A review of services and value provided by EV managed charging

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The goal of net-zero emissions necessitates the high penetration of renewable energy in power systems. Energy storage (e.g., pumped storage, stationary batteries) becomes indispensable for balancing variable renewable resources and varying loads to maintain power system reliability, stability, and security. However, the initial investment in stationary batteries is relatively high [1]. The electric vehicle (EV) is a promising solution to provide the grid services required to integrate variable renewable energy (VRE) into the power system by managing the charging and discharging of their batteries, although the availability and capacity of these batteries may be more variable and uncertain than that of other energy storage systems [2]. This paper presents a review and classification of services that can be provided by EV managed charging and their potential implementation in Australia. An overview of the EV market development in Australia is first presented. Then, the services and value of EV managed charging are summarized. Finally, key EV management approaches are presented for three other countries, and potential insights are summarized for Australia.

According to the IEA report "Global EV Outlook 2022" [3], in 2021, over 16.5 million electric cars were on the road, and electric car sales accounted for 9% of the global car market. Australia has been slow in adopting EVs and lagging behind many other similar economies. In 2011, the Australian Energy Market Commission (AEMC) projected that by the year 2020 EV's share of new vehicle sales would account for up to 10% [4], however, the actual EV market share in Australia was 0.78% in 2020 and 2% in 2021 [5], much lower than AEMC's predictions. To achieve Australia's net-zero emissions commitment by 2050, there is an urgent need to accelerate the uptake of electric vehicles across all vehicle segments, which will both directly reduce emissions by powering the transport sector with renewable electricity and potentially make the grid services required for renewables integration available from EV batteries.

Challenges and opportunities of EV charging load

Many studies have highlighted the problems resulting from unmanaged EV charging load on a mass scale, which has been shown to increase peak demand capacity requirements [6], cause overloads of distribution transformers [7], impact power quality [8], and consequently, increase the power supply costs. In June 2022, the Netherlands, which has one of the densest charging networks in the world, said its power grid will not handle the influx of electric car charging points by 2030 unless smart charging strategies are implemented [9].

Electric vehicle managed charging, which may also be referred to as coordinated / controlled / regulated / scheduled / smart charging, means the charging or discharging of an EV battery is executed under certain decision-making processes. Unlike unmanaged charging which starts once the EV is connected to the power grid, in managed charging mode the charging time, charging rate, and sometimes the direction of power flow is managed or constrained by factors other than the EV owner's intention or EV batteries' capability. For example, participation in strategies determined by an Ancillary Service Provider (ASP), Demand Response Service Provider (DRSP) [10], EV fleet aggregator [11], or local control in response to EV charging tariffs can dictate the charging/discharging of an EV battery. In some articles, 'managed charging of EVs' is taken to mean only unidirectionally (V1G) charging, and bidirectional charging between vehicles and the grid (V2G) or other loads (V2X) is not included in the definition. In this paper, we take managed charging to include bidirectional charging in accordance with [12].

Grid services provided by managed charging and their associated value can be categorized according to different dimensions. Arias et al. classify EV services by the entities for whom the service is intended, including ancillary services for transmission system operators (TSO), services for distribution system operators (DSO), and variable renewable energy generators [13]. Based on [14-16], Fig. 1 summarizes the services and value provided by EV managed charging (i) in power system planning: to reduce the need for investment; (ii) in operation: to assist the system operator or network service provider to manage power quality, security or reliability; (iii) charging cost minimisation; and (iv) decarbonisation benefits.

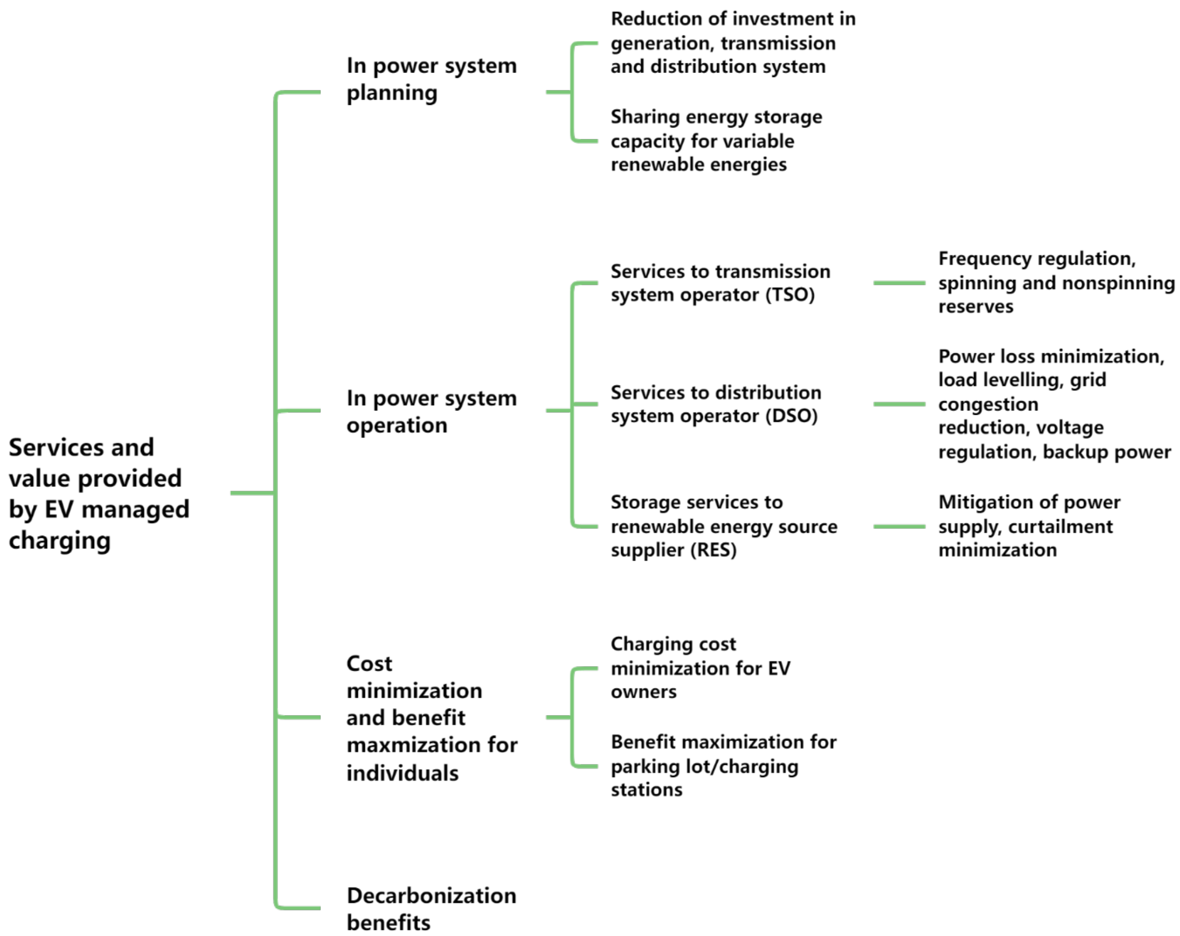

Figure 1. Services and value of EV managed charging

Status of managed EV charging in three reference countries

We choose three countries that have high EV uptake: China, UK, and Norway, and present their experiences in EV managed charging and renewable energy integration and consider applicability for Australia.

China sees the electrification of transportation as a strategic opportunity to expand the automobile industry. It is the largest electric vehicle market in the world, accounting for 53% of global sales in 2021. Also in 2021, impelled by the “Whole County Distributed PV” policy of the National Energy Administration [17], newly installed distributed PV capacity expanded rapidly and exceeded the capacity of centralised PV for the first time in the Chinese market of the year. At the national level, the VRE penetration is still much lower than in many other countries. However, at the regional level, because of the baseload insufficiency, many counties in the “Whole County Distributed PV” project face immense pressure on PV electricity utilization during peak generation hours. Local policies of compulsory energy storage ratio for distributed PV have been introduced. The usage of EVs as flexible energy storage is included in the ‘new energy storage category’ and promoted at the national and local levels. [17-18]. In terms of the EV managed charging practice, in most provinces the EV charging tariffs are designed based on the time of use (TOU) tariffs for residential and business charging. The unidirectional TOU tariff has more effect on commercial vehicles at a business charging station than on residential customers for the difference between peak and valley residential prices is smaller. There are several reported V2G trials in China focusing on functional verification, customer behaviour research, and battery degradation analysis of V2G [27-28]. It is also worth mentioning that in the electric heavy-duty vehicle market, nearly 50% of the sales in the first half of 2022 are battery-swapping trucks. These battery swapping stations for heavy trucks and some passenger cars can act as more controllable energy storage for the power system [29].

The UK national grid has analysed four scenarios for EV smart charging and Vehicle to V2G in the UK [19]. In two of its higher-level consumer engagement scenarios, net EV demand at peak times becomes negative from the 2030s with V2G application, due to more power being fed back to the grid from EVs than is used to charge them at that time [19]. The UK is the first country in the world to legislate smart charging of business charging points at the national level in 2021 [20] and is also leading in the quantity and scale of smart charging and V2G trial projects. According to v2g-hub.com, there are 107 V2G projects around the world, and 22 of these are in the UK [30]. Led by Innovate UK, the “e4Future” V2G trial which started in 2018 is the largest scale V2G demonstration in the world with total funding of nearly £30 million [31]. In this project, 1000 EVs participate in frequency response, energy arbitrage, distribution system services, and energy time shifting services. New business models, consumer awareness, and technologies that support interaction between electric vehicles and the grid are investigated [30].

Norway is leading the world in EV applications with a market share of 86% in new car sales in 2021 [5]. 94% of the energy production in Norway comes from hydropower with inherent flexibility [21], and therefore the excellent potential to balance power production in a future Central-West European power system [22]. However, it is anticipated that in an unmanaged charging scenario, Norway still needs a $1.6 billion power grid upgrade to accommodate the unmanaged charging behavior of the large numbers of EVs expected on the road by 2040 [23]. New tariffs for electricity customers in Norway were introduced from 1st of July 2022, which includes a capacity element to incentivize a reduction in peak load consumption and the use of electric vehicle charging to support grid flexibility [24-25]. Residential consumers with home EV chargers usually have high concurrent power consumption, but the new tariffs will influence the EV charging rate to the valley load period of a home to reduce the total power consumption. Compared to other Nordic countries such as Denmark and Finland, Norway has a smaller number of V2G projects as the high penetration of flexible hydro substitutes the motivation for V2G implementation in Norway [32].

Conclusion

One of the key lessons learned from the other countries’ pilots is that there is no single, generic, universally applicable EV managed charging and grid integration business model. And the tariffs in each region/country are different and vary by the type of consumer (household / commercial /municipal /industrial). As the EV market rapidly evolves, it is important to research the implementation of EV managed charging and flexible services in the Australian context. Australia has the highest penetration of rooftop solar PV in the world [26], and an advanced electricity market mechanism. With these favourable factors combined with lessons for other countries, Australia has a high potential to find a path to a diversified EV-VRE-Power system integration. Meanwhile, other green commute measures for example public transportation, car-share, and cycling will contribute to zero-carbon emission transportation jointly.

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