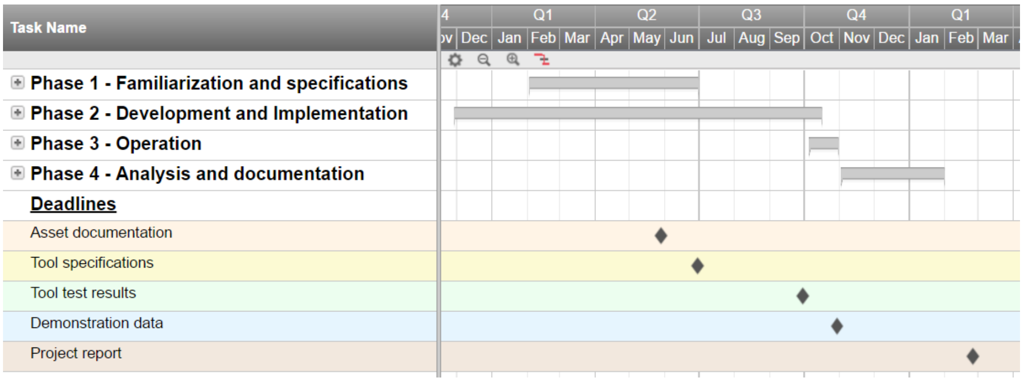

Figure X – Phases and deadlines

The largest change from the initial plan is the duration of the Development and implementation phase due to delays in equipment availability and implementation.

1.4.4 Test usecase and controller

After having implemented the needed technology in phase 2, a test case was developed for the "operation" phase to demonstrate that the DTU developed test software could use the SGU measurements and the RWE backend system to respond to peaks in consumption.

The simple test case consisted of the following steps:
(starting condition, the DTU test software is running with connection to SGU unit and RWE backend services)

The sum consumption (measured by SGU) exceeds a certain threshold
The charging power of connected EVs is reduced using the RWE backend
The sum consumption (measured by SGU) decreases below a certain threshold
The EVs are granted full charging power again

The sequence diagram below illustrates the test logic in the DTU Controller.

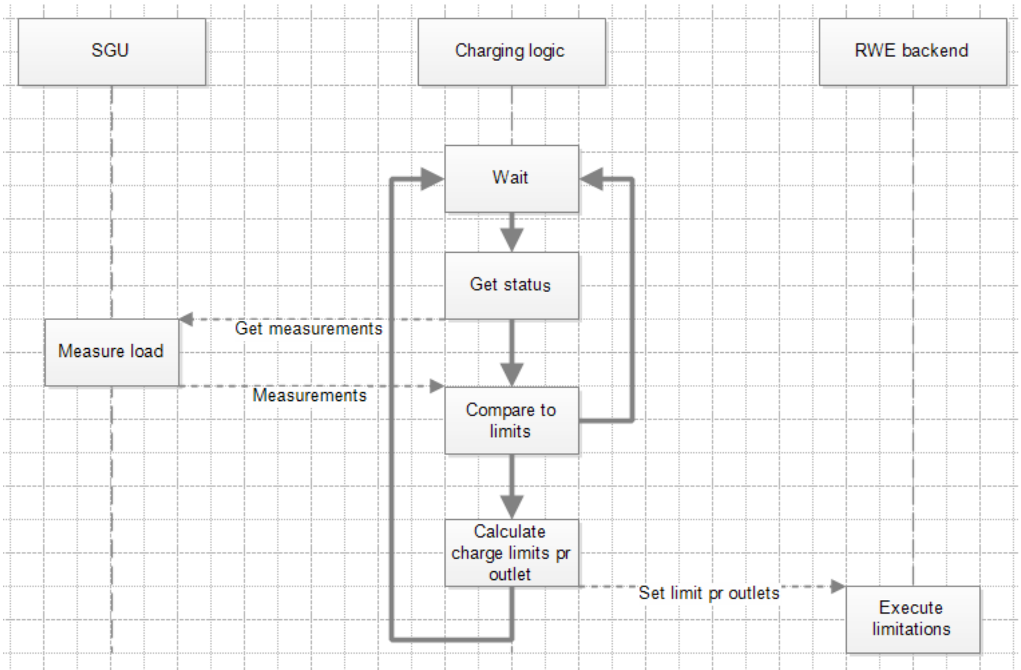

Figure X – Controller logic

Due to the delays in the development and implementation phase the test period was shortened compared to the original timeplan. The above test case however was enough to demonstrate the technologies combined ability to implement load control.

1.5 Project results and dissemination of results

1.5.1 Measuring building and EV consumption

An important step in the project was the ability to measure the building and EV consumption using the SGU.

After having installed and configured the SGU at Islands Brygge, the communication between the DTU controller and SGU was configure and tested. After some communication stability challenges this effort was ultimately successful.

The following graph shows the sum consumption of the Island Brygge building.

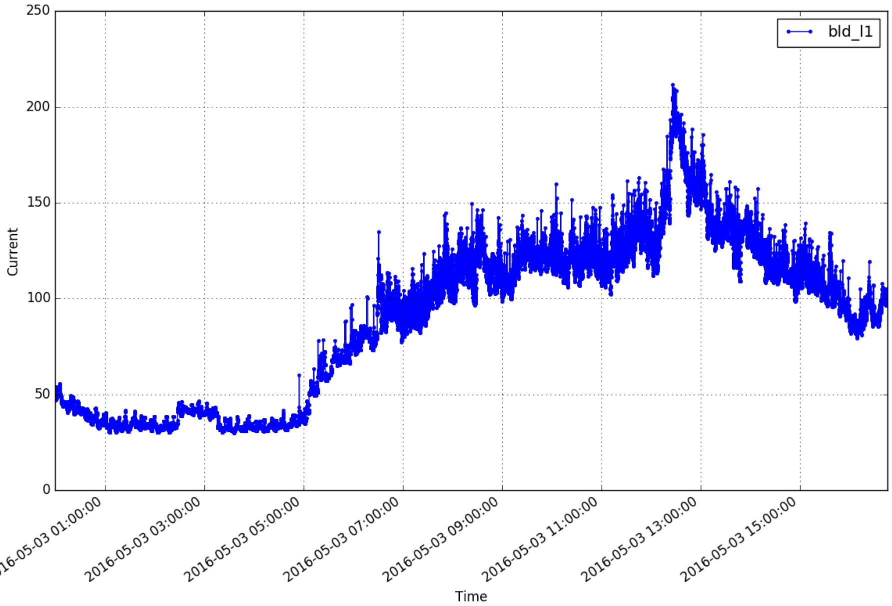

Figure X – Sample of building consumtion

The large building with many users and types of loads may explain the fluctuations in demand. A general trend can be seen however where demands increase by the start of the workday (5:00-7:00) and peaks around noon (12:00-13:00).

Similarly, the consumption from the 2nd measuring point (twelve EVSEs/24 outlets) could also be monitored.

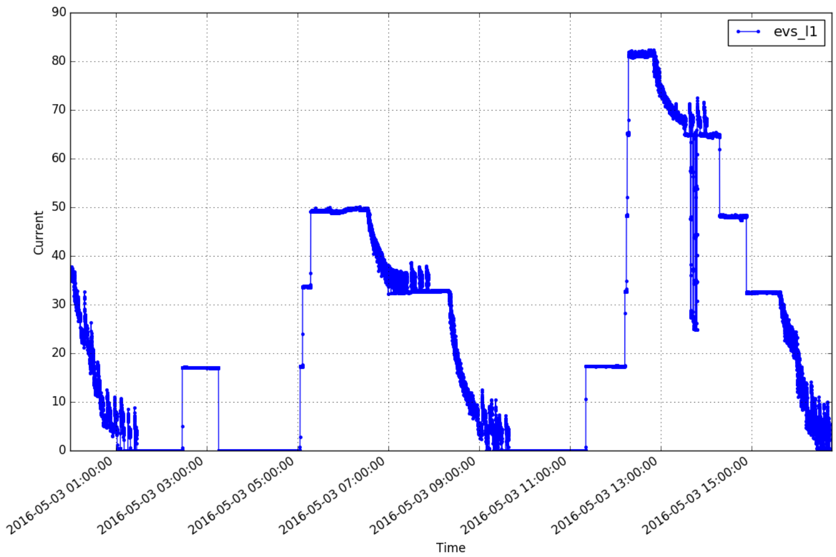

Figure X – EVSE consumption

The steps in figure X (~16 Amp) corresponds to current drawn by EVs being connected to the chargers. In the figure this would correspond to five 1P 16A EVs charging between 12:45 to 13:00.

Since the vehicles are used by multiply user groups the EVSE consumption is subject to uncertainty. Based on the recorded data EV consumption seems to peak in the morning and at midday and late afternoon with little to no charging after midnight. A more thorough investigation of the charging data would, however, be necessary to understand possible patterns in EV charging.

By showing the building and EV consumption together the potential of EV charging control can be illustrated.

The following graph shows the building demand with and without the twelve charging spots.

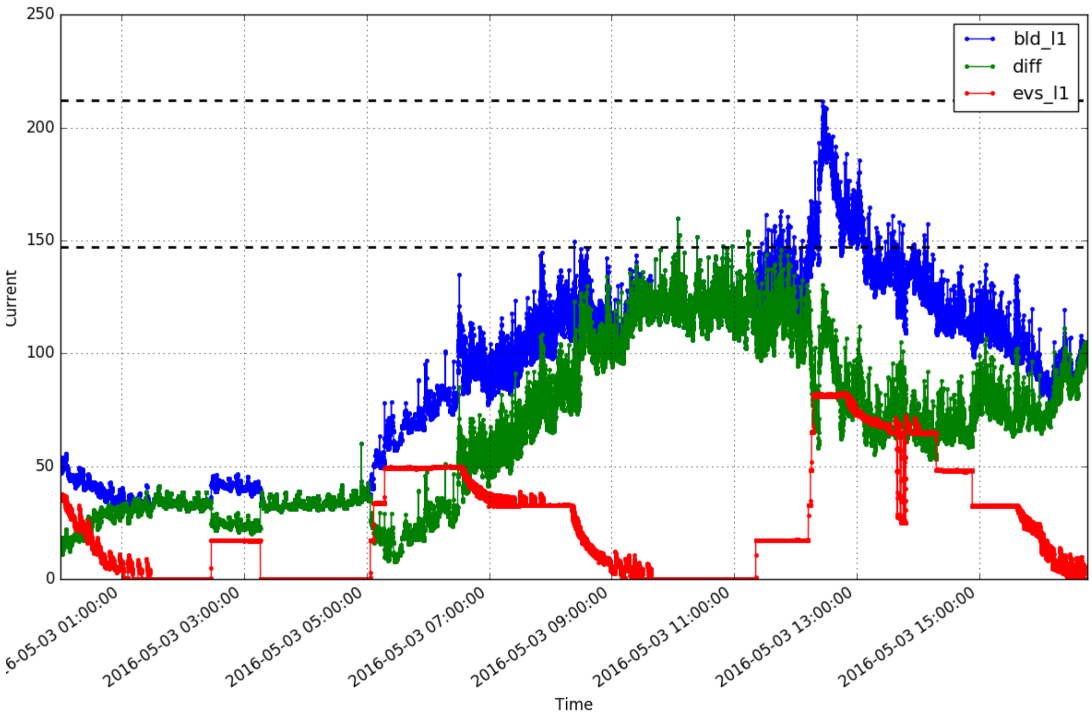

Figure X – building and EVSE consumption

In figure X it can be seen that EV charging (red) can represent a significant share of the full demand (blue) – something which strengthens the usefulness of vehicles for load control.
It can, however, also be seen that EV charging may not coincide with the maximum building consumption (e.g. 09:00 -11:00 in the figure above). Afternoon peaks with a high consumtion from both the building and EVs may be avoided by spreading out EV charging over evening hours.

1.5.2 Defining peaks and thresholds

Since the islands brygge testsite represent a "safe" environment in that building fuses and capacity is much greater than the maximum load from the building including EVSEs – an artificial limit has to be set to trigger the load control mechanism.

To set a suitable limit/threshold, a number of peaks, where the consumtion in short periods of time significantly exceeds the average, have to be identified.

As can be seen from the following graph, showing the building consumption pver a narrower time window than before, the flucturation of demand can make it challenging to identify such peaks.

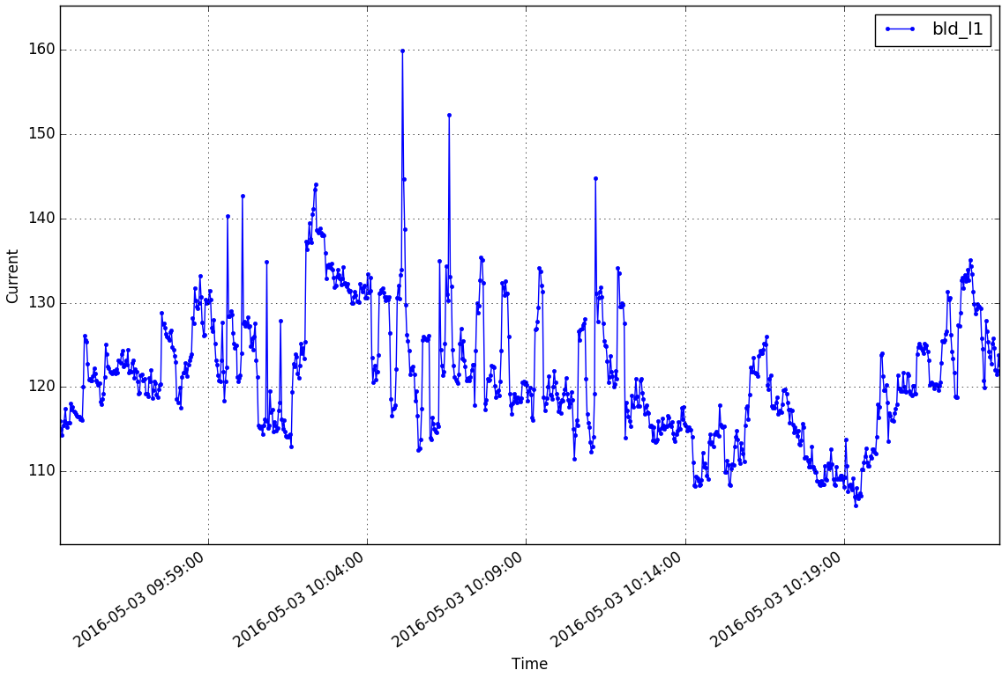

Figure X – Building consumption, 30 minute window

It has not been possible to identify the exact cause of these peaks – they do however pose a challenge in identifying peaks as consumption may suddenly rise and then decrease again immediately after. A simple solution used in the controller is to wait for a consecutive number of samples, exceeding the threshold, before identifying a peak.

1.5.3 Charging control

As a final step, as part of the test case, the RWE backend was used to change the charging power when a peak in consumption was identified. Figure X shows the response by the chargers.

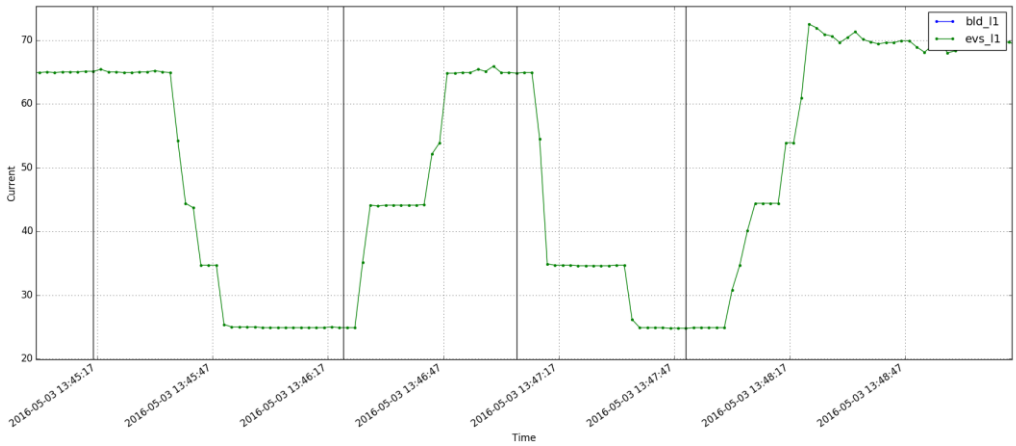

Figure X – Charger response

The vertical line marks the points in time where a request is sent to the RWE backend as part of the load control.

While requests individual EVSE outlets are executed rather fast (2-3 sec from controller request to measured response) it can be observed that requests sent to larger groups of EVSE results in a longer delay (in this case¨30 sec) before all EVSEs react. A possibility is that requests are processed in sequence rather than parallel at the RWE backend.

1.6 Utilization of project results

For the project to add value to a portfolio of Smart Grid capabilities already in place and available in a charging back-end control system, the adding of the sensor technology, so it is possible to measure power and load at the same time, is a key step forward. We hereby add Smart Grid control capabilities rather than having a Smart Grid capability we can utilize separately. What we have accomplished in this project, is adding more capabilities, which work together to optimize beyong one load control handle for the power towards charging an electrical vehicle fleet.

Given the political framework conditions in Denmark towards where the capabilities working in unisom can have an applicable and economical useful purpose, the business case can be difficult to ascertain. However, the ability to measure a load on a single radial and control a new and anticipated external load from electric fleet vehicles, this combination of available and scalable technologies, can have an immediate value.

In the case of the EV fleet owner in the project, the City of Copenhagen, we experienced a surprising and immediate need this capability, which we did not anticipate. Their expansion into electric vehicle fleets at various sites throughout their existing building mass, the load on single radials relative to a fixed amount of acquired possible total capacity of electricity into the building, the developed tool could have immediate purpose and value.

The utilization of new technologies are always dependent on a price/value evaluation, which is always a challenge to introduce into an organization, where these kinds of technolgies are new territories.

The business case will have to be exemplified for each location, building, amount of electrical vehicles, the total load as well as the usage of one or more radials.

The potential however, seems to be there, when looking into a future where fleets are converted to electrical propulsion. These issues and ways to solve load issues locally, are apparent in local grids everywhere regardless of local grid architectures. In places like the Faeroe Islands, where there are no outside grid connections, but an increasing amount of renewable generation from windpower, the ability to measure the load with capabilities to control an expected increase in simultanous loads from charging larger electrical fleet vehicles, is a key parameter for implementation of control systems going forward for the Utility there, SEV.

The competition we do see, comes from within the vehicles themselves, so the automakers, each and every one of them, gives their users a digital handle, which can impact the load individually from the car charging. We still don't see a unified front, where load management can take on fleets of vehicles through the same digital handle, but the potential is there. Further measures from grid owners to measure transformer loads could also become an intercepter towards the potential of the Dynapower product.

We have yet to discuss patents in the Dynapower consortium, but it is a possibility from our viewpoint in the CleanCharge company. We do see large market potential given an uptake in volumes of electrical vehicles, but currently the demand remains elusive. We did however also present our findings on the Faeroe Islands, where the one single DSO, SEV, finds itself focused on being able to control as many lods as possible due to no outside grid connections, but an increasing amount of power generated from variable renewable sources. Further discusssions, were had with leading OEM's at en e-mobility conference in Frankfurt, where interest for the Dynapower product was evident. Having met with a DSO company in Helsingborg in Sweden, the challenge facing fleet owners on a single radial was confirmed there as well. From a current EU Roaming platform perspective, we presented the findings for the Hubject Company in Berlin, to look at ways to integrate the Dynapower product solution in a commercial framework offering just like direct payment, sensor implementation for P-spot charging spot reservations, etc. Often public charging spots are grouped in rows and connected on the same radial. The discussions here are ongoing and again, the commercial application and demand, remains to be seen from further uptake of electric vehicles.

This brings about the discussion of energy policy objectives. Current energy policy objectives, where a Dynapower product has the potential to become a demand driven business, does seem to be alligned. Smart Grid control handles are conceptally accommodated within energy policy objectives, but the demand is not there due to very small amounts of electrical vehicles in Denmark. Further exploratory steps could bring about different current market demand, given the uptake of electrical vehicles in other countries outside of DK.

1.7 Project conclusion and perspective

The project was concluded as worthwhile and important future deployment of electric vehicle fleets and their propensity to strain the local grid from charging simultaneously and on the same radial. The ability to measure the load on the grid separately from the charging load itself from the vehicles, seems very relevant to future expansion of electrical vehicle fleets. The perspectives are very positive given this scenario and was validated by the City of Copenhagen, where local load issues comparable to the demonstration site, came to light during the project. In this perspective, the project and Dynapower product, could become a viable market product. However, the perspectives for a positive business case is a wild card as regulatory and political framework conditions must appear alongside the development of commercial products within Smart Grid control products. When the regulatory and political framework conditions appear, for investing in and paying for a Dynapower product as was developed in this project, the perspectives are very positive.

Annex
Relevant links

(the guidelines should be deleted – they should NOT be included in the final report)

GUIDELINES FOR FINAL REPORT

General
Depending of project type, project size and project complexity the **number of pages** in the final report may vary. For smaller **demonstration** projects the final report normally should not be
more than 20 pages plus possible relevant appendices. For **research and development** projects the final report should not be more tha 50 pages.

The final report will be used for dissemination purposes and the information given in the final report should be suitable for dissemination, cf. point 1.4.

1.1 Short description of project objective and results

The short description should be in two versions:

- an *English version* and
- a *Danish version.*

Each version should be brief, not more than 600 to 800 characters.

1.3 Executive summary

Brief summary of the project and its results and expected utilisation of project results.

1.4 Project objectives

Description of the project objectives and the implementation of the project. How did the project evolve? Describe the risks associated with the project. Did the project implementation develop as foreseen and according to milestones agreed upon? Did the project experience problems not expected?)

1.5 Project results and dissemination of results

Description of main activities and technical results in the project as well as description of commercial results and expectations of the project.

Did the project succeed in realising its objectives? If not, why? Did the project give answer to the problem stated in the project proposal which the funding has been based on. Did the project produce results not expected?

Did the project so far result in increased turnover, exports, employment? Do the project partners expect that the project result in increased turnover, exports, employment?

How has project results been disseminated?

1.6 Utilization of project results

How do the project participants expect to utilize the results obtained in the project? Do any of the project participants expect to utilize the project results - commercially or otherwise? Which commercial activities and marketing results do you plan for? Has your business plan been updated? Or a new business plan produced? What future context is the end results expected to be part of, e.g. as part of another product, as the main product or as part of further development and demonstration? What is the market potential? Competition?

Do project participants expect to take out patents?

How do project results contribute to realize energy policy objectives?

Have results been transferred to other institutions after project completion? If Ph.D.s have been part of the project, it must be described how the results from the project are used in teaching and other dissemination activities

1.7 Project conclusion and perspective

State the conclusions made in the project. Try to put into perspective how the project results may influence future development.

Annex

Add links to relevant documents, publications, home pages etc.