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\section*{Introduction}

The transportation sector has lately been taking a huge part in the disastrous pollution crisis that is widespread around the globe. Thus, the vehicles’ electrification keeps being adopted for its great environmental impact and massive reduction of toxic greenhouse gases emissions. Furthermore, the electric vehicles’ use can be referred to, not only for environmental purposes, but also for energy storage and retrieval. In this case, the energy flow is optimized and controlled based on the electricity supply and demand and the amount of energy available in the storage batteries. Hence, this paper focuses on the energy storage within the vehicles’ batteries. Eventually, this study investigates the consumption and production of energy and their reversible flows aiming to fulfill all the energetic needs of a residential household with the association of renewable energy sources. The system also seeks the fulfillment of the electric vehicles batteries’ needs as means of storage and retrieval, and those of the electric grid when needed. Therefore, the study aims to build an energy management strategy in order to reach a balanced production/consumption system seeking the control and regulation of flows of energy through the elaboration of control law based optimization algorithms.

\section*{Overview}

The studied system involves a residential household with renewable energy sources supply, particularly connected to photovoltaic panels and a wind turbine. It also includes a fleet of electric vehicles that, besides its energy needs and personal usage, can be referred to for energy storage and retrieval. The electric grid also interferes to fulfill the energetic needs or recover the excess of energy when the rest of the system’s components are not enough for the balance inquiry between the energy production and consumption. Specifically, a heuristic algorithm of regulation related to the studied system is first defined through comparing the production and consumption of energy, then verified through Matlab simulations in order to tighten the margin of difference between the supply and demand of electricity. Consequently, this regulation evolves into 3 cases:

1. The energy production exceeds its consumption: in this case, the energy produced by renewable energy sources surpasses the consumption of the home appliances and vehicle’s personal needs, and then the excess of energy can be stored in the electric vehicle’s battery and consecutively in a fleet of electric vehicles. Hence, as soon as there’s an excess of production, the charging process of the electric vehicles intended for energy storage (the energy of which is not particularly needed for their personal trips only) is launched progressively, and once the state-of-charge SoC of the charging vehicle reaches its allowed maximum, the charging switches to the next vehicle (or the next group of
vehicles) of the fleet. So, as long as the vehicles are charging, a new production/consumption comparison is assessed every 5% SoC increase in order to make a decision concerning whether to proceed in the vehicles’ charging or switch to another cycle where the consumption would beat the production. However, once all the fleet’s vehicles are charged, and in case the production still tops the consumption, the excessive energy would then be injected into the electric grid for beneficial incentives, economic regulations and financial purposes.

2. The energy production and consumption are equivalent, thus the balanced system is attained: In this case, the system is in equilibrium and it functions normally without involving any energy storage or retrieval processes. So, the energy produced by the photovoltaic panels and wind turbine would be congruent with the house consumption of appliances and electric vehicle’s needs. The energetic model of the system would then be depicted as follows:

$$N_{H_j} \times P_{f,PV} \times k + \frac{0.01328 \times D^2 \times v^3}{365.25} = \sum_{\text{home appliances}} N_{H_j} \times P_f + E_0 \times d \quad (1)$$

Whereas $N_{H_j,PV}$, $P_{f,PV}$, $k$, $D$, $v$ respectively represent the daily number of hours of use of the photovoltaic panels, their operating power, a correction factor of 1.3, the wind turbine’s rotor diameter and the annual average wind speed. On the other hand, $N_{H_j}$, $P_f$, $E_0$, $d$ represent the daily number of hours of use of the functional home appliances, their operating power, the energy linked to the on-board electric outlet, and the distance travelled by the vehicle. It is to be mentioned that the home appliances refer to any functional household appliances such as those related to heating, ventilation, cooking, lighting, washing, drying, refrigerator, audiovisual and electronics.

3. The energy consumption exceeds its production. Differently, this case comprises the production falling short of the consumption. Thus, the supply of photovoltaic panels and the wind turbine, not being able to fulfill all the household’s needs, the lack of energy would then be covered by the energy already stored within the fleet’s batteries. Consequently, the discharging of the vehicles specifically intended for storage and retrieval is launched, and these vehicles would be discharging progressively, one by one, until reaching their minimal SoC, where a certain amount of energy remains in their batteries for their personal planned trips. Moreover, during discharge, the algorithm keeps repeating the production and consumption comparison with intervals of 5% SoC drop, in order to switch again to the first case or second case when needed. In case the stored energy would still not be enough to cover the lack of production, the insufficiency would then be insured by the electric grid.

Furthermore, it is to be noted that the SoC value of each vehicle in the fleet as well as the energy stored or retrieved are completely stochastic, and once the vehicles are plugged-in, the charging/discharging processes are launched based on the available SoC, thus the amount of energy already contained in their batteries.

Conclusion and perspectives

This study proposes an energy management strategy for the control and regulation of energy flowing between a residential household supplied by renewable energy sources, electric vehicles and the grid, where the vehicles would be used not only for personal needs but also for energy storage and retrieval means. The proposed flow control is performed through the development of a control law based algorithm where the regulation directly depends on the energy consumption and production and their evolution with regards to each other. As a future perspective, it would be interesting to shortly validate the proposed algorithm with a simulation, verified at a later stage by a realistic prototype.

References