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SGEM 3.3.6-1: Gas station conversion to EV fast charging station

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1 Introduction

Before electric vehicles (EV) can truly break through in the future, a faster alternative for slow charging must be found. Most of the kilometers are most likely charged at home over night or at working places during working hours. This will be the cheapest way for the customer. However, there are situations when EV user has true need for faster alternatives. Holidays, weekends and longer trips in general need to be able to be driven through with reasonable comfort and without several hours of charging pauses on the way.

For this reason it might be reasoned to assume that also fast charging or battery swapping is needed. Whichever alternative of these two is chosen, a very rational place for such could be found among present gas station infrastructure. These stations already provide a connection to road network. Also, they have the needed land area in city planning, which issue also might become a hinder for new players and new locations.

2 Charging modes

IEC 61851 gives some technical specifications for an EV conductive charging system [1]. The standardization work is still going on. In the standard under preparation there are defined four modes for charging. These modes are shown in Table 2.1 below. Here the interesting issue is the power rating of each mode. Ultra-high and high modes that might be used in fast charging might be defining the requirements for the grid connection.

Table 2.1 Charging modes

Mode	A max	Phases
1	16	1
	16	3
2	32	1
	32	3
3	32	1
	70	1
	32	3
	63	3
	250	1
	250	3
4	400	1

Ultra-fast charging modes could provide a competitive alternative to present gasoline pumping for internal combustion engine (ICE) vehicles.

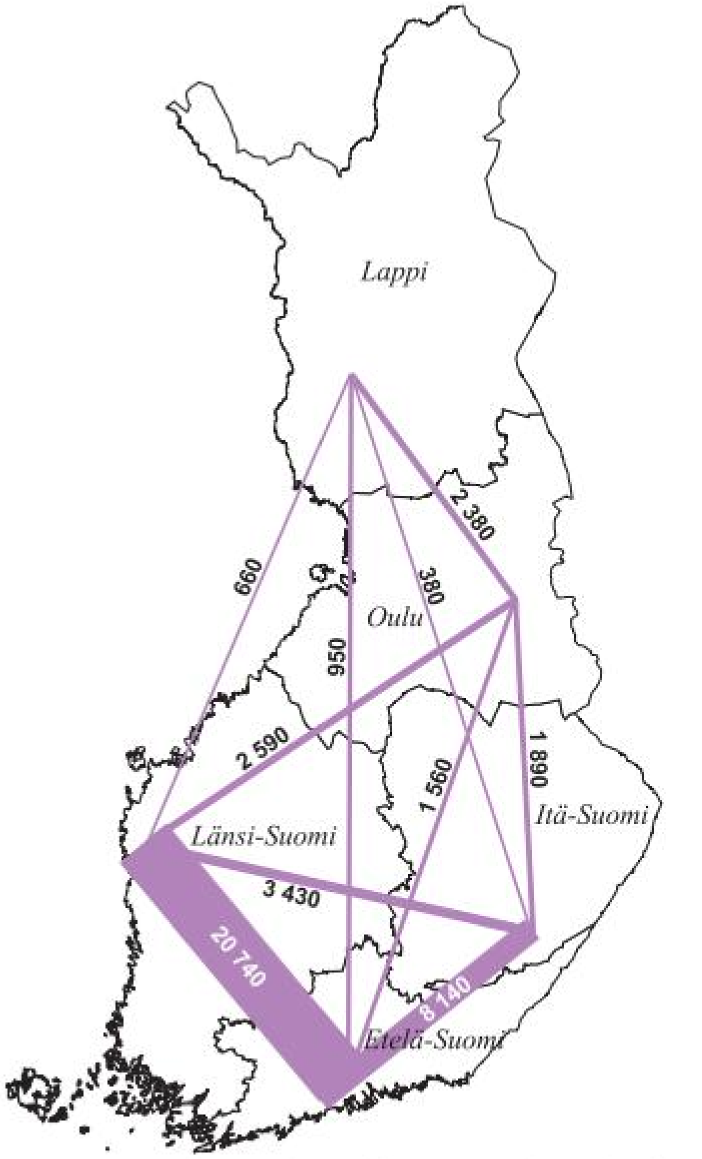
3 Motivation for having fast charging infrastructure

Several car manufacturers seem to be planning to have a fast charging option in their concept. Usually this fast charging is possible up to certain proportion of battery capacity. This is caused by the restrictions defined by the Li-battery chemistry. In Table 3.1 there are listed some samples of EV-models having a fast charging option. Also there is shown the approximated power needed for such fast charging calculated based on the battery capacity and charging time.

Table 3.1 Some EV models with fast charging option [2]

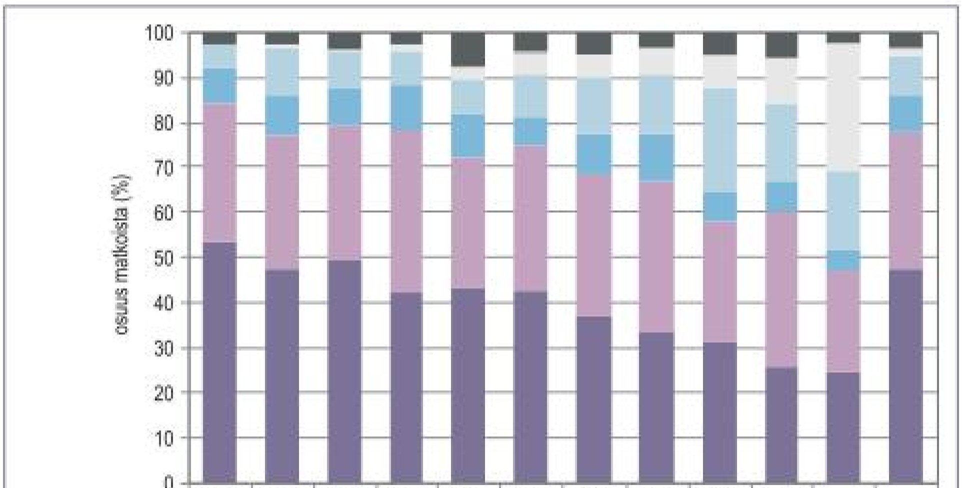
Manufacturer	Model	Intro	Fast charging		P [kW]
BYD Auto	e6	2009-2011	50 %	10 min	300
Chery Automobile Co.	S18	2010	80 %	30 min	60
Hyundai	i10 Electric	2010-2012	85%	15 min	136
Mitsubishi	iMiEV	2009	80%	30 min	64
Nissan	Leaf	2010-2012	80%	30 min	64
Phoenix Motorcars	Phoenix SUT	2010	90%	10 min	216
Phoenix Motorcars	Phoenix SUV	2010	90%	10 min	216
Subaru	Stella EV	N/A	80 %	15 min	64

According to the -04 traffic survey Finns made 96 million trips longer than 100 km, which means in average about 20 trips per person.



Kuva 54 Mannersuomalaisten yli 100 kilometriä pitkät matkat lääneittäin (1000 matkaa/vuosi)

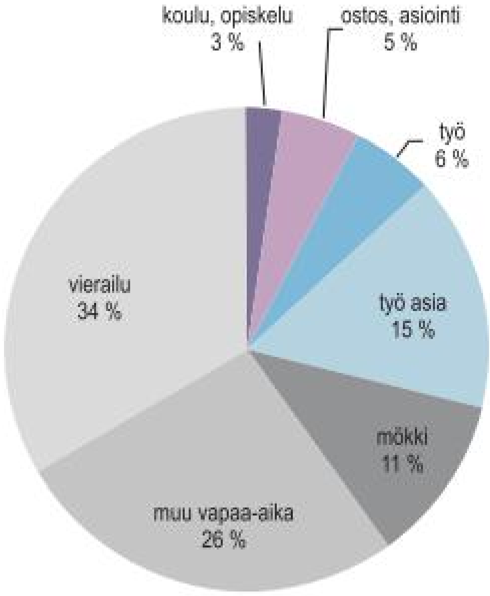
Figure 3.1. Trips longer than 100 km [3]



matkan pituus (km)	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	yli 600	kaikki
muu	3	3	4	3	8	4	5	3	5	6	3	3
lautta, laiva	0	0	0	0	0	1	0	0	1	0	0	0
lentokone	0	0	0	1	2	5	5	6	7	10	28	2
juna	5	11	8	8	7	9	13	13	23	17	18	8
linja-auto	8	9	8	10	10	6	9	11	7	7	4	8
HA matkustaja	31	30	30	36	29	32	31	33	27	34	22	30
HA kuljettaja	53	47	50	42	43	43	37	34	32	26	25	47
kaikki	100	100	100	100	100	100	100	100	100	100	100	100

Kuva 56 Pitkät kotimaanmatkat pääkulkutavan mukaan

Figure 3.2. Trips longer than 100 km [3]



Kuva 55 Pitkät kotimaanmatkat matkan tarkoituksen mukaan

Figure 3.3. Trips longer than 100 km [3]

4 Fast charging stations in Vantaa

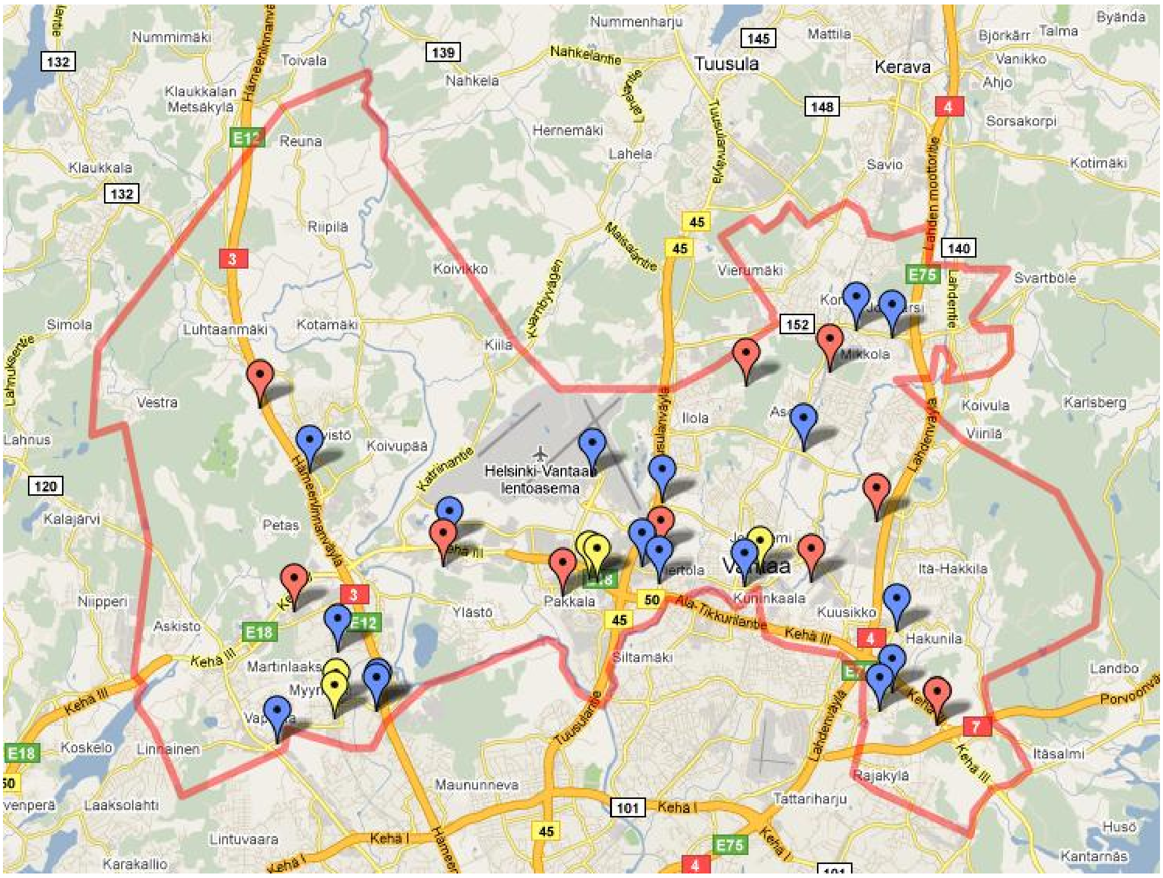


Figure 4.1. Gas stations, primary substations and shopping centers in Vantaa region

The utilization time of peak load of the fast charging station might remain rather low if most of the kilometers are charged at home. For this reason it might be reasoned to believe that in the future an EV fast charging station network cannot be as extensive as is the present gas station network.

Probably only a certain proportion of the present gas stations that are best and most economically conversable to fast charging station, will be conversed to fast charging station. A fast charging station might need a dedicated MV-feeder from the 110/20 kV primary substation and for this reason a suitable place for such is most likely in the proximity of such substation. In Figure 4.1 the red pins present the primary substations and the blue pins present the present gas stations in Vantaa region.

5 A sample of a fast charging station

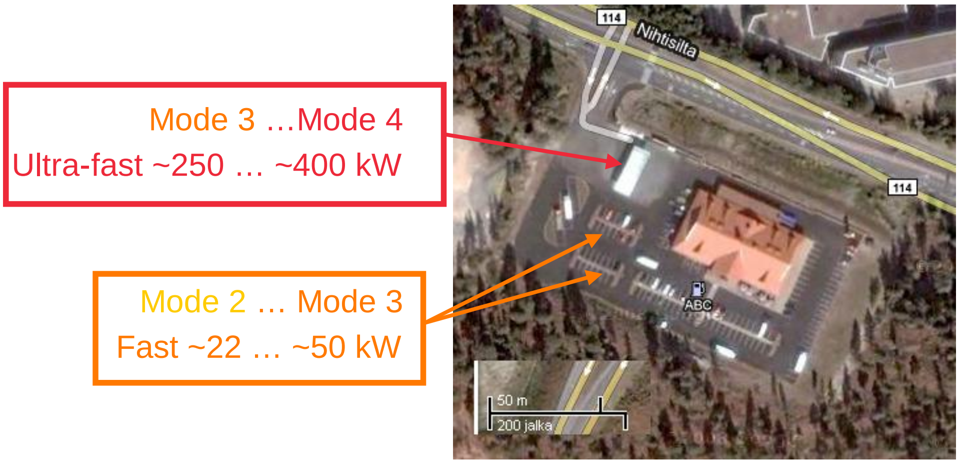


Figure 5.1. A possible sample layout of a modified gasoline station

A conventional gas station is next compared to a fast charging station. The delivered kilometers per hour (station capacity) of an EV fast charging station is fixed to be the same as that of a conventional gasoline pumping station capacity. The gasoline pumping station capacity is approximated as follows.

Gasoline pumping station (for combustion engine)

customer places	8	[1]
time per customer, incl. changing of customer	5	[min]
liters	35	[l]
consumption	6	l/100km
kilometers per filling	583	[km]
Maximum capacity of the station	**56**	**[1000km/h]**

For this sample gasoline station, the maximum delivered capacity is 56 000 km per hour. Now shall be studied, what would be the basic numbers for a comparable EV fast charging station.

Fast charging station (EV)

Maximum capacity of the station	**56**	**[1000km/h]**
Available charging mode		
Charging current	400	[A]
Charging voltage	1000	[V]
AC or DC	DC	
Number of phases (1 tai 3)	1	
Charging power per customer	400	[kW]
Energy consumption of EV	0,25	[kWh/km]
Kilometers per charging	150	[km]
Charged energy	37,5	[kWh]
Customer changing time	2	[min]
Customer-to-customer-time	8	[min]
customer places	**47**	[1]
Peak load of the station	18,98	[MW]

The needed customer places and charging times with different available charging power (high and ultra-high modes) are listed in Table 5.1.

Table 5.1 Number of customer places, charging times and station total power with different available modes

voltage [V]	current [A]	phases [1]	AC/DC	customer places [1]	charging time (passing time) [min]	Station power [MW]
1000	400	1	DC	47	8	19,98
690	250	3	AC	59	10	17,72
690	63	3	AC	198	32	14,94

As can be seen, only the modes with the highest end power rating can compete with gasoline pumping. At 63 amp (690 volt, 3-phase) connection the charging time already exceed half an hour and also the required amount of customer places is very high if the station capacity is wished to keep the same. However, this kind of semi-fast charging might suit customers willing to have lunch break etc. wile waiting for the charging. A combination of both, fast and ultra-fast charging might be worth considering (see Figure 5.1).

6 Discussion

The demand for electric power in fast charging stations (with capacity comparable to present gasoline pumping stations) is extremely high. The peak load is approximately at the same magnitude as that of a typical 110/20 kV primary substation. In addition, the peak load utilization times of such stations might remain rather low, if people in normal circumstances prefer charging at home. This all makes the concept hardly very attractive in business sense. Local energy storages placed at the charging stations might help shaving these peaks and rationalizing the needed grid investments. If the battery swapping technology would be chosen instead of fast charging, the peak load demand problems might not become an issue with the same extent.

It is expected that the full electric vehicles will become common much slower than plug-in hybrid vehicles (PHEV). PHEV would be a rather rational choice in Finnish circumstances, where long trips are needed to be driven occasionally, but most of the kilometers are driven daily in rather short legs. A PHEV could be used on battery during routine daily driving and extended trips could be back-upped with an ICE-driven optimally sized generator. These extra kilometers could be driven using biodiesel or -ethanol etc., which would further help making the entire concept economically sustainable.

References

[1] Bossche, Van den, Peter. Secretary of IEC TC69. Defining and Developing standards. Available at: http://www.park-charge.ch/documents/P_Van_den_Bossche1.pdf

[2] http://www.anitech.net/ev-chargeamerica/electric_vehicles_coming.html

[3] Henkilöliikennetutkimus 04-05 http://www.hlt.fi/HTL04_loppuraportti.pdf