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Final report
-Engineering student internship-

"Cost analysis of different charging types and balancing services at a national scale"

Starting date: 04/06/2018

Ending date: 21/09/2018

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I also want to thank all the other members of Northumbria University for their warm welcome. It was a good internship with friendly people and I believe that we all benefited from the discussions and help we could give each other. A special thanks to my friend David Beck for the funny moments that we spent together.

Finally I would like to thank my parents for the financial support but also for the advices that they gave me during my internship.

Contents

1. Acronyms

EV	Electrical vehicle
FFR	Firm frequency response
KPI	Key performance indicators
OP	Operational pilot
PV	Photovoltaic panel
STOR	Short term operating reserve
V2G	Vehicle 2 Grid
WP	Work package

2. Glossary

Dump charging	Method of charging without any optimization. EVs start charging when they are plugged into the grid until they are fill to the max or they are unplugged.
Smart charging	Method of charging where we can delay the charge of an EV to optimize the cost, carbon emissions, battery degradation, grid instability.
V2G	Method of charging where we can discharge the EV into the grid in order to optimize the cost, carbon emissions, battery degradation, grid instability.
Wholesale price	This is the price of electricity in UK. It depends of many factors but mainly electricity generation and electricity consumption.
Balancing service	UK national grid buys services from suppliers to balance demand and supply and to ensure the security and quality of electricity supply across Britain's transmission system.
Firm frequency response	Firm Frequency Response is a service provided by energy users to help National Grid to keep the system frequency of 50Hz+-1%. This is caused by too much generation compared to demand or vice versa.
Short term operating reserve	This reserve is used to help the national grid to struggle against exceptionally high demand or cover normal demand in the case where a plant is unavailable.

3. Introduction

SEEV4-CITY is a key enabler for an innovative city development integrating clean electric transport and renewable energy production. It also allows to introduce new businesses for renewable energy and ultra-low emission mobility services, social acceptance studies, management guidelines and policy frameworks.

As a partner of this project, Northumbria University works on several aspects of the use of electrical vehicles: battery degradation, business models, charging scheduling, costs and benefits analysis.

From the 04/06/2018 to the 21/09/2018, I did my internship at Northumbria University and also joined SEEV4-CITY. My mission was "cost analysis of V2G comparing to other charging types".

Throughout this report, I will first present the project in which I'm involved then, in a second part, I will present my work during my internship, my difficulties, and also my results.

4. Presentations

4.1. SEEV4-CITY presentation

4.1.1. Problem definition

"Smart, clean Energy and Electric Vehicles 4 the City" known as SEEV4-CITY is a European project started in September 2016 up to October 2019. Supported by Interreg VB North Sea Region Programme and led by the Amsterdam University of Applied sciences. SEEV4-CITY's objective is to stimulate clean transport powered by clean renewable energy.

Due to environmental problems, the top priority of many public authorities is to develop clean transports and clean renewable energies. The problem is that there is a mismatch between energy production, coming from renewable sources and energy consumption. Because of this difference, electrical vehicle are not always charged with renewable energies and electrical instabilities appear in the grid because of peak demand.

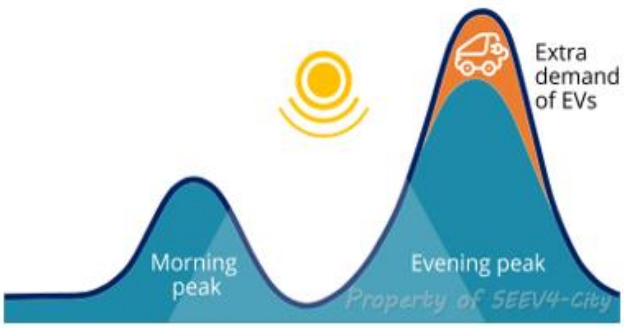


Figure 1: Energy demand and generation mismatch

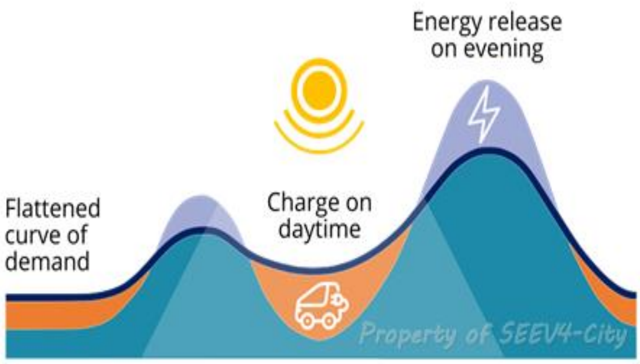


Figure 2: Energy demand and generation with V2G

The solution? Use electrical vehicles (EV) as a short term storage during the day, when the demand is low, and thanks to bidirectional chargers, discharge EV during the evening in order to avoid peak demand. This technique is known as "vehicle to grid" (V2G).

4.1.2. Project objectives

The objective of this project is to develop Smart Charging concepts into business models that integrate EVs and renewable energies planning through Sustainable Urban Mobility & Energy Plan.

"Operational pilots" (OP) which are places, buildings or cities dispatched all over Europe will help reach this objective. These pilots represent different types of V2G applications where EV and renewable energy sources like photovoltaic panels (PV) are interacting.

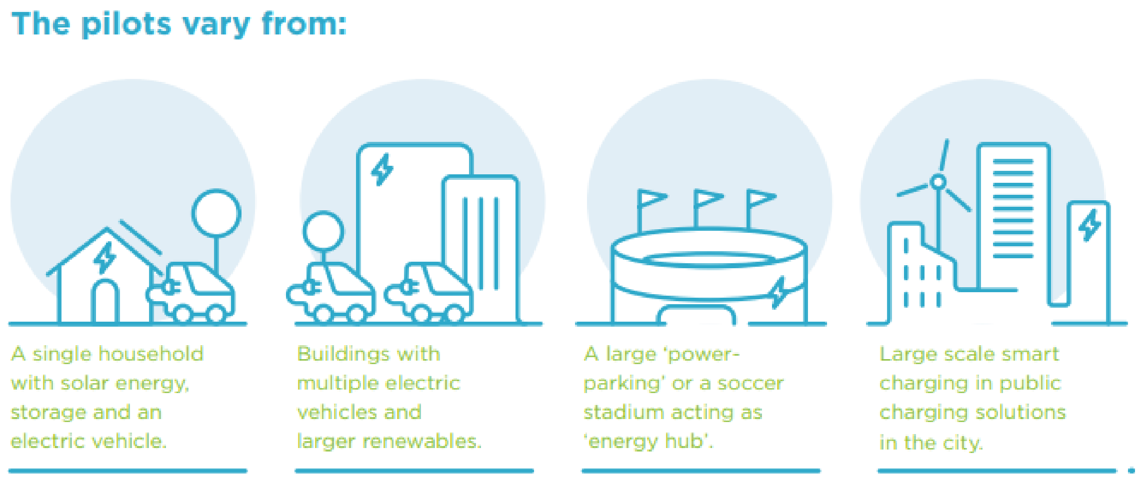


Figure 3: SEEV4-City: Smart, clean Energy and Electric vehicles 4 the city

Have different research subjects:

- Implementing renewable energy sources to charge EVs
- Storage of electricity in EVs
- Variation in EV charging connected to local energy sources
- V2G applications
- Balancing the grid (supply and demand mismatch)
- Energy market participation
- Provide back-up services

And also have specific key performance indicators:

- Increase energy autonomy in SEEV4-City OPs by 25% overall.
- Reduce greenhouse gas emissions by 150 Tons annually.
- Change to zero emission kilometres in the SEEV4-City Operational Pilots.

The gist of SEEV4-city can be summarized in one question:

"How to optimise EV charging costs, increase PV consumption, and reduce stress on the grid, while avoiding significant increase in the peak demand by implementing ICTs and V4energy services?"

4.1.3. Project organization

There are several "Partners" that work for SEEV4-CITY and that want to promote electromobility:

Figure 4: SEEV4-CITY partners

The project is organized into "package". Each package is composed of different partners that will work together on a certain aspect of SEEV4-CITY. For example, "Work package 4" (WP4) have to collect data and make them ready for WP3 and WP5 that works, respectively, on energy model and on business model aspect.

Moreover, each package has its specific Gantt chart with deliverables and key dates.

4.2. University presentation

4.2.1. Northumbria University in SEEV4-CITY

Northumbria University leads WP5 which works on costs and benefits model including:

- Market model
- Battery models
- Grid model
- Infrastructure model

WP5 provide various smart charging/V2G scenarios at different scales to WP3, who will then evaluate these scenarios for the OPs and feed information back for scenario adjustment and model improvement.

4.2.2. Northumbria University project team

Northumbria University is composed by 4 faculties: the faculty of arts, design and social sciences, the faculty of business and law, the faculty of health and life and the faculty of engineering and environment. It is in this last one that I'm doing my internship.

At Northumbria University, the project leader of SEEV4-CITY is Mr. PUTRUS Ghanim. He is responsible for calling the shots for the team.

The internal project team is composed by PhD Students, Professors and also research workers. Everybody has a different mission: some are studying, for example, the bidirectional chargers, others are studying battery degradation and some are studying cost analyses. All project team members have to share their results to the project leader and also to the other team members.

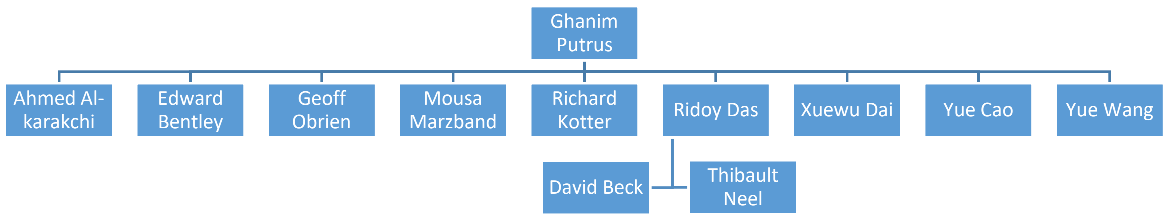


Figure 5 : Northumbria University SEEV4-CITY team members

4.3. Objective SMART and KPIs

4.3.1. Initial conditions

When I started my internship, I joined a European project that has already started. Northumbria University had already done generic business models for OPs and had collected feedbacks of these initial business models but still had to improve them.

My tutor gave me 2 weeks to find my mission subject within the project. After several meetings and researches, I decided to participate in cost analysis missions and more specifically in "cost analysis of V2G" where I decided to look at a national scale because Northumbria project team has already done cost analysis for different OPs but not at a national scale and because the data was more accessible at a national level than at a city scale.

4.3.2. Objective SMART

Therefore, before the 21/09/2018, I will show the cost benefits, at a national scale, of the use of V2G for balancing services like "wholesales market prices", "Short term operating reserve" (STOR) and "Firm frequency response" (FFR). I will add battery degradation and I will compare my results to smartcharging and dumpcharging price.

We can resume my mission in this problematic: "What's the electrical vehicle services that is the more profitable in term of money making?"

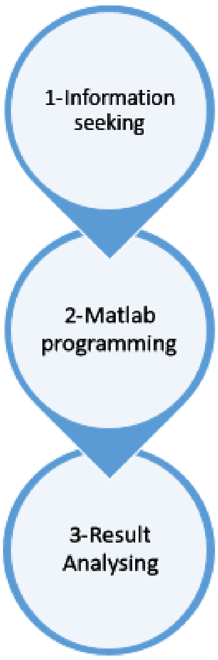
My work will help my colleagues promote V2G or see things from another point of view for the best way to use this solution and maybe it will help improve the business model.

4.3.3. Methodology and Excepted results

As it is shown by the Gantt chart below, I decided to separate my project mission in 4 mains areas:

Figure 6 : Methodology

This methodology will allow me to quantify my progression compared to the end results I hope to achieve. In fact, these areas take approximatively the same time to complete. That means, that each time I complete one of these, it will account for about 25% of the total objective.



Each area will be split up into 3 parts. The first being the search for data on which I could rely on, the second being the exploitation of these data sets and finally, the last part will be analysis of the results.

I chose to take more time to collect information about balancing services like STOR and FFR and for battery degradation because these mechanisms are not that easy to comprehend.

I have a 1 week margin of time that can provide compensation for any eventual setback that I may encounter whilst working.

Most of my calculations will be done via Matlab script and only a few will be realized on Excel. I will also use Matlab to read data stocked in my Excel.

At the end, I expect to get graphs that show how much V2G is profitable compared to smart charging and dump charging. I also want to quantify the money generated by FFR and STOR.

	04-Jun	11-Jun	18-Jun	25-Jun	02-Jul	09-Jul	16-Jul	23-Jul	30-Jul	06-Aug	13-Aug	20-Aug	27-Aug	03-Sep	10-Sep	17-Sep	21-Sep
1-State of art																	
1.1- To read project documentation																	
1.2-To read mission documentation																	
1.3-To Analyse existing Matlab code																	
2-Modeling																	
2.1- Finding general information																	
2.2- Coding + analysis																	
2.3- Dumpcharging information																	
2.4- Coding dump charging + analysis																	
2.5- Smartcharging information																	
2.6- Coding smart charging + analysis																	
2.7- V2G information																	
2.8- Coding V2G + analysis																	
2.9- FFR information																	
2.10- Coding FFR + analysis																	
2.11- STOR information																	
2.12- Coding STOR + analysis																	
2.13- Battery degradation information																	
2.14- Coding battery degradation + analysis																	
3-Project management																	
3.1-To write a master plan																	
3.2-To film my presentation video																	
3.3- To write my internship report																	
3.4-To create an application file																	

5. Technical assessment

5.1. Work description

5.1.1. Users behaviours and general information

Given that data changes depending on the scale, the geographical position, the number of EVs, etc. I had to create, first of all, my study case to set initial conditions to facilitate my research.

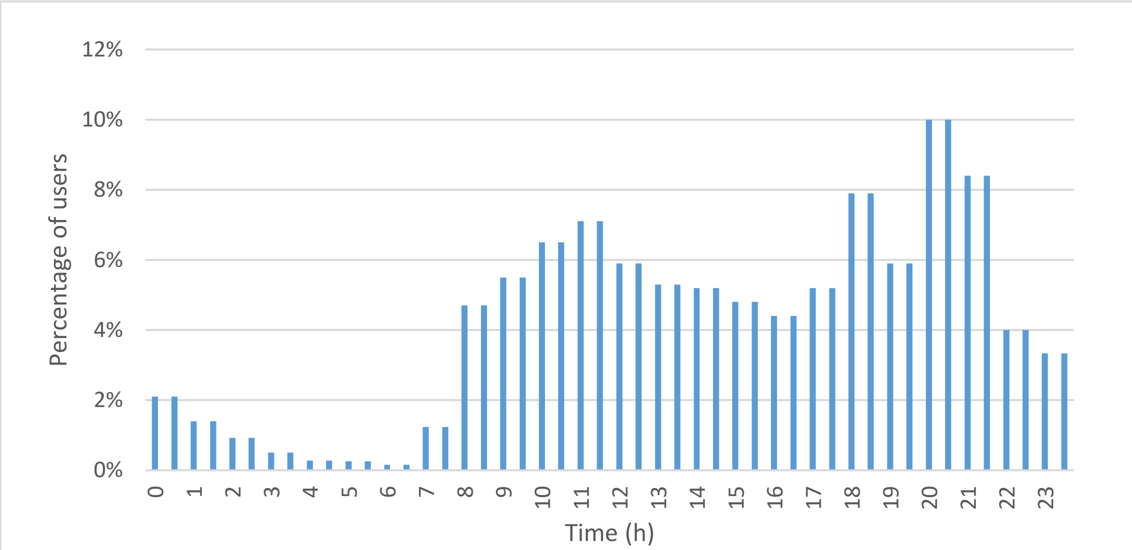


Figure 7: Percentage of users that start

In order to achieve my goal, my study case has to be based on real facts instead of suppositions. That is why I looked for charging behaviours because it will allow me to know the amount of energy used per day for EVs.

This first graph (figure 7) shows us that users charge their EVs throughout all the day and not only between 18h and 22h.

The graph below (figure 8) shows that there is a peak of users who charge their EVs with a SOC of 30%. We can also see that the average of EV users charge their cars with a SOC of 45.25%.

1: "European electric vehicle fleet: driving and charging behaviours" C. Corchero

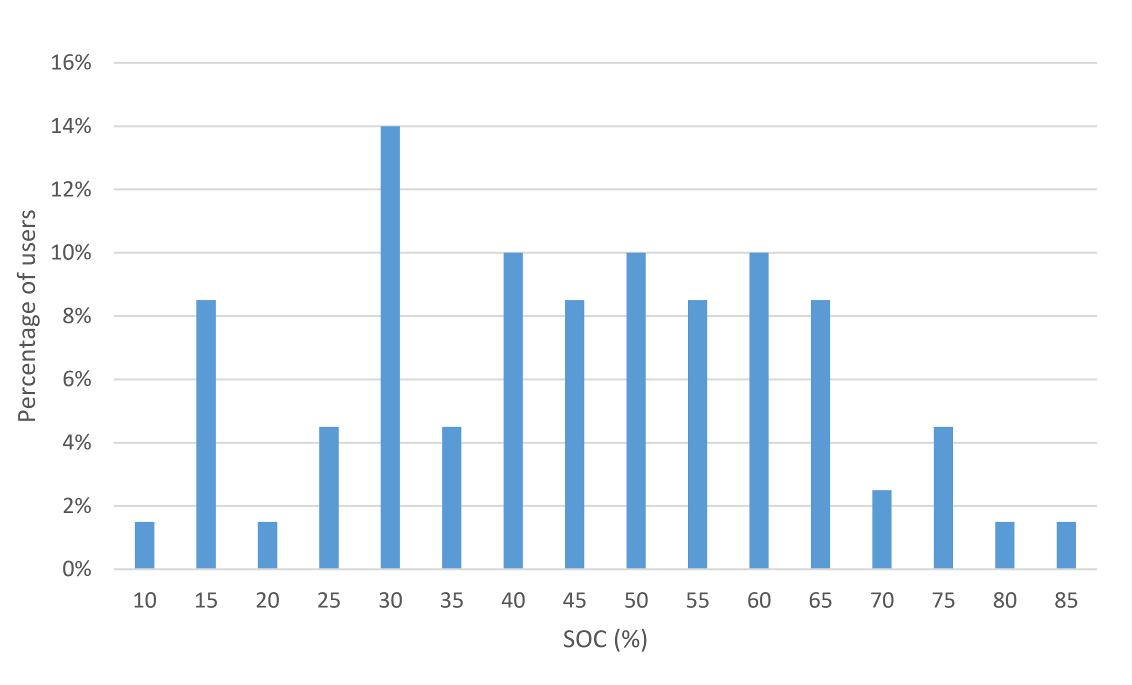


Figure 8: Percentage of users that start charging according their SOC [2]

At this point, I don't know how long it takes to charge an EV. In fact, the charging time depends of the battery of the car and also of the charging rate. This information is important because I will be able to calculate the energy consumed at each ½ hour by charging EV.

There are 133 670 EVs in the UK [3], with a bit less than a hundred different models. As I couldn't get the exact number of each model in UK, I decided to take the number of the 5 most sold EVs on the market, and I extrapolated it to the total number of EVs in UK to get the number of each model in my case study. For example, there are 21 600 Nissan leaf cars in UK. This value represents 26% of the sum of the number of my top 5 EVs. So in my model, there will be 0.26* 133 670 = 34 755 Nissan leaf.

EV Model	Number in UK	Battery capacity	Number in my model
Mitsubishi's Outlander PHEV	33 600	12 kWh	53 468
Nissan leaf	21 600	40 kWh	34 755
BMW 330e	10 000	7.6 kWh	16 041
BMW i3	9 500	33 kWh	14 703
Mercedes Benz C 350e	9 500	6.2 kWh	14 703

Table 1: Top 5 sold EVs in UK [4]

2: Understanding charging behaviour of electric vehicle users" Thomas Franke, Josef F. Krems
3: *Global EV outlook 2018 – IEA*
4: *DfT Vehicle Licensing Statistics*

There are also 17 879 charging points in UK [5] separated into 3 types of charging:

Charging types	Number in UK	Charging rate	Charging rate in my study case
Conventional plugs	2 963	3.7 kW	0.629 kW
Slow charging	11 221	3.7 kW to 22 kW	13.86 kW
Fast charging	3 695	22 kW to 43.5 kW	8.7 kW

Table 2 : The different charging types in UK [5]

The charging rate in my model has been calculated by multiplying the charging rate by the proportion of the different charging types. For example, there are 2 963 conventional plugs in UK with a charging rate of 3.7 kW. This value represent 17% of the total amount of charging point. The charging rate in my model for conventional plugs will be 3.7* 0.17 = 0.629 kW.

Moreover we can calculate the average charging rate which is equal to the sum of all charging rate in my model: average charging rate = 23.189 kW

I made an assumption that all EV users charge their cars to the max. That will help me quantify the time that the different types of EVs are plugged into the grid according to the charging rate, the SOC and also the battery capacity. I obtained tables for each charging type:

SOC	Time (h) to fill the battery with Conventional charging (3.7kW)				
	Nissan leaf	Mitsubishi Outlander PHEV	BMW330e	BMW i3	Mercedes Benz C 350e
10	10	3	2	8	2
15	9	3	2	8	1
20	9	3	2	7	1
25	8	2	2	7	1
30	8	2	1	6	1
35	7	2	1	6	1
40	6	2	1	5	1
45	6	2	1	5	1
50	5	2	1	4	1
55	5	1	1	4	1
60	4	1	1	4	1
65	4	1	1	3	1
70	3	1	1	3	1
75	3	1	1	2	0
80	2	1	0	2	0
85	2	0	0	1	0

Table 3: Charging time with slow charging depending of the SOC

5: ZAP-MAP – charging point statistics 2018

It is interesting to note that the energy consumed by EVs at any hours is equal to energy consumed by EVs that start charging at this hour plus energy consumed by EVs that have been charging.

The screenshot below represent Nissan Leaf's consumption throughout the day. Thanks to figure 4, 5 and table 1, I could get the number of Nissan leaf cars that start charging each ½ hour. From this value, I calculated the number of Nissan leaf that were charging with a certain SOC.

Finally thank to table 2 and 3, I calculated the energy consumed at each ½ hour by EV.

Let's take the example of a Nissan leaf cars that charge with conventional chargers. As show the table 3, it take between 2 and 10 hours to charge to the max the battery. So the energy consumed by Nissan leaf cars at 12h will be:

$$totNRJconsumed_{12h} = NRJconsumed_{12h} + totNRJconsumed_{before}$$

With

$$NRJconsumed_{12h} = average\ charging\ rate * number\ of\ Nissan\ Leaf\ that\ start\ charging$$

$$\begin{aligned} totNRJconsumed_{before} &= average\ charging\ rate\ conventional\ plugs \\ &* [sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 2h) \\ &+ sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 3h) + \cdots \\ &+ sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 9h30)] \\ &+ \ average\ charging\ rate\ slow\ charger \\ &* [sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 10h) \\ &+ sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 11h)] \\ &+ average\ charging\ rate\ fast\ charger \\ &* [sum\ (number\ of\ nissan\ leaf\ that\ start\ charging\ at\ 11h)] \end{aligned}$$

Hour

Number of Nissan Leaf that start charging

Number of Nissan Leaf that start charging with a certain SOC

Energy consumed by EV that starts charging at this hour

Energy consumed by EV at this hour

Day 2

	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12
	0.014	0.0092	0.0092	0.005	0.005	0.0028	0.0028	0.0026	0.0026	0.0016	0.0016	0.0123	0.0123	0.047	0.047	0.055	0.055	0.065	0.065	0.071	0.071	0.059
SOC	487	320	320	174	174	97	97	90	90	56	56	427	427	1633	1633	1911	1911	2259	2259	2468	2468	2050
10	7	5	5	3	3	1	1	1	1	1	1	6	6	25	25	29	29	34	34	37	37	31
15	41	27	27	15	15	8	8	8	8	5	5	36	36	139	139	162	162	192	192	210	210	174
20	7	5	5	3	3	1	1	1	1	1	1	6	6	25	25	29	29	34	34	37	37	31
25	22	14	14	8	8	4	4	4	4	3	3	19	19	74	74	86	86	102	102	111	111	92
30	68	45	45	24	24	14	14	13	13	8	8	60	60	229	229	268	268	316	316	345	345	287
35	22	14	14	8	8	4	4	4	4	3	3	19	19	74	74	86	86	102	102	111	111	92
40	49	32	32	17	17	10	10	9	9	6	6	43	43	163	163	191	191	226	226	247	247	205
45	41	27	27	15	15	8	8	8	8	5	5	36	36	139	139	162	162	192	192	210	210	174
50	49	32	32	17	17	10	10	9	9	6	6	43	43	163	163	191	191	226	226	247	247	205
55	41	27	27	15	15	8	8	8	8	5	5	36	36	139	139	162	162	192	192	210	210	174
60	49	32	32	17	17	10	10	9	9	6	6	43	43	163	163	191	191	226	226	247	247	205
65	41	27	27	15	15	8	8	8	8	5	5	36	36	139	139	162	162	192	192	210	210	174
70	12	8	8	4	4	2	2	2	2	1	1	11	11	41	41	48	48	56	56	62	62	51
75	22	14	14	8	8	4	4	4	4	3	3	19	19	74	74	86	86	102	102	111	111	92
80	7	5	5	3	3	1	1	1	1	1	1	6	6	25	25	29	29	34	34	37	37	31
85	7	5	5	3	3	1	1	1	1	1	1	6	6	25	25	29	29	34	34	37	37	31
	6	4	4	2	2	1	1	1	1	1	1	5	5	19	19	22	22	26	26	29	29	24
	18.54441	**15.54604**	**13.18778**	**10.92597**	**8.965445**	**7.02929**	**5.735162**	**4.472754577**	**3.913109**	**3.372265**	**2.768795**	**2.183278**	**5.329343**	**8.499633**	**19.64787**	**30.80427**	**34.57924**	**38.35591**	**42.22689322**	**46.08276**	**48.85671**	=(BY67*2-

5.1.2. Charging types analysis

5.1.2.1. Dump charging

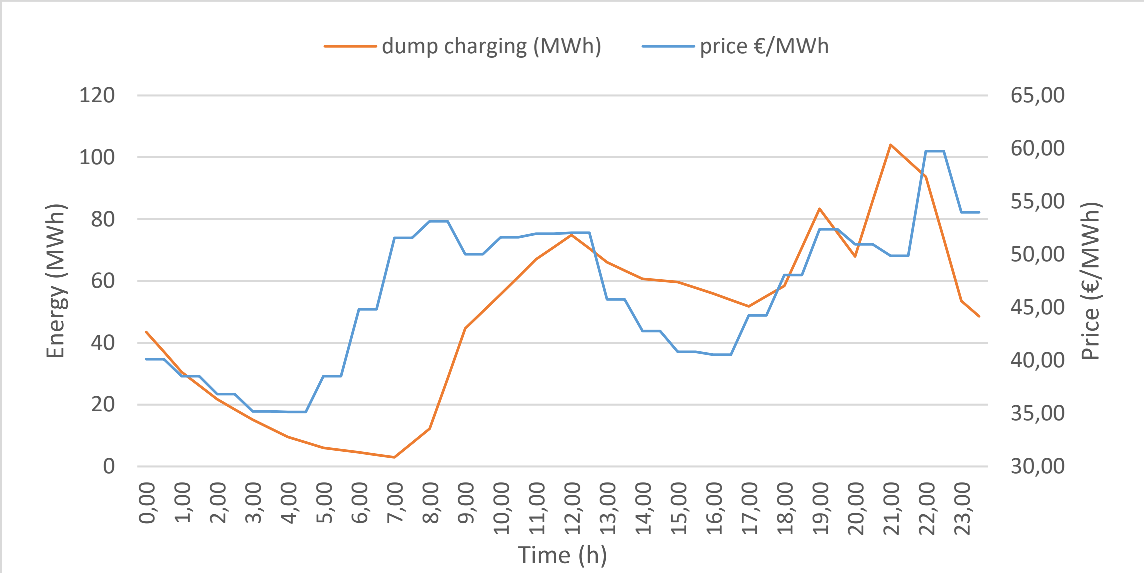


Figure 9: Dump charging consumption per day

Figure 9 shows us dump charging consumption in the UK (in orange). We can note that most of the EVs consumption is made when the price of electricity (in blue) is high. If we could charge EVs between 0h and 5h we would save lot of money. Figure 10 shows us that, at a national scale, dump charging (in blue) doesn't increase energy consumption significantly (in orange). But this behaviour may not happen at a local scale. We can also note that wholesales price (in yellow) doesn't depend of energy consumption [6].

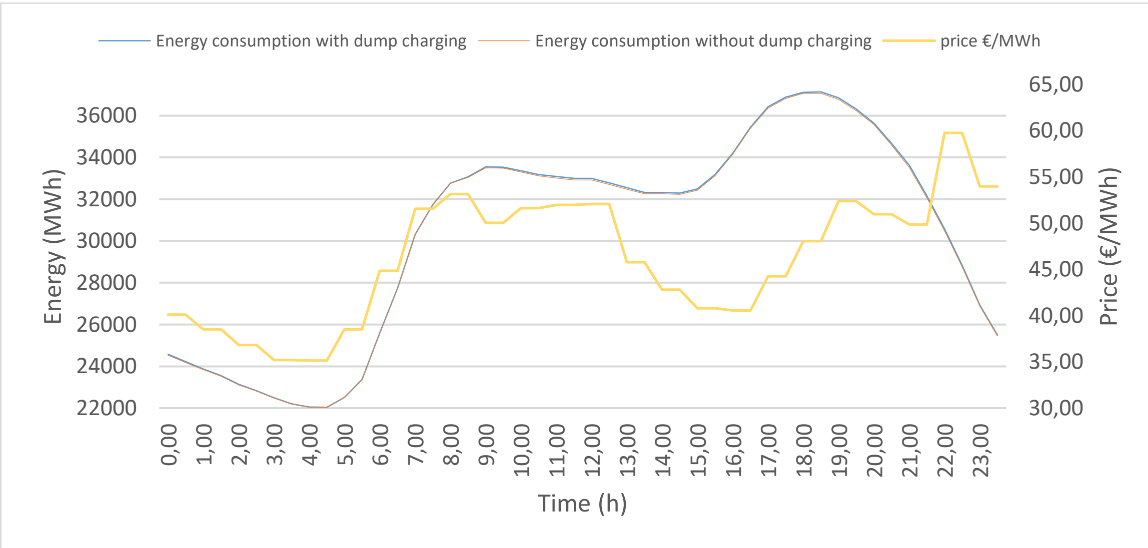


Figure 10: Energy generation in UK [7]

6: www.epexspot.com
7: http://www.gridwatch.templar.co.uk

5.1.2.2. Smart charging

```
%%%%%%%%%%%%%%%%%%%% Smart charging %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%minimizing the cost
obj1 = @(x)sum(DailyWholesalemarketprice.*x);    %x = energy flow (MWh)

UB1 = min(DailyMaxconsumption*ones(1,48),Capacitymax*ones(1,48));
LB1 = zeros(1,48);

Aeq = ones(1,48);
Beq = DailydumpchargingNRJ;
x0 = zeros(1,48);

Dailysmartcharging = fmincon(obj1,x0,[],[],Aeq,Beq,LB1,UB1);
Dailysmartchargingprice =
sum(Dailysmartcharging.*DailyWholesalemarketprice,2);
DailyEnergyconsumptionWSC = DailyEnergyconsumptionWOEV +
Dailysmartcharging;

Batteryevolution1 = [];
for i=1:length(Dailysmartcharging)-1
Batteryevolution1(1,1) = Startingcapacity;
Batteryevolution1(i+1,1) = Batteryevolution1(i,1)+
Dailysmartcharging(i);
i+1;
end
```

The code above is the code for smart charging, I decided to use optimization to minimize the cost of charging which is equal to "DailyWholesalemarketprice "*"smart charging consumption".

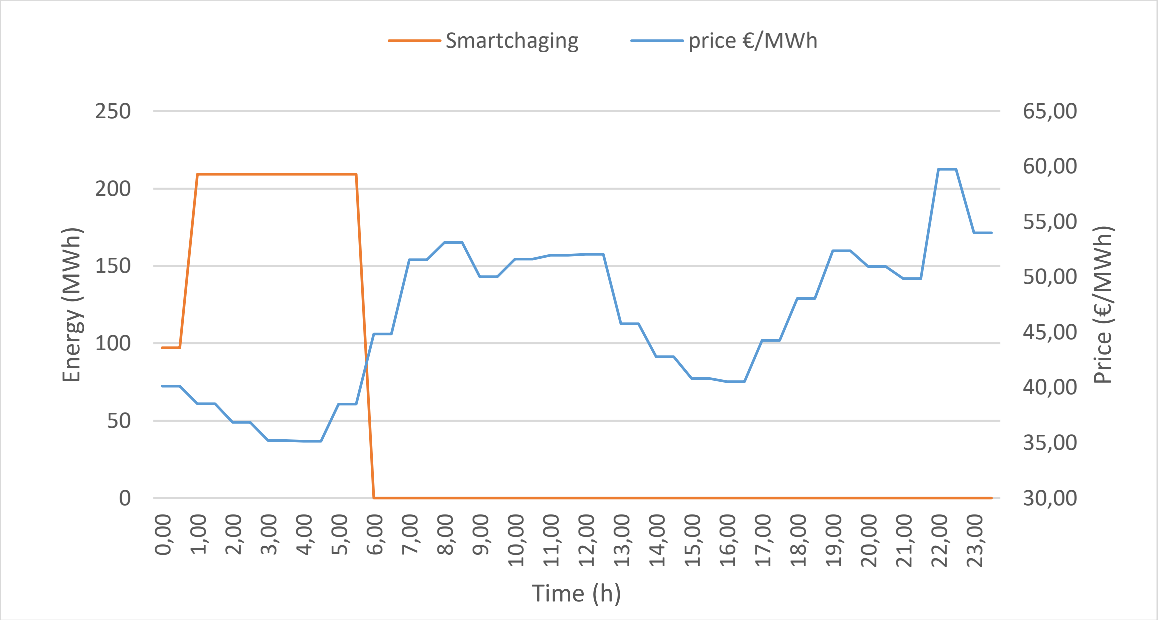


Figure 11 : Smartcharging consumption per day

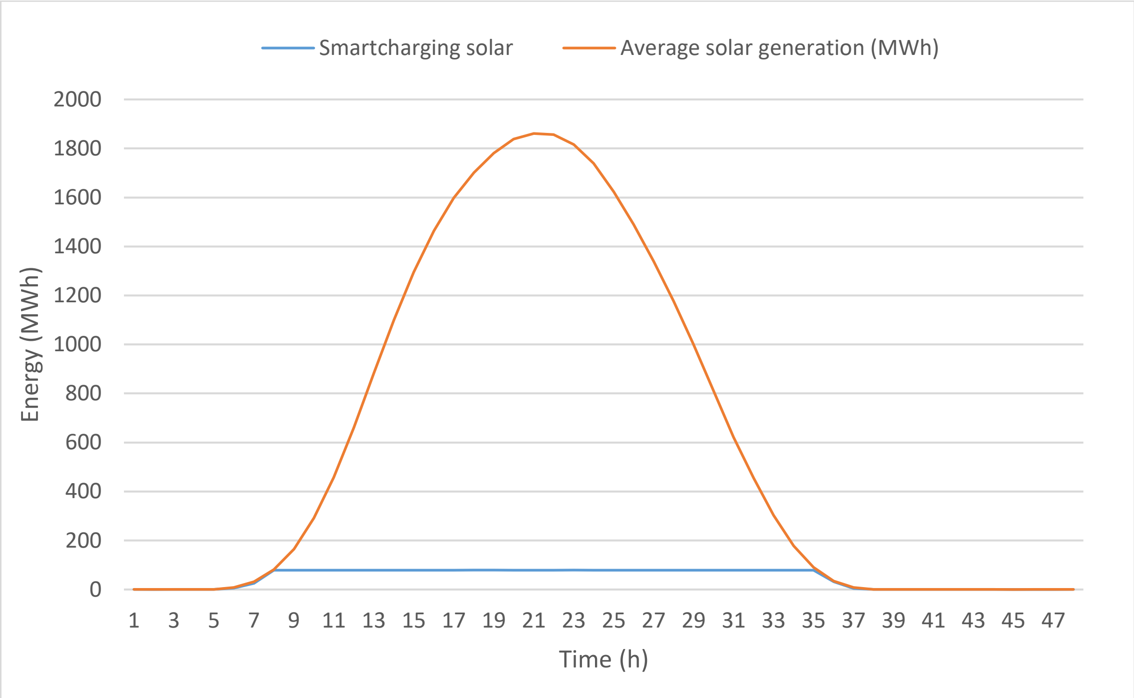


Figure 12 : Solar generation per day [8]

We can also use smart charging in order to maximize the use of solar generation, this method should be more useful at household scale where we want to charge EVs only with clean energy. We can see in figure 12 the average solar generation per day in the UK (in orange) and the smart charging consumption (in blue). We can also point out that UK provide enough solar energy per day to charges all EVs.

5.1.2.3. V2G

```
%%%%%%%%%%%%%%%% V2G %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%minimizing the cost
obj3 = @(x)sum(DailyWholesalemarketprice.*x);

Amax = tril(ones(48,48));
Amin = tril(-ones(48,48));
A = [0.5.*Amax;0.5.*Amin];
Bmax = -Startingcapacity + Capacitymax*ones(48,1);
Bmin = +Startingcapacity - Capacitymin*ones(48,1);
B = [Bmax;Bmin];

Aeq = 0.5.*[zeros(48,48);ones(1,48)];
Beq = zeros(49,1);
Beq(49,1) = DailydumpchargingNRJ;
x0 = zeros(1,48);

DailyV2G = fmincon(obj3,x0,A,B,Aeq,Beq,[],[])/2;
DailyV2Gprice = sum(DailyV2G.*DailyWholesalemarketprice,2);
```

8: the university of Sheffield-Solar generation

The code above is the code for V2G. There are several constraints that we must take into account.

- First the minimal capacity which represents the battery capacity that we don't want to go below. It is equal to a SOC of 10% plus the capacity needed to do an average travel in a day.
- The maximal capacity which represents the battery capacity that we can't exceed. Cars are parked 95% of the time, so I made the assumption that the max capacity was equal to 95% of the total capacity.
- The energy max provided by chargers: This constraint is here to avoid to charge all EVs in a short time period. It is equal to the sum of charging rates of all types of chargers.
- The daily energy that we have to provide: It is equal to the average energy consumption by EVs. This value is equal to the sum of dump charging consumption in the UK (figure 6).

Figure 13 : V2G consumption per day

As we can see figure 13, we are charging EVs when the price is low and discharging when the price is high. This should allow us to save lot of money (see figure 15).

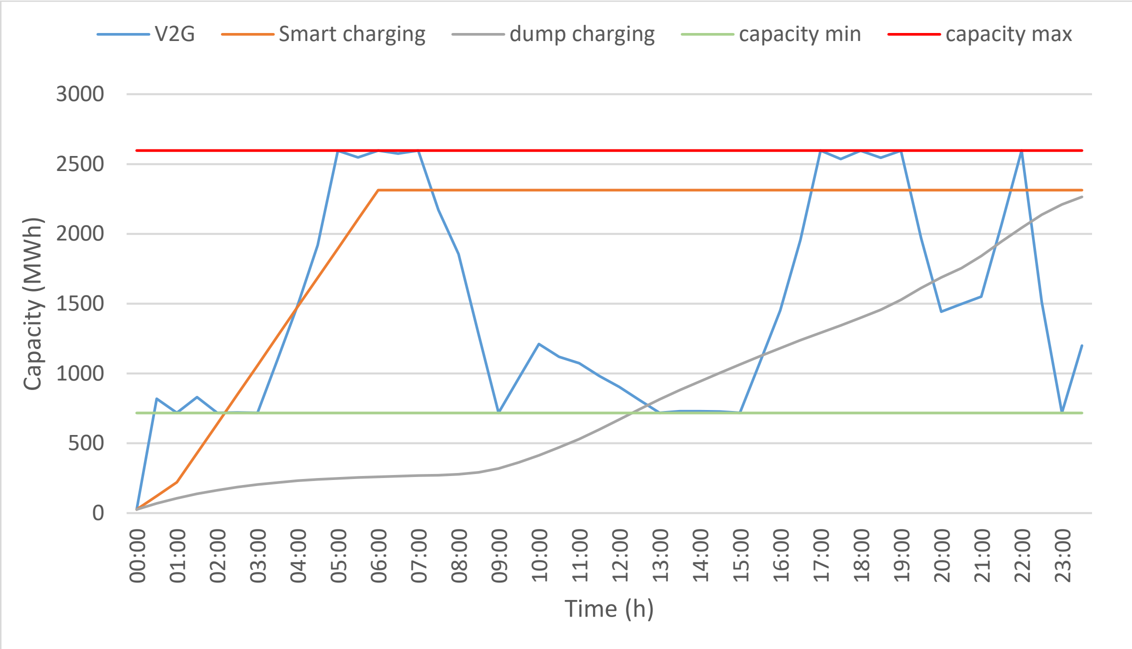


Figure 14: Evolution of the battery capacity with different charging method

Figure 14 shows us that we never exceed the capacity max and we never discharge more than the capacity min. We can also note that dump charging is not convenient in term of time because it takes around 12h to charge to the minimal capacity.

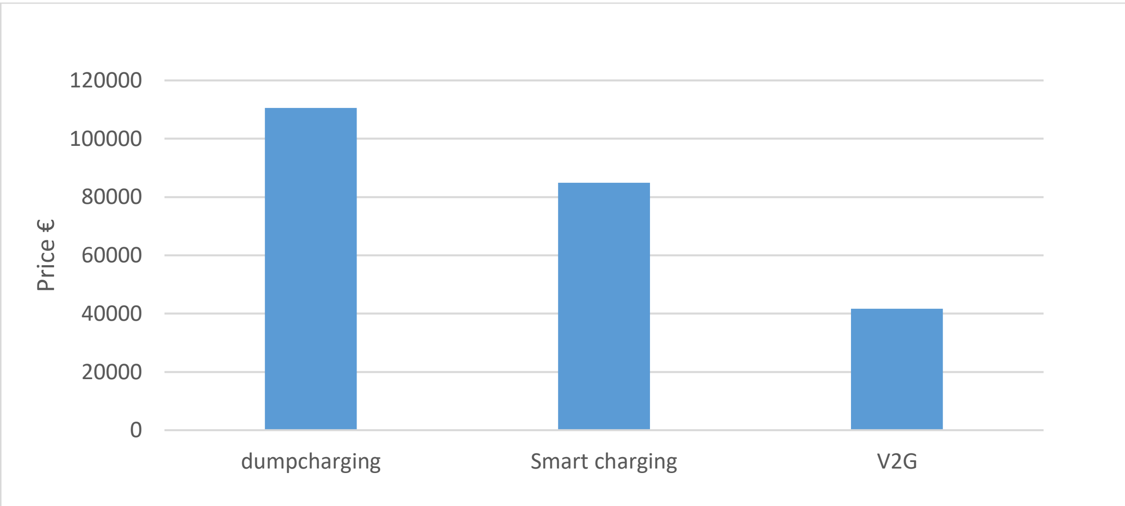


Figure 15: Cost of different charging methods per day in UK

As we can see in figure 15, V2G looks like the perfect charging method. For the same amount of energy used, it reduces charging price for about 62% compared to dumpcharging and 50% compared to smart charging.

5.1.3. Balancing services

5.1.3.1. STOR

Suppliers of balancing services are paid for availability and utilisation.

- Availability payment (€/MW/h): this payment is for being available to provide the service within a defined availability window.
- Utilisation payment (€/MW/h): This payment is for delivering the service for a contracted volume.

For STOR service, we assure that at any moment of the day, we can provide the contracted volume to the grid owner. In this case, we cannot discharge EVs under a certain value which is equal to the minimal capacity plus the contracted capacity. Contracted capacity is equal to the maximal value of the average STOR demand.

STOR input

- STOR availability payment = 4.25 €/MW/h
- STOR utilisation payment = 150, 54 €/MW/h
- Contracted capacity = 560 MW

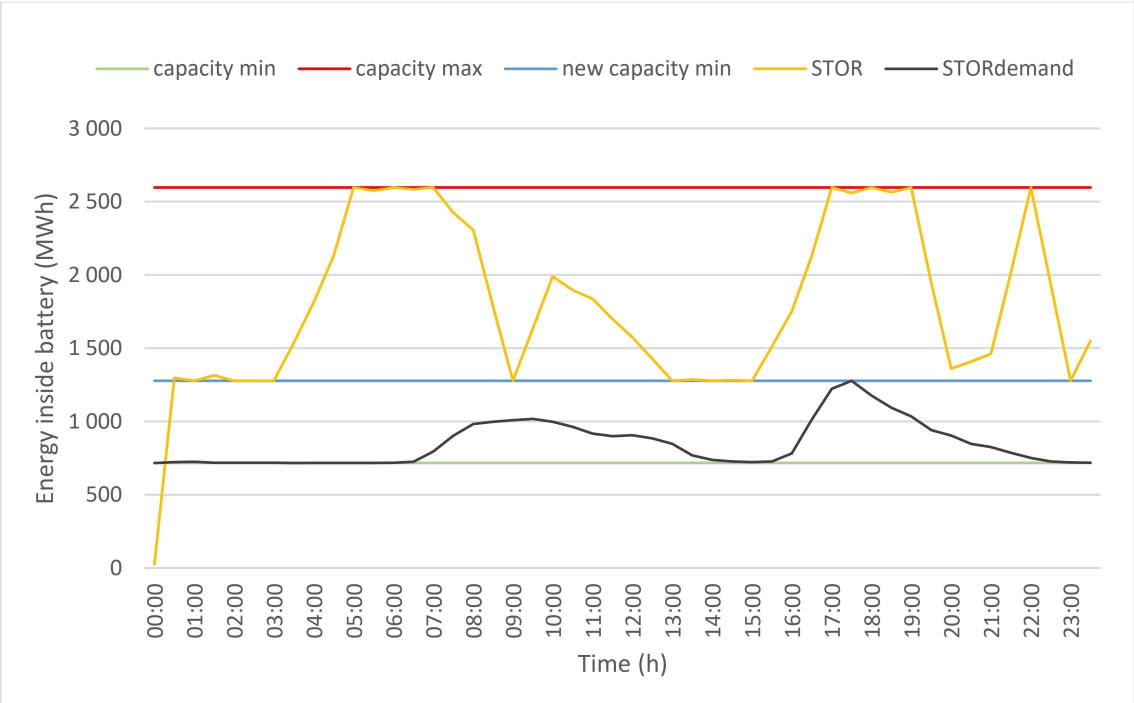


Figure 16: Evolution of the battery capacity with STOR [9]

9: STOR Annual Market Report 2016-2017 Data

5.1.3.2. FFR

For FFR service, we make sure that we can provide at any moment of the day a certain power depending of the frequency of the system.

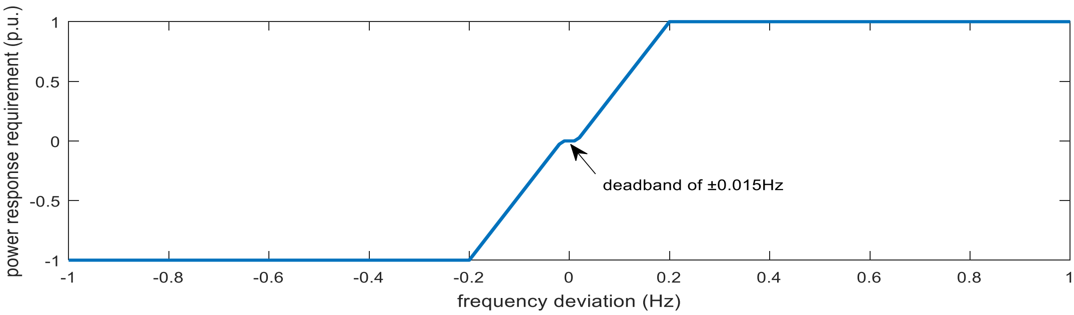


Figure 17: Power response depending of the frequency deviation

For example, when system frequency is equal to 49.80Hz, we have to provide a capacity equal to the power response multiplied by the capacity contracted. To compare, STOR and FFR we will take the same capacity contracted.

FFR input

- FFR availability payment = 26.25 €/MW/h
- FFR regulation up = capacity provided*1.25*wholesalesmarketprice
- FFR regulation down = capacity provided *0.75*wholesalesmarketprice
- Contracted capacity = 560 MW

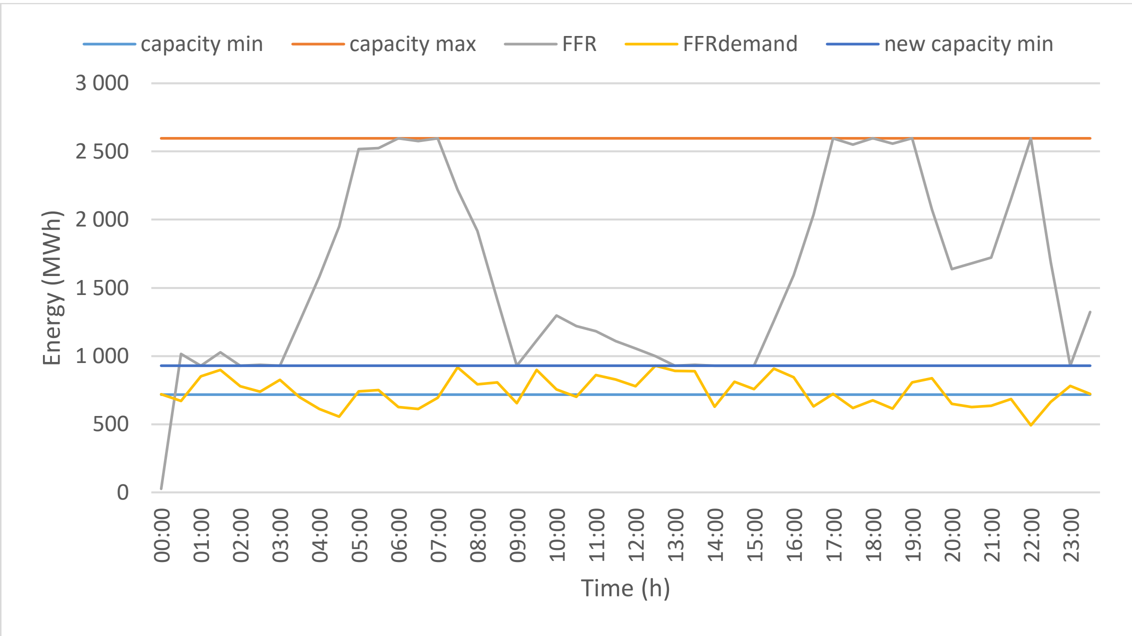


Figure 18: Evolution of the battery capacity with FFR [10]

10: https://www.gridwatch.templar.co.uk / Loughborough Pilot 18 July 2018 final report

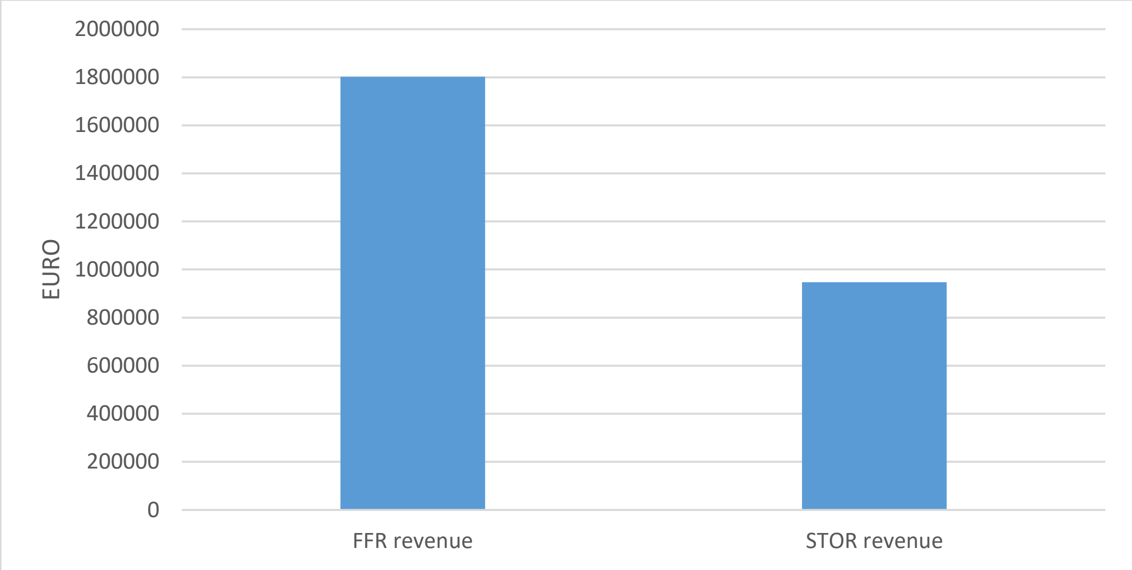


Figure 19: Revenue of different balancing service

FFR looks like to be the best balancing service in term of money making for the same capacity contracted. However, this result doesn't take into account the fact that national grid can reject or accept the offer from supplier.

5.2. Difficulties and final results

Throughout my internship, I encountered many difficulties: from understanding the different mechanisms of the grid to their programming, I had to regularly modify my work according to the remarks that were made to me. Indeed, I spent part of my time looking for information and formatting them to present them to my colleague and very often, he corrected me on my errors or on what I could add to my code

Finally, according to the KPIs that I have set early on, I think I've done 75% of my job because I still have to add battery degradation to my model. I couldn't accomplish my goal because I spent more time than expected trying to automate the energy used by EVs (figure 9) to finally do it with Excel (page 18). I spent also more time than expected coding V2G and STOR because I had never done any optimization under Matlab before. Morever, I was also stuck for a long time when I wanted to code the optimization program for FFR because I needed data that I couldn't access. Finally, I should have given myself a larger margin of time for eventual errors due to personal problems and I should have gotten ahead of the planned task rather than following my gantt chart to the letter.

I think it would be interesting in the future to add battery degradation to my model in order to see if V2G is still as cost effective as smart charging (because discharging and charging the battery continuously, degrades it faster). Moreover, it would be interesting to see whether the network would actually accept such contracted capacity set in my model. We could also look at the reduction of C02 emissions due to V2G, quantify it and see what it represents as a cost.

6. Experience assessment

I chose to take the topic "relationship at work" because I did my internship in a team where each member had the will to move the project in which they were involved forward: SEEV4-CITY. Having to respect a specific Gantt, it was necessary that the internal communication to the team was done in an easy way. Moreover, I did this internship with a colleague from EIGSI who did not have the same mission as me but who was also involved in SEEV4-City. He had to create a universal model to quantify battery degradation based on several parameters. I would have used that model to complete my mission.

Thus, throughout my internship, I was able to interact with different people who all had different nationalities but also different backgrounds and technical knowledge. So I didn't have the same relationship between my colleague EIGSI and my supervisor who was the team leader.

My internship went very well and I think it's probably due to the relationship between all the team members. I noted several points in favour of this good atmosphere :

1. Since we were all speaking in English, there was no distinction between calling somebody « tu » and « vous » as such, when I was addressed or addressed to a colleague I had the feeling that the barrier due to seniority or job position was reduced.

2. The work atmosphere was warm and friendly. I don't remember a single person being in a bad mood. This affects the perception that we have for a person but also the perception that we have of our work. We are more motivated to work with smiling people than sad people.
3. Everyone respected each other and remained courteous.
4. No one was left behind. Indeed me and my colleague from EIGSI, despite of our initial limited knowledge on the subject, we were still invited to each progress meeting in which we were asked our opinion on subjects which were still unknown to us. In addition, we regularly had to present our work to the other members of the team, who did not hesitate to give feedback but also to create debates around a few technical points. So, I didn't feel useless, and I knew that even if my work wasn't up to my expectations, it would allow my colleagues to have another look at some aspects of V2G.
5. Everyone trusted everyone else. No one was behind anyone else watching what he was doing. This increase the self-esteem of employee and also their creativity.
6. Finally, the university was not just a place where we talked only about work, but on the contrary, we regularly talked about things and others.

I think that these different points improve not only the relationship between work and the employee but also the relationship between all employees. However, we can provide a critical look at the points listed above.

1. First of all, in the majority of French companies, there will always be « tu » and « vous ».
2. In addition, not checking what employees do can affect productivity because employees may not perform their duties during their work hours.
3. Being invited to all meetings can be a waste of time in the way that some employees might not be concerned by the subject of the meeting.

7. Conclusion

This internship was a huge opportunity, very enriching for me because it allowed me to discover in detail the sector of the research, its actors, its constraints and it allowed me to take part concretely in an european project through my mission. Morever I could work on a key subject for the future of transportation on which many industrials are working too: bidirectional chargers.

This internship allowed me to understand that the research missions were not the most adapted to me and that's why, I prefer to orient my professional career towards the industry that suits me better. In fact, having one mission to do for 4 months discouraged me a bit when I was in the middle of the internship. I also need to work somewhere where interaction between all employees is more present. In the continuity of this internship, I would like to carry out my next professional experience on the other side of this project: on the side of renewable energy suppliers.

Finally, I would like to express my satisfaction in having worked in good conditions and a pleasant environment.

8. List of Figures

9. Bibliography

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