Chapter 16

Electric Vehicles in the Smart Grid

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ABSTRACT

This chapter presents a coordination algorithm for charging electric vehicles that can be used for avoiding capacity problems in the power distribution grid and for decreasing imbalance costs for retailers. Since it is expected that the fraction of electric vehicles will exceed 50% in the next decades, charging these vehicles will roughly double the domestic power consumption. Not all parts of the grid are expected to be able to provide the required power. Good estimates of the vehicles’ use (routes driven, trip duration and length, when and where cars are parked) is crucial information to test the grid. The authors have chosen to use FEATHERS, an agent-based behavioral model, to provide this information. In a first case study, charging is coordinated to prevent grid capacity problems. In a second case study, charging and discharging of electric vehicles is employed by retailers to lower imbalance costs and by vehicle owners to lower charging costs. The coordination scheme can halve the imbalance cost if only charging is considered. If, on the other hand, electric vehicles can both charge and discharge, imbalance costs can completely be avoided and some revenues can be generated. The proposed coordination algorithm is a distributed algorithm, where all sensitive information that is privately owned, such as parking times, trip information, battery management, etc. is only used by the EVs. The functioning of the proposed algorithm is illustrated by simulations. It is shown that the charging can be rescheduled so that grid capacity violations are avoided. The novelty of this work is that both spatial and temporal information is used.
**INTRODUCTION**

Global primary energy production will grow with 8 to 36% by 2035 according to (Energy Information Administration, 2010), but electricity demand grows by around 80% by 2035, requiring 5900 GW of total capacity additions. In addition, electricity generation is entering a period of transformation as investment shifts to low-carbon technologies — the result of higher fossil-fuel prices and government policies to enhance energy security and to curb emissions of CO2. Also, the European Environment Agency (2008) again stated in its most recent Energy and Environment report that the production and consumption of energy place a wide range of pressures on the environment and on public health. At all decision bodies, both locally and at the European level, there is an increased awareness that a significant portion of the rising global demand for electric energy will be met by renewable energy sources which will significantly contribute an increasing share of the total energy supply.

In the last 20 years, a large increase in renewable energy has occurred and this transition seems not to be saturated, yet (Energy Information Administration, 2010). Both wind turbines and solar installations are widely applied. They are usually distributed over large areas and the amount of power produced is not driven by the actual consumption, but rather by the available wind or sunshine. In addition, these renewable energy sources are more difficult to predict, resulting in increasing fluctuations in energy supply and consequently in energy prices. If no measures are taken, this will ultimately result in an unstable power grid. Some days too much power is produced, while on other days the production cannot meet the demands.

From an economical point of view, renewables will cause larger fluctuations on the markets. In case a lot of renewable power is predicted, prices will be low on the day-ahead market and vice versa. All deviations from what is predicted are reflected in the prices on the imbalance market. One promising solution is smart grids. The basic idea is to, partially, adapt the electricity demand to the available supply. During two public holidays in 2012 (Pentecost and 31st of December), when the industrial consumption was low, it happened that too much wind power was available on the Belgian market, resulting in negative prices for power (Elia, 2013). So wind turbines operators actually had to pay to put their produced power on the grid. So far, the opposite did not take place at large scale: during wind still days in winter, it may happen that there is not enough power available from renewable sources and that all countries in e.g. Western Europe need to import power from each other. This might result in some controlled black-outs.

In conclusion, on the one hand, centrally coordinated industrial plants are being replaced by distributed smaller plants. These small plants need to react in a controlled way to changes in demand to keep the power grid stable. On the other hand, the availability of power will change. During peak production, power will be abundantly available, while at other moments shortages may happen. A solution to both problems is to make large parts of the power grid smart by tuning the power consumption to the available power. To achieve this, devices needs to be able to communicate to the grid operators and maybe to each other. This paradigm shift, from centrally coordinated production to distributed coordinated consumption and production is called “the smart grid”.

One of the candidates to operate in a smart grid is electric vehicles (EVs). Nowadays the number EVs is still negligible, but studies point out that the fraction of EVs will be 70% by 2035 (Energy Information Administration, 2010). This includes hybrid and plug-in hybrid vehicles. Typically, an EV consumes about 200 Wh/km. Assuming an average speed of 50 km/h and an average daily use of about 45’, this leads to an additional consumption of about 2-4 MWh for every household equipped with an EV. In other
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