

# Impact of the integration of electric vehicles in low voltage residential electrical networks

## Impacto de la integración de los vehículos eléctricos en las redes eléctricas de baja tensión residencial

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### ABSTRACT

This paper assess the impact of the inclusion of electric vehicles on existing residential networks in Santander, a region in Colombia. The study is based on consumer profiles supplied by the network operator. It takes in account the national electrical code and charging profiles of commercial electric vehicles. The paper aims to determine whether an electrical vehicle can be plugged in the existing electrical low voltage network.

**Keywords:** Residential electrical networks, charging infrastructure, electric vehicles.

### RESUMEN

En este trabajo se evalúa el impacto de la inclusión de los vehículos eléctricos en las redes residenciales existentes en Santander, una región en Colombia. El estudio se basa en perfiles de consumidores suministrados por el operador de red y toma en cuenta las especificaciones y normas que regulan el diseño y construcción de redes eléctricas residenciales, así como los perfiles de carga de vehículos eléctricos comerciales. El trabajo tiene como objetivo determinar si un vehículo eléctrico puede ser conectado en la red de baja tensión eléctrica existente.

**Palabras clave:** Redes eléctricas residenciales, infraestructura de carga, vehículos eléctricos.

### Introduction

Residential low voltage electric networks in Colombia design respects technical specifications determined by a national electrical code [2]. Plugging electrical vehicles (EV) in these networks increases not only the power delivered but also the power losses and voltage drops [1-5].

This paper focuses on determine the impact of plugging EV on the existing electrical infrastructure for residential users in Santander, a region of Colombia. The national electrical code specifies the minimum wire sections for the feeders, then it indirectly specifies the minimal nominal power for residential units. The national code specifies for each socioeconomic strata the section of the conductors and the quantity of circuits are determined by the constructed area.

This work aims to determine whether is possible to connect an EV as extra electrical load to the existing infrastructure in residential centers. It is based on the information provided by the network operator, the national electrical code for residential networks and the charging profiles for EV commercially available in the market.

As the EV becomes a reality, not only on developed countries, this research aims to be a contribution to the implementation of poli-

cies that determine technical specifications to design new low voltage residential networks where EV can be safely connected in Santander.

There are different scenarios for the study of integration of electric vehicles in low voltage residential electrical networks. The first considers single-family residence units (houses) and the second considers multi-family residence units (buildings). In the former the feeder, the metering point and the EV charger are relatively close; in the latter the metering is close to the point of recharge, but far from the feeder. This paper focuses on the first scenario.

### CHARGE OF EV IN A LOW VOLTAGE RESIDENTIAL ELECTRICAL NETWORK.

Safely charging EVs using the existing electrical infrastructure depends on the residential unit load profile, on the wire section and also on the type of charger used in the vehicle.

#### *Stratification in Colombia.*

Socioeconomic stratification in Colombia is a geographical classification of residential areas based on the average income of the residents in the sector. This allows differentially charging public services: the high strata pay more and the lower strata pay less. As the energy consumption increases with the household income,

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stratification is used to determine technical specifications to design residential electrical networks. For this reason, electrical networks in high strata are designed with higher nominal power than networks in low strata.

#### Average consumption profiles.

Figures 1 and 2 show profiles of consumption determined by the regional network operator in Santander. Depending on the socio-economic strata, the average consumption in Santander is 4.04, 3.67, 5.13, 5.99, 6.94 and 7.88 kW/day, respectively for strata 1 to 6.

#### Low-voltage residential electrical networks.

Residential electrical circuits for residential units in Colombia can be 120V single-phase, 208V bi-phase or 208V three-phase. The minimum gauge cable in all topologies is the AWG #8. Depending on the topology the minimum rated powers in residential units are 4.56, 7.9 and 13, 69 kW.

#### EV chargers.

This work scope to study existing residential low voltage networks. Taking account of the rated powers on the national electrical code, it can be concluded that semi-fast and fast chargers cannot be considered, at least with the current normativity. The inclusion of these chargers would require updating the national electrical code for low voltage networks. As only slow chargers could be connected to existing residential networks, in order to simplify the study, only the peak power of the EV chargers is considered.

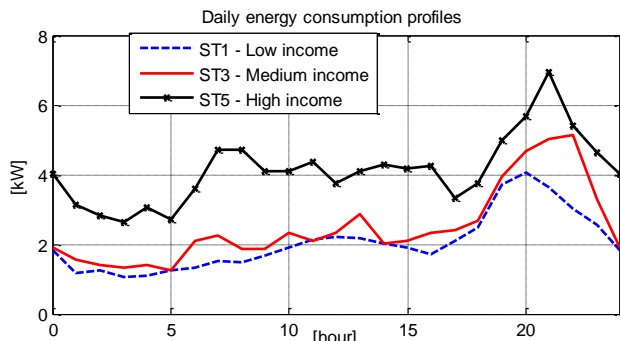


Figure 1. Consumption profiles in residential areas strata 1, 3 and 5.

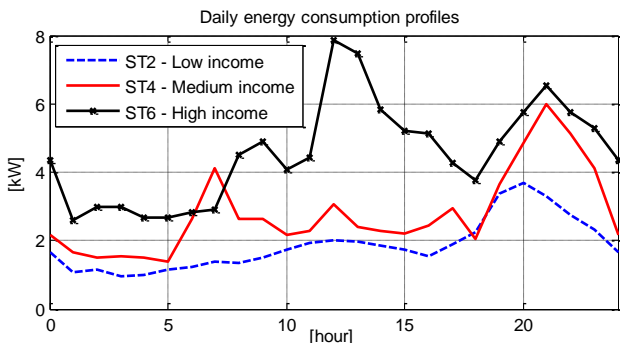


Figure 2. Consumption profiles in residential areas strata 2, 4 and 6.

#### Simulation results.

Simulations are presented for the lower and the higher strata as representative for this study. Two different scenarios are considered. In the worst case scenario the EV is charged simultaneously with the peak consumption. This is a likely scenario considering that network operators in Colombia do not apply differential charges in peak hours. A second scenario considers the hypothetical inclusion of differential electricity charges and the charge of the EV is performed in valley hours. This is the ideal scenario to the user because the lower cost of the energy and for the operator which can have flatter demand curves. For simulation the 3.3kW Nissan Leaf charger is considered.

Figures 3 and 4 present simulation results for the lower (ST1) and the higher (ST6) strata respectively. Two different cases are considered: single phase and bi-phase circuits. Simulations results show that in low strata residential units with single-phase circuits the considered EV cannot be charged using the existent electrical infrastructure, nevertheless, in bi-phase and then in three phase circuits it is possible to safely charge EVs at least using slow chargers. This is mainly due the relatively low power consumption profiles compared with the minimum rated powers in the national electrical code.

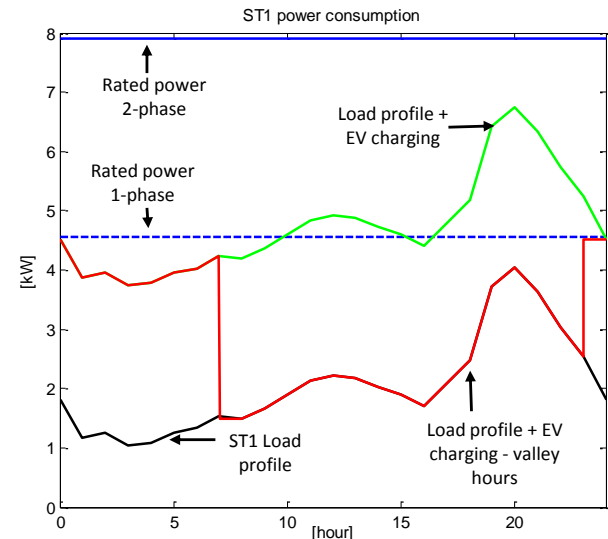


Figure 3. Power profile - Charge of EV in ST1.

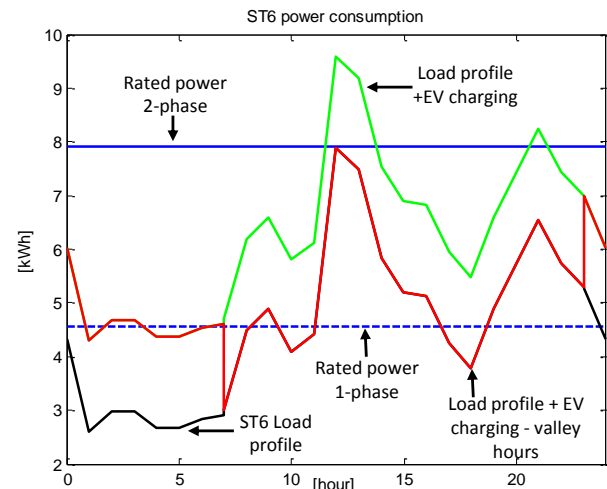


Figure 3. Power profile - Charge of EV in ST1.

Simulation results shows that in higher income strata neither in single-phase nor in bi phase circuits EV can be safely charged. Nevertheless, in three phase circuits with a rated power of 13.69kW the considered EV charger can be plugged to the existent electrical infrastructure

### Conclusions and outlooks.

During the next years it is not expected to have EV connected to the grid in low income residential sectors; however it seems that existing EV can be connected in bi phase and three phase circuits in residential networks in single-family resident units. On the other hand, in high income residential sectors where the penetration of EV is expected to be fast increasing, it could be more complicated to connect EV due to the fact that the power consumption is high and the networks are then operating close to the nominal power. Only in three phase circuits EVs could be safely charged.

According to the results obtained on this research, it seems that with the existent normativity, electrical vehicles cannot be connected to the low voltage networks in Santander, Colombia.

For this reason it could be necessary to either update the national electrical code to consider deploying new electrical infrastructure to enable charging EV in safety.

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