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Opportunities of electric vehicles as a part of smart solutions

***Abstract**. Today's discussion opens opportunities for involving non-traditional, especially intermittent energy resources into operation of electricity grids and distribution systems. Proposed so called Smart Solutions like Smart Grid and Smart Cities suppose use of electric vehicles as its part. The main opportunity of involving electric vehicles should be accumulation of electric energy in the vehicle storage system and its possible release during the peak time in daily load diagram.*

***Streszczenie.** W artykule analizowano możliwości udziału nietradycyjnych źródeł energii w systemie dystrybucyjnym. Zaproponowano tak zwany system Smart Solution]i Smart City z wykorzystaniem samochodów elektrycznych. Ładowanie akumulatorów samochodowych może się odbywać poza szczytem poboru energii. (**Możliwości wykorzystania pojazdów elektrycznych jako element Smart Solution**)*

Keywords: Electric Vehicle, Distribution System, Accumulation, Daily Load Diagram
Słowa kluczowe: pojazdy elektryczne, system dystrybucji energii, smart solution

Introduction

21st Century is changing global map of energy demand. BRIC countries (Brazil, Russia, India and particularly China) are growing rapidly and their energy demand follows economy growth. Especially China has changed within one decade from the world biggest exporter of primary fuels (coal) to the world biggest importer in spite of the fact that own coal production in China grows as well. This represents reduced resources and increasing price for Europe.

Another aspect is that ambitious targets of European Union, regarding climate change means a new view of energy mix and energy usage. Targets, known as 20-20-20, have impact to decisions of some EU countries. The purpose of those decisions is to support use of electric vehicles namely for individual transport in cities resulting in 10% share of electric vehicles in 2020 including necessary development of distribution infrastructure.

Following EU Roadmap 2050, regarding target in greenhouse gas emission reduction, some countries have already decided to adopt even more ambitious goals to reduce CO_2 emission in 2050 by 80% or even 90%. What would be an impact of that decision for transport in practice? Probably almost full transport electrification because use of vehicles powered by petrol or gas engines would mean further production of CO_2. An alternative can be electric or hydrogen vehicles.

But today's reality is different. For example in the U.S.A. there is less than 1% of electric vehicles in America's car fleet [1]. Also mass construction of a fairly high density of charging stations must precede any mass ownership of pure electric vehicles outside of the suburbs, where the vehicles could be charged in their garages. That is why researchers at IHS Global Insight put the share of pure electric vehicles at just 0.6% of world sales in 2020 [1], [2], why most published scenarios put the likely share of electrics at no more than 25% of new sales by 2050 [1], [3] and why even Germany, ready to subsidize the ownership of electric cars with major new incentives starting in 2012, is aiming at putting no more than about 1 million electric vehicles on its roads by 2020 [1], [4]. With nearly 55 million vehicles total on German roads in 2010, electric cars would claim only about 1.5% of all German passenger cars by 2020 [1].

So reality would be probably different from expectations. This however does not mean that we can stop the process of preparation on the generation, transmission and distribution side, to preserve our ability to react on the situation that can rapidly change and work in R&D to utilize possible opportunities.

Potential Impact on Electricity Generation

Economic, technology and environmental incentives are changing the face of electricity generation, transmission and distribution. Centralized generating facilities are giving way to smaller, more distributed generation partially due to the loss of traditional economies of scale [5].

For over a century we've systematically built a complex infrastructure of power plants, connected with high-voltage transmission lines to load centers where lower-voltage distribution lines provide power to homes and businesses. Power system ensures our safety and security, and is vital to future growth in productivity and prosperity. This asset, an infrastructure built and maintained on our behalf, is aging, with existing technologies reaching their end of life and others becoming obsolete, overstressed, and unable to meet the demands of high penetration of intermittent energy sources and potentially plug-in electric vehicles (PEVs). While it has served us remarkably well until now, it is incumbent on us to upgrade it to meet the changing demands and future electric needs of our 21st Century economy and society [6].

There are tendencies to support and speed up introduction of more electric vehicles. Although the reality differs from goals and expectations it would be right to describe what can happen on the generation side.

There are references saying that the electric version of a car whose size would correspond to today's typical vehicle (a composite of passenger cars, SUVs, vans, and light trucks) would require at least 150 Wh/km; and the distance of 20,000 km driven annually by an average vehicle would translate to 3 MWh of electricity consumption [1]. It corresponds with information from Europe where average calculated consumption is 180 Wh/km [7].

Situation in the Czech Republic is presented in Table 1, showing still increasing number of vehicles. Share of passenger cars, including vans is shown in Fig. 1 and from both Tab. 1 and Fig. 1 is clear that growth of passenger cars is slower than that of commercial vehicles. Because of economic crisis, we can assume for demonstration calculation a constant number of passenger cars responding to their amount in 2011 (4,582,903 registered vehicles) [8].

Within seven years there was 18% increase of the total vehicles amount, from which 15.75% was increase of passenger cars but 41% was that of commercial vehicles.

Year	Road motor vehicles, total	Vehicles		
		Passenger cars, incl. vans	Commercial vehicles	Special-purpose commercial vehicles
2005	6 231 601	3 958 708	415 101	51 457
2006	6 490 393	4 108 610	468 282	48 777
2007	6 806 332	4 108 610	533 916	46 672
2008	7 081 145	4 423 370	589 598	43 609
2009	7 119 323	4 435 052	587 032	39 300
2010	7 221 943	4 496 232	584 921	36 660
2011	7 358 727	4 582 903	585 873	34 797

Table. 1 Registered vehicles in the Czech Republic [8]

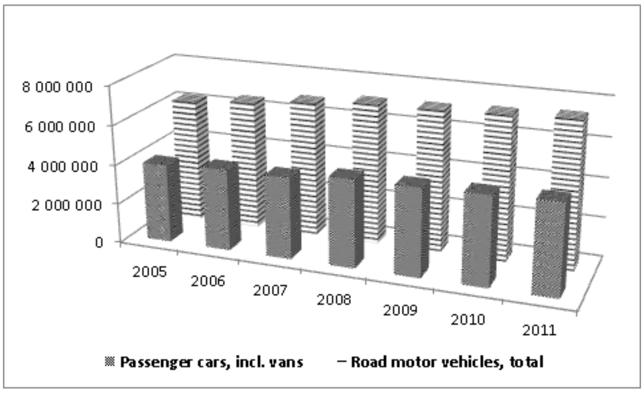

Fig. 1 Road motor vehicles registered in the Czech Republic

Assuming various percentages of electric vehicles, their average consumption of electric energy and passed kilometers per year, we can receive their possible future electric energy demand due to their operation.

Passenger cars, incl. vans 2011	Driven kilometres per year	Average consumption [kWh/km]	Driven kilometres per year	Average consumption [kWh/km]	Driven kilometres per year	Average consumption [kWh/km]
4 582 903	**10 000**	**0,15**	**15 000**	**0,15**	**20 000**	**0,18**
Electric vehicles	%	Consumption [MWh]	%	Consumption [MWh]	%	Consumption [MWh]
458 290	10%	687 435	10%	1 031 153	10%	1 649 845
916 581	20%	1 374 871	20%	2 062 306	20%	4 949 535
1 374 871	30%	2 062 306	30%	3 093 460	30%	7 424 303
1 833 161	40%	2 749 742	40%	4 124 613	40%	9 899 070
2 291 452	50%	3 437 177	50%	5 155 766	50%	12 373 838

Table. 2 Consumption of electric vehicles

Table 2 shows possible consumption of electric vehicles in the future according to parameters described above. In case of 10% replacement of present cars by electric vehicles with average consumption 0.15 kWh/km and the distance of 10,000 km driven a year, the total annual consumption will increase by 687 GWh per year.

This represents approximately capacity of one power station with installed power 130 $MW_{inst.}$ and load factor 8,000 hrs./year. It can be, for example, covered also by a part of nuclear power station. It can be also represented by a power station or stations with installed power 458 $MW_{inst.}$ and load factor 1,500 hrs./year. This consumption can be for example covered also by renewable resources like wind or PV solar panels. However these sources would not guarantee continuous supply.

Described situation would not impact power generation in the Czech Republic too much because it represents just 0.85% of net electricity generation in 2011.

On the other hand supposing replacement of 50% of existing passenger cars, SUVs, vans, and light trucks by electric vehicles with an average consumption 0.18 kWh/km and the distance of 20,000 km driven annually the situation would change. Annual consumption would be similar to the medium size house, but with mobile character. Comparison of these alternatives is in the Fig. 2.

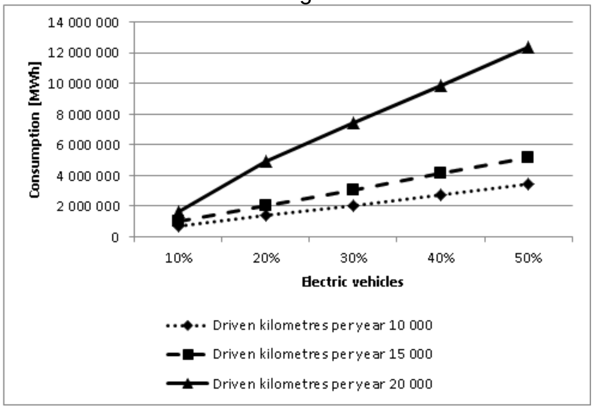

Fig. 2 Electricity consumption comparison

The situation described above would cause the total consumption increase by 12,374 GWh per year. This is more than 15% of the net electricity generation in the Czech Republic in 2011.

This electric energy could be covered for example by nuclear power plant with installed power 1,550 $MW_{inst.}$ and load factor 8,000 hrs. or by thermal power plants and CGTs with 2,500 $MW_{inst.}$ and load factor 5,000 hrs. and/or by renewables with 8,300 $MW_{inst.}$ and load factor 1,500 hrs. This capacity is achievable in the Czech Republic but without guarantee of continuous supply.

However probability that above mentioned high demand scenario really happens should be considered as very low. Without some really unexpected events e.g. oil crisis or something like that the real electric vehicles market share will grow quite slowly and their maximum amount in 2020 can take around 20%. However most probably less than 10% seems to be the realistic estimate. It means that on the generation side different factors influencing power generation would appear rather than the electric vehicles power supply demand.

Opportunities for Transmission and Distribution

Electric vehicles can have some impact also to electricity transmission and distribution. This impact can be both positive and negative. As mentioned above the positive impact can be transformed into opportunities and potential negative impact should be predicted and eliminated.

Transmission

Additional electricity transmission demand caused by electric vehicles will not be high. Only in case of dramatic market share growth of electric vehicles is necessary to transmit additional energy through transmission grid. Thanks to robust dimensioning of the Czech transmission grid should be probably necessary to eliminate only some bottlenecks, but no be requirement for fundamental increase of capacity can be expected.

General threat seems to be the balancing of the system in winter time when maximum power load and additional demand could cause instability due to the lack of generation and ancillary services.

Opportunity and potential positive impact of electric vehicles utilization can be their ability to accumulate energy at time when there is an imbalance of the system due to unexpected overproduction from distributed energy sources and low demand.

The expectation that electric vehicles market share grows high before 2020 does not look realistic, so probably opportunities for transmission grid will not be significant in the near future.

Smart Grids

Although there is no standard global definition, a smart electricity grid is generally defined as an electricity network allowing devices to communicate between suppliers to consumers, allowing them to manage demand, protect the distribution network, save energy and reduce costs. They can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. Smart meters – which provide utilities with a secure, two-way flow of data – may be part of a smart grid, but alone do not constitute a smart grid. Electric vehicles should be a part of smart grid solutions [9].

The expected development and growth of the electric vehicle in Europe will equally require appropriate infrastructure in homes and will need adaptations in some homes for smart and safe charging. A significant advance in battery technology is essential to lower the cost and increase the performance of electric vehicles in future years, as is the build-up of electrical energy infrastructures and charging systems. An electric vehicle can simultaneously serve as both a means of transport and as a mobile energy-storage device [10].

Smart Cities

Increasing urbanisation is one of the great megatrends of our time. By 2050 there will be an additional three billion people on Earth, 70% of them living in cities, and these cities will be generating 80% of global emissions and accounting for 75% of the world's energy consumption. Today, many urban infrastructures are reaching their limits, for example, in relation to secure energy supply, transport, buildings, healthcare provision, safety and security, water and waste management.

Smart cities combine competitiveness, sustainability and quality of living, the three elements being intimately entwined. A smart city will be a "System of Smart Systems" addressing the different areas [10].

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The large number of electric vehicles expected in cities will require the planning and installation of dedicated energy infrastructure and service systems. The connections between the existing systems with the new areas requiring investment create a need for future infrastructures based on Smart solutions, assuring energy efficiency and proper quality standards.

Electromobility, as such, is a new concept of mobility, including electric vehicles, eBikes and a new infrastructure, which together give Europe an opportunity to combine the strengths of different transportation modes. eMobility is also the test case for the smart grid and cities in Europe.

The electrical network will comprise the energy and communication networks. It has to connect new types of loads and also the discharging of electric vehicles [10].

From the text above is obvious that Smart Grids and Cities concepts suppose electric vehicles as a tool for accumulation. But electric car should be ready for both charging and discharging as well.

Distribution

Electric vehicles are connected via charging stations directly to distribution networks. This can be an opportunity for balancing the system. In case there is more generation than demand, electric vehicles can serve as an accumulator. But today's charging stations work only one way. It means they are able to charge electric vehicle battery but they are not able to discharge them during the peak time if necessary.

For purpose of fulfilling the vision of smart grid on the distribution system level the new type of stations is needed. This new type should be able to do both charge and also discharge the electricity storage system in the electric vehicle. Distribution system has got different character than transmission system. Typical daily load diagram is quite flat during the working time in the Czech Republic (see Fig. 3).

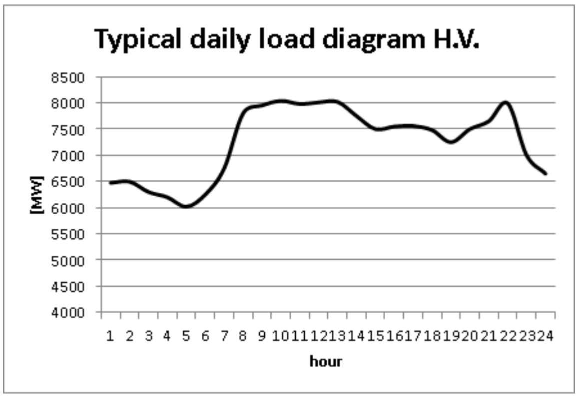

Fig. 3 Daily Load Diagram of Transmission System, High Voltage, September

But distribution system on Low Voltage level has got shifted peak into afternoon time. It is caused by consumption character because there is minimum industry connected. Characteristic daily load diagram for L.V. level can be seen on Fig. 4.

Some threats and unsolved technical problems are still open. There is difference between urban and rural areas.

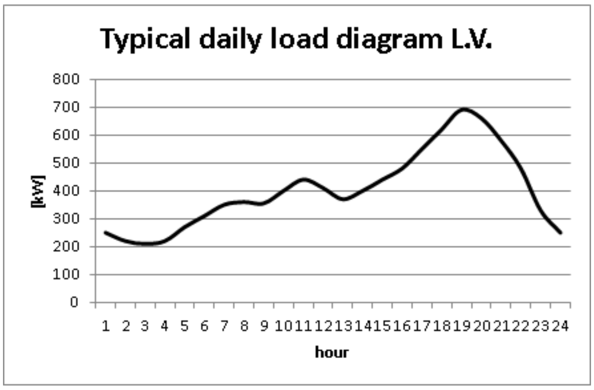

Fig. 4 Daily Load Diagram of Distribution System, Low Voltage

Typical for urban areas is high density of inhabitants. Many of those inhabitants live in blocks of buildings. They have no garage and they park their cars outside at the public parking places. It seems that charging of electric vehicles at those places can be quite difficult to arrange. Those urban electric car users would probably charge their vehicles either at working place or some other public places like shopping parks. It would imply huge concentration of electricity demand for a short time at one place with impact on distribution network. Dimensioning of such place can be one of the bottlenecks. Huge demand during the peak time, then peaks in the afternoon just after working hours end and minimum load during rest of the day. Charging equipment can be used inefficiently in those cases. During the peak the problems with power quality supply can be expected, e.g. voltage etc.

Possible solution would be time shifting and management of charging stations. Discharging possibilities will not be allowed at public places. It would be possible probably at the stable places (e.g. company facilities, office buildings etc).

For rural areas low density of inhabitants is typical, usually living in individual houses with garages, commuting daily. Here is an opportunity to use electric vehicles as accumulator, charge them during the night time, smooth daily load diagram and also take advantage of their discharge when necessary and possible.

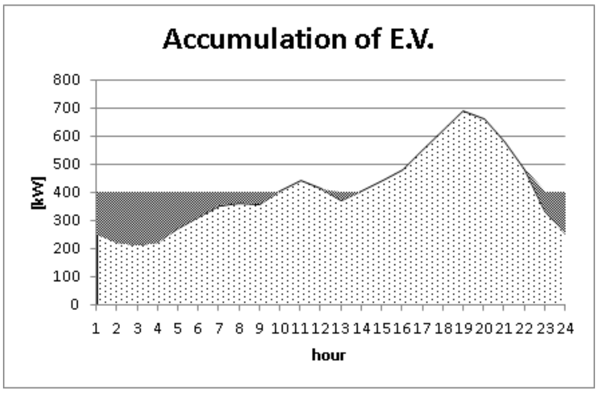

Fig. 5 Possible opportunity of electric vehicles to Daily Load Diagram of Distribution System, Low Voltage

Opportunity to accumulate electricity is illustrated above (see Fig. 5). It gives an opportunity to optimize distribution transformer load. However it would be necessary to manage their charging regime during off-peak time not to overload transformers.

Threats are about proper charging management, not to overload L.V. networks, to ensure quality of electricity supply because charging can cause both interference to network and negative voltage drop. Especially in rural areas having long lines where overload can happen causing quality supply quality worsening.

This is the reason why to do another research work to optimize maximum factors for future operation and eliminate possible negative interferences. Also future discharging should be considered properly including all aspects.

Conclusion

The paper deals with possible extension of electric vehicles utilization and its consequences. Introduction of electric vehicles probably does not proceed as fast as it has been expected. This interim time should be used for another analytic and research work to consider its future impact on distribution system and the necessary capital expenditures.

Anyhow the situation of current state is changing significantly and considering an electric vehicle which is to be charged at different locations and at the same time, it is necessary to take into an account also the fact that the customer would like to have one invoice including e.g. the domestic consumption and the electric vehicle charging. In this situation there are obviously numerous challenges like having in place charging infrastructure with needed communication infrastructure, identification infrastructure, etc. [11] which is another direction for future R&D.

On the one hand there is an opportunity for electricity accumulation, smoothing daily load diagram and load optimization in the low voltage networks. On the other hand there is possible negative impact e.g. overloading, timing, and negative interference and voltage stability problems.

To introduce electric vehicles as a functional part of smart grids and cities there will be necessary to continue research and development of station enabling both charging and discharging to use accumulated electric energy when needed and having in mind the mobile character of electric vehicle both as consumption and accumulation as well.

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