The Role of Soft Laws for Electric Vehicle Grid Integration in South Africa

This document outlines the use of soft laws as a response to manage EV uptake and charging patterns, given the context of non-compliance to hard laws in managing rooftop solar uptake.

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Acronyms and abbreviations

EV	Electric vehicle
NMD	Notified Maximum Demand
PV	Photo-voltaic
SSEG	Small-Scale Embedded Generation

Document overview

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This document aims to provide insight into strategies for managing the impact of increased EV penetration on the distribution grid and municipal revenue that speak to the local context. It outlines the parallels of regulating residential rooftop solar and EV uptake, and the role of soft laws in regulating the charging patterns of EV owners, as opposed to hard laws.

This work draws from research undertaken by Josh Dippenaar as part of his PhD thesis.

Executive summary

Electric vehicles are essential in decarbonizing the transport sector globally and sales of EVs are predicted to increase exponentially in the next decade. Distribution companies need to closely manage this rapid uptake of EVs in order to protect grid infrastructure and ensure that the EV transition is just.

Smart charging of EVs can significantly reduce power system costs and align charging load with variable renewables. Aggregated EV charging has the potential to change the way that the grid operates. However, because it is likely that a large portion of EV charging will take place at home significant uptake is likely to violate operational limits

Load and revenue growth will be accompanied by increased power system costs. Costs can be significantly reduced through managed charging. The costs associated with disproportionate EV charging at peak times would include Infrastructure upgrades, grid reinforcement and power losses. These costs will be passed onto consumers through higher electricity prices. High EV penetration will also result in a decline in revenue from fuel levies charged through fuel sales and energy rates may need to be adjusted to recover the amount lost from the fuel levy.

Hosting capacity studies enable network planners to avoid going beyond operational constraints, however, these studies are often difficult to perform and are based on various uncertainties. Different methods have been used to evaluate hosting capacities. Three of the

main types of EV hosting capacity measurements are 1. Static hosting capacity; 2. Dynamic hosting capacity; 3. Active hosting capacity.

There are many similarities between the grid integration of SSEG and EV charging. Over the past few years there has been rapid growth in the number of rooftop solar systems in South Africa. In general, South African municipalities have used static hosting capacity studies to determine the amount of SSEG that can be installed and attempt to regulate through SSEG registration. Although this simplified measure used to determine the grid's hosting capacity has allowed distribution utilities to safely connect hundreds of megawatts of SSEG it is ultimately restrictive and leads to conservative estimates of the actual SSEG hosting capacity of the grid. Required SSEG registration in South Africa is a regulatory strategy that has also faced many challenges as the majority of SSEG systems remain unregistered and unregulated.

Hard laws are regulatory mechanisms that are formally enacted which generally impose binding limits and penalties for non-compliance and require various lengthy formal procedures to set in place. In the face of rapid technological innovation and fast paced transitions hard laws often struggle to keep up. Soft-laws refer to a range of quasi-legal instruments that can be implemented relatively quickly and lack the binding and direct impact of hard laws. Soft-laws allow for more flexibility and are an important regulatory tool to use in combination with hard-laws to manage relatively fast paced transitions.

Some examples of soft laws used to manage the grid integration of EVs are time-varying electricity tariffs, smart charging incentives and regulation of chargers, incentives to create charging synergies with renewables, as well as communication and stakeholder engagements.

1. Introduction

Electric vehicles (EVs) are essential for decarbonizing the transportation industry to achieve a future with net zero carbon emissions. As a result, EVs are receiving a lot of regulatory support globally, which caused a substantive increase in EV sales during the 2010s, increasing from 120,000 in 2012 to 6.6 million in 2021 (IEA, 2021). Through the 2020s, EV sales are anticipated to increase even further, with the stated policies scenario resulting in EV sales of over 25 million by 2030 (IEA, 2021). Renewable energy output is rising, alongside EV adoption. Both these trends are altering how distribution network's function. Historically, these grids were built with large power plants integrated into them to provide a predictable aggregated load made up of numerous small consumers.

Hosting capacity analysis has been the focus of the work on controlling the adoption of EVs on distribution grids (Nour et al., 2020). The maximum amount of new energy generation or load that may be connected to the grid without risking its reliability or degrading power quality is referred to as a network's hosting capacity. The idea of hosting capacity was initially put forth to evaluate requests for small-scall embedded generation (SSEG) integration, but it has since been modified for demands for EV integration (Ismael, 2019). The conversion of technological hosting capacities into rules that encourage behaviour compliance has received little attention.

Grid integration is the process of adjusting power systems operations to the introduction of new energy technologies while remaining economically viable. To manage the integration of distributed energy resources such as EVs and rooftop solar, it is important for distribution companies to have some level of visibility, control and guidance over the connection of these resources to the grid. In order to manage the grid integration of EV charging, distribution companies can utilize one or a combination of these features through a set of regulations (IEA, 2022). Local governments must consider responses to protect the grid and its ability to provide affordable services to all its citizens, since unmanaged EV uptake, driven by higher-income households, will increase service costs to all, including those least able to afford it. The mechanisms of this inequitable cost burden will be discussed further in section 2.

Management of SSEG uptake and management of EV uptake share a number of commonalities. Distribution utilities must create SSEG-specific rates and interconnection procedures in response to the growth of SSEG. A comparable regulatory system is needed to manage EV charger installation. Many lessons from the successes and failures of the policy response to SSEG can be applied to the development of an EV regulatory framework.

Section 2 of this report will discuss the impacts of grid integration of EVs on the power system and distribution utilities' revenue. Section 3 will go on to discuss strategies used to manage this impact through impact assessment. Section 4 will then look at the challenges with the strict regulation of SSEG installation in South Africa. The difference between hard and soft law regulations will be discussed in section 5. Section 6 presents some examples of different soft law regulations that have been implemented to manage the grid integration of EV charging internationally. Finally, section 7 presents the conclusion.

2. Impacts of grid integration of electric vehicles

2.1. Power system impacts

Smart charging of EVs has the potential to significantly reduce power system costs and shift demand to align charging load with renewables.

Increased uptake of EVs will increase electricity demand, which has an effect on distribution planning (Bin Moon et al, 2018). The degree of these effects, however, is considerably influenced by EV charging patterns (Muratori, 2018). Charging patterns will determine whether there is an increase in demand during peak hours or not, or if EVs will assist with renewable energy curtailment. Research shows that if left unmanaged, EV charging generally takes place as on arrival at a charging station (Babrowski et al, 2014; Azadfar et al, 2015). If charging patterns are such that consumers generally charge at home, this means a significant proportion of EV charging will fall within peak hours. This will increase peak demand and increase the need for more expensive flexible generation.

Optimizing charging at specific times of the day is known as smart charging. Smart charging has the potential to significantly reduce the power system costs associated with inefficient charging. EV charging behaviour patterns can be used to shift demand and align charging load with cheaper and cleaner variable renewables, such as wind and solar (Bin Moon et al., 2019).

Aggregated EV charging can change the way that the grid operates. South African distribution grids were designed to serve a predictable load small consumer. The localized effects of EV charging on distribution grids, however, are more complicated, because EVs add significantly to typical residential loads (Coignard et al., 2019). Because the majority of existing distribution networks were not built with EV loads in mind, there is a very significant possibility that the additional EV load can result in violations of operational limits.

2.2. Revenue impacts

The electricity needed to charge EV batteries will create load growth opportunities and associated revenue growth for distribution utilities. Although there is the potential to increase the revenue of utilities, this increased revenue will be accompanied by increased power system costs. These costs can be reduced significantly through smart and managed EV charging patterns (Lyon et al, 2012). It is important for distribution utilities to manage charging to reduce the associated costs and take advantage as much as possible of the benefits that flexible EV charging can bring to the power system through its synergies with variable renewables (IEA, 2022).

An acceleration of unmanaged EV charging, specifically that which coincides with peak demand periods, will increase generation requirements and result in significant increases in power system costs (IEA, 2022). These costs will arise from the need for increased generation, transmission infrastructure upgrades, distribution grid reinforcements, and increased power losses (Bin Moon et al., 2019). These increased costs resulting from unmanaged charging patterns of EV owners would be passed on to all customers through higher energy prices. This will contradict the objectives of a just energy transition, since the cost burden is being driven by high-income households, but is passed on to the entire system, including low-income households.

Increased EV charging will also have an impact on the cost of customer services and business operations. More EV owners will put pressure on utilities to offer customer service alternatives like EV-specific connection queues, as well as new income opportunities through exclusive EV rates or packages for EV owners that may enable on-site solar and/or storage (Daniels & O’Donnel., 2019). In order to serve this new client base, it will be necessary to strike a balance between these service offerings and the probable need for extra customer support personnel and related expenditure.

Revenue from fuel levies and taxes, which are now recovered through gasoline sales revenue, will be lost as EVs begin to make up a larger proportion of the national transport system. Owners of EVs avoid paying the levies and taxes imposed on the sale of petroleum, since they switch from buying fuel for transportation to purchasing electricity. As a result, electric utilities may need to create systems to incorporate these costs into the electricity rates they charge EV owners (Montmasson-Clair et al., 2020). In order to recoup transportation-related levies as taxes, such as accident insurance money, utilities will need to change energy rates as a result of the impact that EVs would have on their financial flows. When creating regulations for EV charging, it will be crucial to take these income implications and opportunities into account. The just transition implications of how these costs are recouped must be considered. If the fuel levy is recovered from public charging, these costs are likely to fall on poorer customers using public transport, while wealthier EV owners will have the ability to charge at home. Therefore, any additional cost passed through electricity rates need to be linked to private home-based EV chargers.

3. Strategies to manage impact of EVs on distribution grids

The number of new energy-generating or energy-consuming devices that can be connected to the grid without affecting the dependability or quality of the power for the other connected customers is known as the hosting capacity. Grid operators frequently utilize hosting capacity studies to evaluate and convey the effects of distributed photo-voltaic (PV) systems on performance indicators and allowable limitations. It is important that similar hosting capacity studies are undertaken to establish the grid's capacity to host EV charging and that these studies are communicated to charge point operators and consumers.

Hosting capacity studies enable the simulation of practically every conceivable connectivity scenario. A network's EV hosting capability may then be evaluated using the findings of the impact assessment studies, as opposed to evaluating each individual EV connection request. In essence, hosting capacity analyses enables network planners to avoid going beyond operational constraints in advance. These studies are often difficult to perform, as they are based on various uncertainties. Charging patterns are also based on human behaviour, which is difficult to control. These difficulties have sparked a significant body of literature on the creation of reliable EV impact assessments (Quirós-Tortós et al., 2015; Deb et al., 2018). Three main types of EV hosting capacities are proposed:

1. Static hosting capacity
2. Dynamic hosting capacity
3. Active distribution grids

A static hosting capacity is based off the worst-case peak demand points of the year and combines the maximum EV charging load with the non-EV peak load. This hosting capacity is then determined as the level of EV charging that will violate the operational limits of the distribution grid (Temiz & Guven, 2016). A downside of this hosing capacity approach is that it is inflexible and produces conservative estimates of the grid's capacity to host EVs. These conservative estimates can deter EV uptake in areas that are in fact suitable if charging is managed effectively.

Dynamic hosting capacities are more flexible and represent the locational and time-varying nature of a grid's operating condition. Locational hosting capacity acknowledges that the hosting of EV chargers can be accommodated in certain locations on the grid but not in others. Locational hosting capacity allows grid operators to determine where the grid has the most capacity and incentivize charging in those specific locations (Jensen & Uyehara, 2020). While grid operators can regulate the location of public charging stations, it is very difficult to regulate the location of at-home charging points. Aggregated at-home charging in areas where the grid is constrained could require costly grid upgrades to provide additional supply. Managing EV charging schedules to prevent charging during times when the grid is overloaded is an alternative to upgrading the grid. The main goal of time-varying hosting capacity evaluations is to identify the times when the grid has capacity for EV charging. Dynamic hosting capacities take advantage of the flexible nature of EV charging to optimise EV uptake. Its implementation, however, requires some regulations and incentives to effectively manage charging patterns.

Active distribution networks have a combination of distributed energy resources, including rooftop solar, batteries, and EVs. In this network the systems operator has control over the grid through power electronics and smart devices. EVs are an essential part of this network as EV smart chargers have the ability to increase charging power in response to excess variable generation, reducing renewable energy curtailment (Quiros et al., 2018). With appropriate control, grid systems operators will be able to eliminate the negative impact of EV charging on the grid.

4. Rooftop solar and regulatory non-compliance in South Africa

There are many similarities between managing the adoption of rooftop solar and managing the use of electric cars. The explosion of SSEG systems has forced electricity distribution utilities to respond by developing SSEG specific interconnection rules and tariffs. A similar regulatory framework will be needed to regulate the adoption of EVs. In developing this framework, many lessons can be learned from the successes and failures of the policy response to SSEG.

Over the past five years, South Africa has experienced rapid growth in the number of behind-the-meter rooftop solar systems, mainly due to rising electricity prices. At the end of 2021, the total installed capacity of SSEG systems was over 1 gigawatt (SALGA, 2020). Despite the fact that most utilities have extensive SSEG interconnection processes, the majority of these systems remain unregistered and unregulated (SALGA, 2020). The low residential registration rates are the result of various challenges. Residential customers are not always aware of the required registration and distribution utilities have little capacity to enforce registration (SEA, 2021).

Distribution companies in South Africa use simplified connection criteria, NRS 097-2-3, when evaluating SSEG connection requests (NRS, 2014). The criteria represent the hosting capacity of a typical low voltage network for SSEG. According to the criteria, the maximum generation size allowed depends on two factors:

1. The type of network: It depends on whether the network serving the client is shared (serving other clients) or dedicated (serving only this client).
2. The notified maximum demand (NMD) reported by the customer.

The criteria implemented indicate the conditions under which generators with a low voltage connection can be connected to the public electricity network without the need to carry out detailed network studies. SSEG system requests that exceed these criteria must follow an alternative process that requires a detailed network study. This simplified connection criteria can be referred to as “static” hosting capacity, because it represents the potential worst time of the year. At the time of development, in 2014, these simplified connection criteria were fit for purpose and several distribution utilities benefited from their use, safely connecting hundreds of megawatts of SSEG to South African distribution networks (SALGA, 2020).

However, recent studies indicate that these static hosting capacities, which represent the worst cases over time, can provide a conservative estimate of SSEG hosting capacity. The worst-case conditions generally only exist for a small percentage of the year, and these immediate failures, if short-lived, may not be considered failures by existing standards.

Although the implementation of a conservative hosting capacity prevented any violation of operational limits, the lack of more detailed grid studies resulted in significant project delays and discouraged solar installations in potentially viable areas. As a result, this rigid implementation of conservative static hosting capacity has resulted in an underutilised SSEG market in South Africa, which in turn hampers the potential job opportunities related to a vibrant SSEG sector.

There are lessons to be learned from this experience with using static hosting capacity studies and legally required registration to manage SSEG installation. Similar simplified connection criteria will limit the permitted capacity of EV chargers based on the customer’s low voltage grid and NMD. Therefore, residential customers with lower NMDs will be limited to installing slower EV chargers, which will significantly increase charging times and potentially discourage EV uptake. This approach of implementing hard SSEG limits in terms of capacity limits and registration of systems has proven to be an inadequate tool to properly manage the grid integration of this distributed energy resource.

5. Soft vs hard laws

Hard laws are legal and regulatory governance mechanisms that are formally enacted in accordance with accepted procedures and are binding in nature (Thiere, 2021). Hard laws generally impose formal limits and have associated penalties for non-compliance. These laws typically require cost benefit analyses, a notice and comment process, and other lengthy formal procedures.

Lawmakers and regulators face a number of challenges in trying to regulate the uptake of new technologies in the face of rapid innovation. These can generally be categorised into four major problems (Hagemann et al., 2018):

1. The pace problem: Where technological innovation is taking place at a pace faster than law-making.

2. The “rule volume” problem: Where the creation and adoption of new laws contribute to an increasingly large and complex set of regulations.
3. The coordination problem: When regulators struggle to classify new technologies correctly.
4. The knowledge problem: When there is a lack of information on how these technologies are shaped.

As a result, regulators are increasingly turning to a collaborative ‘soft-law’ approach in managing the uptake of new technologies. Soft laws are generally adopted relatively quickly and focus more on collaboration among stakeholders. They refer to a range of quasi-legal instruments that lack the binding and direct impacts and enforcement characteristic of hard laws. The precise definition of soft laws is unclear and disputed in the literature (Abbot et al., 2012). Soft laws are generally accepted as a wide range of governing mechanisms that provide guidance to stakeholders in the absence of binding legal norms. Examples of soft law mechanisms include:

- Recommendations
- Guideline documents
- Codes of conducts
- Industry standards and certificates
- Education and awareness campaigns
- Multi-stakeholder processes

Soft laws allow for more flexibility and speed of implementation but are generally implemented in the shadow of hard laws (Mandel, 2020). Both hard and soft laws are effective regulatory mechanisms and can be used together. A combination of soft and hard laws should be implemented to incentivise and manage EV charging patterns in South African municipalities. The regulatory mechanisms implemented should consistently be reviewed and updated based on international experience and need as EV uptake and technological innovation improves in South Africa.

6. Examples of soft law regulation for managing grid integration

6.1. Time-varying electricity tariffs

Time-varying electricity tariffs are an important market-based regulatory instrument to prompt behavioural responses for EV users to charge off-peak. Tariff rates are often set at higher rates during peak periods. These market-based policy instruments are a form of soft law to guide consumer behaviour rather than restrict it in a legally binding manner. Time-varying tariff structures have been found to be effective in shifting EV charging loads and reducing the impact of EV charging both for the systems operator and EV owners (Ensslen et al., 2018).

Time-varying tariffs have been found to be more effective in managing demand if they are accompanied by a customer engagement campaign (Coignard et al, 2019). It is important that customers are aware of the financial benefits of shifting their EV charging behaviour to when the grid has available capacity.

6.2. Incentives and regulation of chargers

Regulators must decide among a range of policy mechanisms to prompt investment in smart chargers. For example, in Belgium and Luxembourg, tax incentives were provided for the residential purchase of smart EV chargers that can be digitally managed through protocols (IEA, 2022). This soft law aimed to prompt the purchase of smart chargers and allow for some level of active control over the distribution network. The Netherlands developed charge point tender guidelines that made smart chargers with open charge point protocols the standard publicly available home-based EV chargers.

6.3. Encourage synergies with renewable generation

Flexible charging of EVs presents an opportunity to create synergies with widespread variable renewable energy generation. Daytime charging can assist with increased consumption when excess solar is available. Due to the injected energy being out of balance with consumption, areas with high rooftop solar PV penetration may suffer issues with excessive local voltage (overvoltage) in periods of low demand, for example sunny weekends. Similarly, EV charging during peak hours can have the opposite effect, resulting in undervoltage. Co-ordinating charging and solar generation can have the effect of increasing mutual hosting capacity (Fachrizal et al, 2021). Therefore, encouraging workplace or daytime charging can reduce the negative impact of increased variable renewable energy and EV charging on the grid.

Regulators in the United States have implemented training programmes for building managers in office buildings to install and manage EV chargers and published workplace charging guidelines to incentivise daytime charging[1]. Another means to encourage workplace charging is through incentives for the installation of charge points, as was implemented in the UK through their workplace charging scheme[2].

6.4. Communication and stakeholder engagement

Planning for increased uptake of EVs, and updating regulations based on their effectiveness, requires visibility. A major challenge in regulating the charging of EVs is that private passenger vehicles that charge at home are not publicly visible. Based on South Africa's experience with residential SSEG installations, the registration and monitoring of at-home EV charging does

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[1] US Department of Energy, Alternative Fuels Data Center: Workplace Charging for Electric Vehicles (energy.gov). Link: https://afdc.energy.gov/fuels/electricity_charging_workplace.html.

[2] UK Government, Office for Zero Emission Vehicles: Grant schemes for electric vehicle charging infrastructure. Link: https://www.gov.uk/government/collections/government-grants-for-low-emission-vehicles#workplace-charging-scheme.

not seem viable. Implementing minimum communication requirements on charge points and vehicles can assist with visibility and inform charging strategies and regulations.

Information can be collected on potential EV hotspots from the electronic National Traffic Information System (eNaTIS) database. License renewal data provides information on the vehicle type (EV or internal combustion engine) as well as the owner’s residence. Information on public charging patterns can also be collected from charge point operators, such as GridCars. This process will require multi-stakeholder engagement processes with national stakeholders and charge point operators to set up mechanisms for data-sharing.

7. Conclusion

Regulation can both encourage and stifle innovation. As new technologies evolve, regulators must adapt their regulatory approach. EV charging technology is evolving rapidly and traditional regulations are struggling to keep up. For example, wireless charging of electric vehicles on the go has proven to be a viable alternative to socket charging. Therefore, hosting capacity developed around the introduction of EV plug-in charging patterns may no longer be suitable as these technologies develop (Ulrich, 2020). With the rapid adoption of EVs, much research has been done on the impact of EVs on the energy system. The most noticeable impact will affect regional distribution networks. To ensure that power quality standards are met, distribution system operators must develop EV hosting capabilities to optimize EV uptake given their grid constraints.

Soft law mechanisms provide a useful tool for improving the effectiveness of EV regulation. These tools include financial incentives, multi-stakeholder engagements, best practice guidelines, and education and training campaigns. Governments that are starting to develop regulations for integrating electric vehicles into the grid are encouraged to use these soft law instruments.

Notwithstanding their benefits, concerns have been raised about the non-binding nature of soft laws. In the case of EVs regulations, a lack of enforcement and implementation could threaten the sustainability of the distribution grid and in some cases hard laws should be implemented where soft laws need to be strengthened. Distribution utilities should use a combination of hard and soft laws that are continuously reviewed and updated to keep pace with the evolving regulatory needs in the transition towards EVs.

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