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Smart Charging in the Netherlands

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Abstract

As the Dutch electric vehicle (EV) fleet continues to expand, so will the amount of charging sessions and the overall amount of electricity required for charging these EVs increase. This expanding demand for energy will add on to the already existing strain on the grid, primarily during peak hours on workdays in the early morning and evening. This growing energy demand requires new methods to handle the charging of EVs, to distribute the available energy in the most effective way. Therefore, a large number of ‘smart charging’ initiatives have recently been developed, whereby the charging session of the EV is based on the conditions of the energy grid. However, the term smart charging is used for a variety of smart charging techniques, often involving different optimization strategies and charging processes. For most practitioners, as well as academics, it is hard to take stock of the large range of smart charging initiatives initiated in recent years, how they differentiate from each other and how they contribute to a smarter charging infrastructure. This paper has the objective to provide an overview of smart charging initiatives in the Netherlands which focus on smart charging at a household level (private or semi-public charging point) and develops a categorization of smart charging initiatives regarding objectives, proposed measures and intended contributions. Analysis shows that smart charging either comes in the form of load shifting or energy curtailment. Depending on the form of smart charging, different optimization strategies and functionalities are added.

Keywords: electric vehicle, smart charging, the Netherlands, grid congestion, charging infrastructure.

1. Introduction

The Netherlands currently ranks as one of the leading countries in the world regarding electric vehicle (EV) adoption [1]. With currently over 100.000 EVs nationwide, the Dutch government has the aim to double the EV fleet in size by 2020 and reach the milestone of one million EVs by 2025 [2]. The Netherlands hosts a relatively dense charging infrastructure, particularly in the four major urban areas (Amsterdam, The Hague, Rotterdam and Utrecht). Consumers are incentivized with tax benefits on private charging points and (semi-)electric cars and an increasing amount of fast charging stations have been deployed alongside Dutch highways.

The development of a dense charging infrastructure leads to new energy-related problems regarding the strain it puts on the grid. Charging profiles of EVs tend to coincide with energy profiles of households, leading to an increased strain on energy grids, which in turn might lead to (costly) grid capacity investments. The incorporation of EVs is expected to almost double the current average electricity demand per household [3]. Given that EVs that are connected to a charging point generally start charging right away, the evening peak in energy demands increases significantly, which can lead to harmful effects on the existing energy grid [4].

In order to tackle these charging problems, several charge point operators, energy retailers and other involved parties have launched so-called ‘smart charging’ initiatives. Smart charging initiatives have the aim to distribute the available power as efficiently as possible within the scope of the desired connection time, regardless of the setting of the charging infrastructure. Research has proven that smart charging in the

Netherlands is more cost-efficient with regard to the energy grid, opposed to traditional uncoordinated charging [5].

Yet consensus on the definition of smart charging appears to be lacking amongst the different smart charging initiatives. The conceptualization of smart charging as a service differs per initiative, often involving different processes and optimization strategies. Therefore, smart charging can entail a variety of charging strategies, depending on how smart charging is defined by the provider. Most smart charging initiatives are currently research projects and test pilots, signaling that this charging development has not been deployed on a larger (commercial) basis.

Since smart charging is used by a variety of charging initiatives in the Netherlands, the objective of this paper is to analyze the different smart charging strategies aimed at individual EV drivers, focusing on smart charging for EV owners who make use of private and semi-public charging infrastructure. This analysis is done by studying the different smart charging initiatives in the Netherlands in combination with a literature study, by looking at the respective aim and effects of the different initiatives and the different optimization strategies that are used. Note that smart charging is also used as a term to denote load balancing between multiple charging points, which becomes relevant in situations where an office building with a parking lot has multiple EV charging stations. In these situations load balancing optimizes the available energy between charging stations by dividing the available power over the different charging stations, depending on the amount of EVs charging. Those scenarios of smart charging are beyond the scope of this paper.

With this research this paper aims at providing a better overview of the vast number of initiatives regarding smart charging. As such it aims to inform practitioners and policy makers about running activities in this field. For scientists this paper provides a useful categorization which can help to monitor initiatives on smart charging over time as well as start cross-evaluating different smart charging initiatives.

This paper is organized as follows: first, the different characteristics of smart charging initiatives will be discussed. These characteristics can be divided into (i) the nature of intelligence (or ‘smartness’) applied, (ii) optimization strategies pursued, (iii) functionalities added, and (iv) main beneficiaries. Per category, several smart charging initiatives will be described as examples. Second, notable developments and differences will be highlighted. Last, conclusions are provided.

2. Characteristics of smart charging initiatives

If we were to capture the objective of smart charging as objectively as possible, smart charging can be seen as a charging strategy that takes the power grid condition and parameters into account, in order to avoid potential power grid congestions [6, 7]. EVs have the potential to be a flexible power demand source: some studies have calculated that PHEVs, for instance, are parked for more than 90% of the day [8]. If the EV is connected to a charging point for the approximate 22 hours of the day it is stationary, the charging of the EV can be flexible; there is no need for an EV to have a full battery an hour after connecting to a charging station if the EV then remains at the charging station for the consecutive seven hours. In other words: there is not always a need to start charging the EV right away, nor to start charging the EV with the highest amount of power (in kW) possible.

2.1. Smart aspects

This brings us to the smart aspect of smart charging. The ‘smart’ aspect is the primary variable of the smart charging strategy, since this functions as the tool to alter the energy demand of the EV. Smart charging strategies take two different approaches: energy curtailment or energy load shifting.

The first strategy (“energy curtailment”) alters the amount of energy directed to the EV, which means the EV will charge at a lower power rate, depending on general grid conditions, such as overall energy demand and local distribution capacity. This might mean that an EV charges considerable slower at a public charging point at times when energy demand is high or when multiple EVs are charging there as well. When the private charging point of an EV is connected to a household equipped with a smart meter and control devices, the energy flow to the EV charger can be adjusted based on the total energy consumption of the household. That means that an EV might charge slower if the dishwasher, washing machine and dryer are simultaneously running. An exemplary project in the Netherlands is *Flexpower*, a smart charging research project based on energy curtailment.[1] This means that pilot users who plug in their EV during peak hours (17:00 - 19:00) will receive less kWh than when charged outside of peak hours.

The second charging strategy ("load shifting") alters the starting time of the charging session to avoid peak-hour demands. This often means that the EV charging sessions will be postponed until after the peak hours, when the demand for energy gradually decreases. This strategy can be combined with an optimization strategy: postponing the charging session until midnight for instance, when the price of energy is cheaper due to the low demand. An example of a smart charging initiative that works with load shifting is *MRA-E Flexpakket*.[2] When EV drivers who are part of the MRA-E pilot connect their EV to a charging point and scan their charging card after 17:00, the charging of the EV will automatically be postponed until after 20:00. EV-drivers also paid less euro per kWh when charging outside peak hours.

Both strategies require certain information from the user. First and foremost, the system needs to take the user preferences into account, such as the user's departure time and the desired battery state of charge (SoC) at the moment of departure [9]. Users are often able to set these preference by using a graphical user interface (GUI). GUIs exist in the form of a smartphone applications or a smart meter monitors. Consequently, both strategies also require information from the charging system, such as the maximum charging rate, the initial battery percentage and the amount of energy required to complete charging [9].

2.2. *Optimization strategies*

A second way to categorize and differentiate smart charging initiatives is by looking at their optimization strategies, or in other words: with which objective in mind is the intelligence in charging applied? Both energy curtailment and load shifting can be used to optimize on different goals, for instance reducing grid impact, maximizing costs through trading on the energy markets or increasing the share of renewable energy charged.

The first optimization strategy of smart charging is grid impact reduction. These smart charging strategies aim at minimal impact on the grid, preventing (costly) grid investments. This can be done by utilizing both 'smart' aspects, but requires that smart charging initiative to have alleviation of the grid as a primary goal.

Second, smart charging could be deployed as a charging strategy that reduces the cost of charging an EV for an individual user by making use of fluctuations in the price or production of power on the energy market, such as Day Ahead Markets (DAM) or Energy Imbalance Markets (EIM). Prices of power tend to fluctuate, based on availability and demand. During the nighttime, when the demand of power is low, power tends to be cheaper. When energy retailers or charge point operators are able to make use of these varying energy prices by trading on the energy market and are able to control the charging sessions of an EV fleet, they can start the charging session of the EV fleet at night, when the price of energy is low due to the abundance of energy generated and the low demand [7]. If they share this profit with the EV user, this means that the EV user pays a lower price per kWh when smart charging compared to normal charging.

The third optimization strategy aims at the incorporation of sustainable energy while decreasing the reliance on fossil fuel based energy. EVs might be charged during times when large supply of renewable energy is available. Imbalance markets are able to forecast the generation of renewable energy from different sources [10]. This renewable energy can be supplied by the grid so that EV drivers can make use of it through the public charging infrastructure. Alternatively, the production and consumption of renewable energy can also happen in a decentralized way through photovoltaics (PV) on an EV driver's house. This means that the EV driver can directly make use of his own generated renewable energy by charging his car with it, assuming that the driver owns a private charging point.

A good example of a smart charging initiative that combines both the optimization of cost reduction and renewable energy is *#ichargesmart* by Jedlix.[3] By making use of flexible time regimes, the smart

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[1] https://www.elaad.nl/flexpower/

[2] https://www.greenflux.nl/laadnetwerk/pilot:-mra-e-flex-pakket

[3] https://jedlix.com/

charging system selects charging moments when the price of energy is at its lowest. The financial benefit that is gained by making use of this low price of energy is then (partly) shared with the EV driver, who receives a small sum of money, which he is able to track in the smartphone application. Additionally, if (a surplus) of renewable energy is available during these charging moments, the EV will also be charged with as much renewable energy as possible.

2.3. *Functionalities*

Several smart charging initiatives have developed additional features in order to enhance their smart charging strategies, which also distinguishing them from other smart charging initiatives.

The first category is that of community engagement. Community engagement refers to the engagement amongst users using the same platform. This feature allows users to communicate with each other based on a shared need. Think for instance of inhabitants of the same street communicating via a smartphone application to discuss when who would like to make use of the street's only public charging spot, as is done in the *Social Charging* smartphone application.[4]

The second enhancement to smart charging is that of a Vehicle-to-Grid (V2G) connection. A bidirectional V2G connection allows the battery of the EV to act as a storage unit, functioning as a regular EV battery in terms of smart charging, but also allowing the user to discharge the battery to supply the household or grid with its energy. A V2G connection thus not only optimizes the energy flow from the grid to the EV based on the condition of the grid, but also optimizes the energy flow from the EV back to the grid based on the grid's conditions [11]. This allows for a scenario where the battery of the EV can be charged throughout the day, for instance by the photovoltaics (PV) owned by the household, to then supply (renewable) power back to the household when the energy demand is high. A V2G connection therefore allows for a more flexible use of energy by enabling the supply of energy back to the grid as well. When applied to EV-fleets, this type of bidirectional control allows the EV-fleet to be controlled as a single power source [12]. This means that discharging an EV-fleet during peak hours can lower the peak energy demand [13]. Since studies have found that PHEVs are sometimes stationary for more than 90% of the day, EVs with a V2G connection do not only make a flexible demand source, but also a flexible supply source [8].

A good example of a smart charging initiative that combines both user engagement and V2G connections within the smart charging initiative is *Smart Solar Charging (LomboXnet)*.[5] Smart Solar Charging is a local smart charging initiative that takes place in the neighborhood of Lombok in Utrecht. Several of the neighborhood buildings have solar panels on their rooftops which are connected to the neighborhood's public charging stations. The EVs are thus not only charged with renewable energy but this energy is also generated by different neighbors. Additionally, these EVs can discharge their batteries with the locally generated renewable energy during peak moments to balance grid.

A third functionality is the incorporation of smart meters. Some smart charging initiatives connect the smart charging sessions of EVs with the use of household smart meters. A smart meter allows users to monitor their household energy usage in combination with their EV, if they have a private charging station. The smart meter can, if a bidirectional power flow is possible, monitor the energy flow from the EV to the household [14]. The added benefit of a smart meter is that, in combination with a communication infrastructure and control devices, the smart meter can real-time monitor the household energy consumption and, based on this data, adjust the total energy demand of the household [15]. The control devices allow certain appliances to adjust their energy demand. In this scenario, the EV can be seen as a subset of the household appliances, albeit one that draws a considerable amount of power. In this scenario, the smart meter can throttle the power supply to the EV battery by adjusting the amount of kWh used for charging.

A prime example of a smart meter that can control the private charging point is *Maxem*.[6] Maxem measures the total energy demand of the household, including the charging point. Based on the total energy consumption, Maxem will adjust the power flow to the charging point. Additionally, Maxem also aims at

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[4] www.social-charging.com

[5] http://www.lomboxnet.nl/smart-solar-charging

[6] https://maxem.io/nl/

optimally using the household’s own renewable energy by reducing the energy drawn from the grid when renewable energy is generated.

2.4. Beneficiaries

Lastly, smart charging initiatives tend to differ in the extent to which the optimization is aimed at different stakeholders or beneficiaries. Beneficiaries tend to range from EV drivers, municipalities, charge point operators (CPOs) to distribution system operators (DSO).

The adoption of smart charging to a large public requires careful examination of the daily routine and individual preferences of EV drivers [16]. A study by Will and Schuler has shown that early electric vehicle adopters in Germany are motivated to accept and adopt smart charging if this means that they contribute to grid stability and the integration of renewable energy sources [17]. Smart charging initiatives can choose to give the driver active control over the smart charging, meaning the driver has to give consent for smart charging at every charging instance, or smart charging can be done without the owner in the control loop [18]. In the first case, smart charging is thus enabled based on the feedback from the user, which might be lacking at certain instances. Therefore the consumer can be incentivized to use smart charging, primarily by making use of a financial incentive in which the user receives cost-reduction, even if this reduction is minimal. For instance, in the case of *Logical Allocation with smart charging* by network operator Enexis, the EV will charge after midnight, resulting in a cost reduction of €0,02 per kWh for the EV drivers [19]. Therefore, the consumer is categorized as a beneficiary of smart charging if they receive a financial benefit or if the smart charging strategy incorporates the usage of decentralized generated renewable energy, such as solar energy from a user’s own solar panels. Additionally, the consumer is also a beneficiary of the charging strategy if the EV is charged at a faster speed than usual.

Parties such as energy retailers or distribution system operators can benefit from the flattened demand curve as a result of smart charging. By making use of load shifting, the Dutch EV fleet can charge during off-peak hours, stabilizing the grid and preventing (or limiting) costly investments into the expansion of the energy grid, making the Distribution System Operator (DSO) the main beneficiary in this scenario.

Subsequently, the municipality is a direct beneficiary of smart charging if the local urban electricity grid of the municipality does not require reinforcement. This is enhanced by examining the local energy demand (and supply, where applicable) and schedule the charging of the EVs accordingly. In this scenario, municipalities might see a local energy demand profile which might vary from other municipalities, depending on the presence of business parks or industrial areas for instance.

A last form of beneficiary is the entity, such as an e-mobility service provider or charge point operator, that is able to aggregate the energy demand from different EV charging sessions. These parties are also called ‘aggregators’. In this context, the role of an aggregator is to group up different EV drivers into a single unit, which is then used on energy markets [20]. Aggregators are beneficiaries in smart charging strategies if they are able to shift the energy demand from the charging sessions to a timeslot where overall energy demand is low and energy availability is high. In such a scenario, an aggregator is able to buy energy at a low cost on the energy market and sell this to the consumer at a slightly higher cost, but still at a lower cost than the tariff the consumer would usually pay. The aggregator benefits from the price difference.

3. Notable developments

If we look at *table 1*, several developments and differences between smart charging initiatives stand out.

First of all, few smart charging initiatives focus on smart charging as a commercial service for EV users. Currently, *Jedlix* (#IChargeSmart) and *Cohere* (Maxem) are reaching out to a consumer base. Most other projects listed in *table 1* are research projects to test the technical benefits of smart charging in different regions or to explore financial incentives. These initiatives might be developed into commercial smart charging projects after the initial research phase.

A second interesting development is the (lack of) smart charging initiatives that develop a form of user engagement amongst users. Since EV drivers who reside in high-density urban areas often lack a private charging point, a public charging point is often shared amongst multiple EV owners, usually neighbors. Smart charging often requires an EV to be connected to the charging station longer than the time necessary for the charging session. This means that clear communication between the users of the public charging points might prove beneficial in order to optimize the charging point occupation. Especially projects such as *Smart Solar Charging*, where local renewable energy production and distribution to the public charging infrastructure is a central feature, community engagement plays a significant role. In the foreseeable future, local urban projects such as these might appear elsewhere, applying smart charging on a local level.

A third interesting development is the increasing attention for V2G connections, especially in literature. A V2G connection can be seen as an addition to smart charging strategies: the EV will not only be charged within a flexible time regime, but also discharged within a flexible time regime. As with smart charging, V2G connections are not yet widely available to consumers. Additional research can be undertaken to look into V2G alternatives such as V2Business, V2Vehicle and V2Community.

The last notable development is the growing attention for the incorporation of renewable energy into the charging strategy of EVs. Whether locally generated or not, renewable energy is volatile. If smart charging allows an EV to charge when a steady supply of renewable is available, renewable energy can be optimally used.

Not listed in *table 1*, but also a notable development, is the location of the intelligence that allows for smart charging. Both forms of smart charging require a certain intelligence capable of either adjusting the amount of energy directed to the EV or shifting the energy load to a different time. This intelligence is mostly being built into charging stations, requiring software to be installed in ‘regular’ charging stations to support smart charging. Depending on the features offered by the smart charging initiative, additional intelligence might be found in other devices, such as ‘smart’ households meters (with control devices), smartphone applications or the EV itself. Certain EVs already allow the user to postpone the charging session through settings the user is able to adjust in the display of the car or the car’s app.

4. Conclusions

The increasing strain on the Dutch energy grid due to the increasing energy demand from EV charging will ultimately require a smart solution. Smart charging appears to be a promising solution to this expansion but is currently still in a development phase. Although a sizable amount of smart charging initiatives have been launched in the Netherlands lately, the bulk is aimed at research and has not yet reached the stage of commercial roll-out. Nevertheless, these research projects have shown potential and differentiate themselves from each other by their optimization strategies and functionalities. With a growing interest from the Dutch government and regional municipalities, smart charging might have the potential to become the new default charging strategy in the nearby future to assure a stable Dutch energy grid.

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Smart Charging Initiatives in the Netherlands		*Commercial services*		*Infrastructural projects*	*Research projects*[7]							
		#IChargeSmart	**Maxem Smart Charging**	**Smart Solar Charging (LomboXnet)**	**MRA-E Flex Pakket**	**Flexpower**	**Logical Allocation with smart charging**	**Flexible charging rates Noord-Brabant**	**Smart Grid in Balans**	**Enexis huis**	**Me^2**	**Amsterdam flexible charging**
Smart Aspect[8]	**Time**	X		X	X	+		X	X	X	X	+
	Power		X			X	X					X
Optimization	**Grid impact**			X	X	X		X	X	X	X	X
	Energy market	X			X	X	X	X	X	X	X	X
	Renewables	X	X	X		X			X	X		X
Functionalities	**Community engagement**			X							X	
	V2G			X								
	Household smart meters		X							X	X	
Beneficiaries	**Consumer**	X	X	X	X		X	X		X	X	X
	Distribution System Operator			X	X	X		X	X	X	X	X
	Municipality			X	X	X		X	X	X	X	X
	Aggregator[9]	X		X	?	?	X	?			X	?

Table 1: an overview of smart charging initiatives and the different characteristics

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[7] Research projects are pilots designed as a test case or used otherwise to acquire new insights and data into the effects of smart charging for the consumer, involved parties and the grid. Note that some research projects listed above may already have been completed.

[8] Note that *Flexpower* and *Amsterdam Flexible Charging* focus on both smart aspects. Although the charging strategy primarily focuses on the charging speed of the EV (power), the charging speed is adjusted based on the overall energy demand during and peak-hours (time). The '+' indicates that this is the secondary smart aspect.

[9] A '?' indicates that, based on the description of the smart charging initiative, an aggregator is most likely present in the project but cannot be confirmed.

Project:	Partners:	Service offered based on 'smart charging':
#IChargeSmart	Jedlix (Eneco)	The EV will be charged at a certain time, based on the daily feed from the imbalance market. Goal to have a certain amount of renewable energy in the mix.
Maxem Smart Charging	Cohere	Maxem utilizes 'load balancing' between the EV and the energy consumed (and produced) by the household.
Smart Solar Charging	Lomboxnet, General Electric, Schuuring, Nissan, Stedin, LomboXnet, LastMileSolutions, Upp Energy, NewSolar, EBU and Gemeente Utrecht	The EV will mainly be charged when solar power that is generated by the solar panels from the neighborhood is available. Additionally, the EVs can function as batteries by storing power (from photovoltaics) and delivering this power back to the grid when needed.
MRA-E Flexpakket	MRA-Electrisch and Greenflux	The EV will automatically start charging after 20.00 when connected to a charger during the peak hours (17:00 – 20:00). Additionally, users pay less per kWh when charging outside peak hours.
Flexpower	ElaadNL, TU Eindhoven, The New Motion, Liander, Greenflux, Delta and EV-Net	The EV will be charged faster if charged outside of peak hours and will be charged slower when charging during peak hours. The last part of the pilot aims at the incorporation of renewable energy and low energy tariffs.
Logical Allocation with smart charging (*Logische Allocatie met smart charging*)	Enexis	Allows for the role of a service provider as aggregator, meaning that it can sign contracts with multiple energy suppliers so that consumers can choose between these suppliers. Charging is always postponed until after midnight.
Flexible charging rates Noord Brabant (*Flexibele Laadtarieven Noord Brabant*)	Enexis, Driivz, ElaadNL, Greenflux, The New Motion and 36 municipalities	The EV will be charged outside of peak hours, to make use of the low price of energy.
Smart Grid in Balans	Greenflux, Enexis, Renault, ICT.eu, Sycada.Green, ICU Charging Equipment, Wageningen UR, Antae group and Accenture	The EV will be charged based on the availability of (local) renewable energy. Matches energy supply and energy demand. The app gives an estimation in costs.
Enexis huis	Enexis	The EV charger is connected to the household smart grid, utilizing smart charging to adjust the energy flow based on the demand and production. Costs and (self-produced) renewable energy are taken into account as well.
me^2	Amsterdam University of Applied Sciences, Universidade Católica Portuguesa, LISBOA E-NOVA, MediaPrimer, MOOSMOAR and VPS Virtual Power Solutions.	The EV will be charged when both the energy demand and the price of energy is low.
Amsterdam flexible charging	Municipality of Amsterdam, Nuon, Liander and ElaadNL	EVs are charged faster when energy demand is low. Aims at using as much locally produced renewable energy as possible while also taking the varying energy tariffs into account.

Table 2: an overview of the partners involved per smart charging initiative and the definition of the smart charging offered

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