UNIVERSITÀ DEGLI
STUDI DI SALERNO

Ministero dell'Istruzione, dell'Università e della Ricerca

.DIEM

Facoltà di Ingegneria

Dipartimento di Ingegneria dell'Informazione ed Elettrica e Matematica Applicata.

Dottorato di Ricerca in Ingegneria dell'Informazione
XIV Ciclo - Nuova Serie

ABSTRACT

Electric Mobility: Smart Transportation in Smart Cities

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Anno Accademico 2014 - 2015

One of the mega trends over the past century has been humanity's move towards cities. Public Administration and Municipalities are facing a challenging task, to harmonize a sustainable urban development offering to people in city the best living conditions. *Smart cities* are now considered a winning urban strategy able to increase the quality of life by using technology in urban space, both improving the environmental quality and delivering better services to the citizens.

Mobility is a key element to support this new approach in the growth of the cities. In fact, transport produces several negative impacts and problems for the quality of life in cities, such as, pollution, traffic and congestion. Therefore, *Sustainable Mobility* is one of the most promising topics in smart city, as it could produce high benefits for the quality of life of almost all the city stakeholders.

The boldest and imminent challenge awaiting mobility in smart cities is the introduction of the electricity as energy vector instead of fossil fuels, concerning both the collective and the private transports. *Electric public transport* include electric city buses, trolleybuses, trams (or light rail), passenger trains and rapid transit (metro/subways/undergrounds, etc.). Even though railway systems are the most energy efficient than other transport modes, the enhancement of energy efficiency is an important issue to reduce their contributions to climate change further as well as to save and enlarge competition advantages involved. One key means for improving energy efficiency is to deploy advanced systems and innovative technologies.

Additionally, electrification of the private road transport has emerged as a trend to support energy efficiency and CO_2 emissions reduction targets. According to the International Energy Agency, in order to limit average global temperature increases to 2°C - the critical threshold that scientists say will prevent dangerous climate change -, by 2050, 21% of carbon reductions must come from the transport sector. Full *electric vehicles* (EVs) use electric motor and battery energy for propulsion, which has higher efficiency and lower operating cost compared to the conventional internal combustion engine vehicle. Today, there are more than 20 models offered by different brands covering different range of sizes, styles, prices and powertrains to suit the wider range of consumers as possible. The continuous development of lithium ion battery and of fast charging technology will be the major facilitators for EVs roll out in the very near future. However, the present EVs industry meets many technical limitations, such as high initial price, long battery recharge time, limited charging facilities and driving range.

Although it is desirable a fast development from the start of electric mobility, its impact on the existing power grid must be assessed beforehand to see if it is necessary prior an adjustment of power infrastructure or/and the introduction of new services in the power grid. In fact, the interconnection of EVs on the power grid for charging their batteries potentially introduces negative impacts on grid operation: uncontrolled charging can significantly increase average load in the existing power systems, with problems in terms of reliability and overloads. If uncontrolled EV charging is added to the system, this can have effects both at the distribution and at the generation level.

Controlled or smart charging will allow a much greater number of cars in the cities, avoiding local overload and allowing a faster EVs penetration without requiring an imminent improvement of the electricity generating and grid capacity. Smart charging might also allow load balancing both at sub-station and at the grid level, particularly with charging at peak wind supply times. This kind of use of EV battery capacity for storing electric energy may ease the integration of large scale intermittent electricity sources such as renewable energy sources.

The proposed PhD Dissertation is developed in the context just described, mainly focusing the attention on the impact that electric mobility will have on the power systems and the effectiveness of solutions aimed to increase the reliability and resilience in the smart grid. In particular, it is addressed a scenario analysis regarding the electric vehicles charging management and some innovative solutions to increase energy efficiency in electrified transport systems. The first chapter emphasizes on the key aspects related to the sustainable mobility in the smart cities of the future. It provides a brief overview on the transport sector energy consumption expected in the next years. In particular, the chapter shows the significant contribution that the electrification of urban transport may provide to the sustainable mobility, and the serious concerns related to its impact on existing power systems.

Chapter 2 proposes a solution method for an optimal generation rescheduling and load-shedding (GRLS) problem in microgrids in order to determine a stable equilibrium state following unexpected outages of generation or sudden increase in demand. The chapter mainly focuses on the mathematical formulation of the GRLS problem and the proposed solution algorithm. Finally, simulations results carried out by using a real case study data are presented and discussed.

In Chapter 3, a simple and effective methodology is proposed to analyze data acquired during the fulfillment of the *COSMO* research project, and to identify typical load pattern for the EVs charging. The chapter also presents a novel scheduling problem formulation, flattening the demand load profile and minimizing the EVs charging costs, according to the electricity prices during the day. Finally, some simulations results are discussed, showing the effectiveness of the proposed methodology. Chapter 4 introduces some innovative solutions for energy efficiency in urban railway systems focusing, in particular, on energy storage systems and eco-drive operations in metro networks. The mathematical formulation of these optimization problems and the proposed solution algorithms are illustrated and discussed. The obtained results are part of the activity carried out in the *SFERE* research project. Finally, Chapter 5 ends the Dissertation with some concluding remarks and further developments of the proposed research activity.