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Company Energy Management System for Optimising EV Charging: Integration of V2V Technology and Real-Time Control

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Abstract

This paper proposes a company energy management system (CEMS) composed of an optimisation model, a forecasting module, a market price API, and a real-time control module, and a mobile application. The CEMS is applied to one electric vehicle supply equipment (EVSE) with six connectors, three non-controllable (on-off), and three controllable (smart charging). The CEMS manages the EVSE to meet user demands while respecting the technical constraints of the three-phase network of the company and non-controllable loads. Additionally, one smart connector is equipped with vehicle-to-everything (V2X) technology, referred to here as vehicle-to-vehicle (V2V), as it discharges one vehicle to charge another. A case study based on a company system with one EVSE and typical company demand profile limited by a three-phase transformer of 75kVA was considered to validate the CEMS proposed. Therefore, the results obtained show effective management of the EVSE, meeting user needs according to priority levels based on roles within the company, such as directors (super priority), fleet (high priority), employees (medium priority), and visitors (low priority) while preserve the proper functioning of the company.

Nomenclature

Indices

$conn$	Index for connectors
ev	Index for electric vehicles (EVs)
$evse$	Index for electric vehicle supply equipment (EVSE)
f	Index for phase
t	Index for time

Parameters

C_t^{buy}	Import price at time t
C_t^{sell}	Export price at time t
$degcost$	Battery degradation cost factor
E_{ev}^{min}	Minimum allowable SoC for EV

E_{ev}^{max}	Maximum battery capacity of EV
E_{ev}^{target}	Target SoC for EV
η_{conn}	Charging efficiency of the connector
η_{ev}	Charging efficiency of EV
$\overline{p}_{ev}^{ch}$	Maximum charging power rate of EV
$\overline{p}_{ev}^{dch}$	Maximum discharging power rate of EV
$penalty1$	Penalty cost associated with
$penalty2$	Penalty cost associated with
$priofactor$	Priority weighting factor based on the EV user's role within the company

Variables

$a_{ev,t}$	Binary variable that represents if EV is charging at time t
$b_{ev,t}$	Binary variable that represents if EV is discharging at time t
$E_{ev,t}^{ev}$	State of charge of EV at time t
$E_{ev,t}^{minsocrelax}$	Relax variable of EV SoC
$E_{ev,t}^{targetrelax}$	Relax variable of EV Target SoC
$P_{conn,t}^{conn}$	Power allocated to connector at time t
$P_{ev,t}^{evch}$	Charging power of EV at time t
$P_{ev,t}^{evdch}$	Discharging power of EV at time t
$P_{f,evse,t}^{evse}$	Phase-specific power of EVSE at time t
$P_{f,t}^{import}$	Phase-specific power imported from the grid at time t
$P_{f,t}^{export}$	Phase-specific power exported to the grid at time t
y_t	Binary variable that represents if company is importing at time t
z_t	Binary variable that represents if company is exporting at time t

1 Introduction

As the adoption of electric vehicles (EVs) accelerates globally [1], [2], the efficient management of charging infrastructure has emerged as a key challenge, particularly in corporate settings where multiple users with varying priorities and schedules rely on a limited number of EV supply equipment (EVSE) [3].

Several studies have been conducted in recent years to explore the optimal conditions under which EVs should be charged. These investigations have considered a variety of scenarios, such as the influence of demand response (DR) strategies that incorporate vehicle-to-grid (V2G) technology, allowing EVs to function as dynamic energy resources by both drawing power from the grid and supplying it back during high-demand periods [4], [5]. The implementation of these strategies has been analysed across various settings, including public parking infrastructures [6] and residential energy communities [7], each presenting unique operational constraints and user behaviour patterns. The authors in [8] explore the integration of smart EV charging into a residential home-energy-management system (HEMS). It develops a coordinated scheduling framework that jointly optimizes household loads and EV charging, using load and price forecasts, to minimize energy costs (and emissions) while respecting grid and user-driven constraints. Through simulation on realistic consumption and driving profiles, the authors demonstrate that their approach shifts charging to off-peak periods, smooths household demand peaks, and can adapt dynamically to weather and price driven uncertainties. A simulation model for an in-company smart EV charging system was proposed in [9]. The authors design a virtual environment that captures the interaction between multiple EV chargers, corporate load profiles, and grid constraints, enabling testing of diverse charging strategies without real-world deployment in [9]. Their model incorporates user arrival/departure schedules, charging power limits, and dynamic pricing signals, and supports both centralized and decentralized control algorithms. Through scenario analysis, they demonstrate that smart-charging policies can flatten demand peaks, reduce energy costs, and respect on-site transformer limits, providing a practical tool for firms to evaluate and implement optimized EV-charging solutions. These studies highlight the importance of tailoring energy management approaches to the specific characteristics of each environment, a principle that forms the basis of the development Company Energy Management System (CEMS) presented in this paper.

The CEMS proposed here is focuses in to optimize the use of EVSE in a corporate environment. The CEMS integrates an optimisation model, forecasting module, market price application programming interface (API), real-time data, mobile application, and control modules. These components ensure the EVSE meets users' needs, minimizes energy costs, and adheres to grid constraints. Key challenges addressed include balancing user demands, efficient energy distribution, and integrating smart technologies like vehicle-to-everything (V2X). The system's deterministic optimisation model is ideal for accurately characterizing parameters like demand profiles and grid limitations [10]. Figure 1 show the CEM proposed.

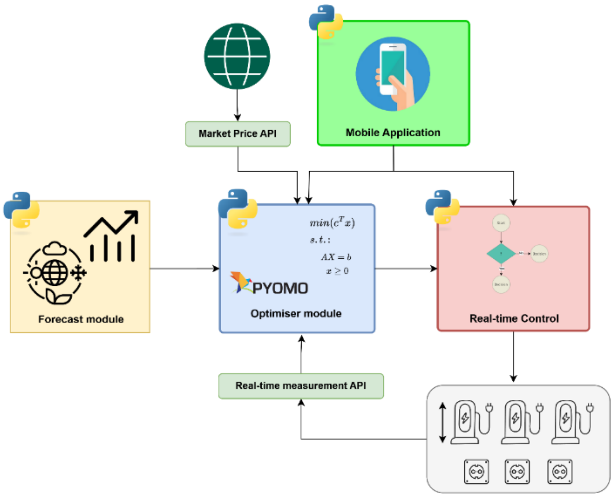

Figure 1: CEMS proposed.

2 Company Energy Management System

The CEMS is applied to a single EVSE with six connectors, divided into two types, non-controllable connectors (on-off): three connectors provide either full power or no power, offering limited flexibility during peak demand when power must be shared among users, and controllable connectors (smart charging): the other three connectors allow real-time control of the power delivered to each EV. Smart charging adjusts the charging rate based on user priority, grid conditions, and energy market prices. The CEMS optimisation model ensures efficient power distribution by prioritizing users (directors, fleet, employees, visitors) and allocating charging resources accordingly [11]. The CEMS operates within the constraints of a three-phase power network, preventing phase overloads while managing competing non-controllable loads. Using a market price API, it receives real-time energy prices to optimize costs by scheduling charging during cheaper periods. A forecasting module predicts future energy demand, enabling the system to adjust schedules and reduce inefficiencies from unbalanced demand. The mobile application allows end users to interact with the CEMS by introducing information related to energy requirements, initial state-of-charge (SoC), departure time, and users' conditions inside the systems (whether the user is an employee, visitor, fleet or the director). The real-time control module allocates charging resources dynamically, communicating with the EVSE to monitor non-controllable and smart connectors. It promptly addresses unexpected demand changes, ensuring system stability, especially during peak hours when charging infrastructure is in high demand.

One of the smart connectors in the system features V2X technology, enabling bidirectional energy flow. This study focuses on vehicle-to-vehicle (V2V) functionality, where one EV can transfer energy to another, adding flexibility during high demand. V2V helps reduce grid strain by redistributing energy between EVs, allowing the system to meet super-priority users' needs without relying on external power.

The CEMS uses a priority-based management, categorizing users into: Directors (super priority): Directors' vehicles are charged first, even during peak demand, ensuring minimal downtime. Fleet (high priority): Fleets' charging needs are met when energy is available after super-priority users. Employee (medium priority): Employee' charging needs are met when energy is available after directors and fleet users. Visitors (low priority): Visitors are charged only if excess capacity remains after directors, fleet and employees are served. This hierarchy ensures efficient resource allocation.

The main technical challenge addressed by the CEMS is managing the three-phase network, ensuring balanced power distribution to avoid overloads that could cause equipment failure or disruptions. The system accounts for non-controllable loads competing for power and continuously monitors and adjusts energy distribution to optimize smart EVSE performance while respecting network constraints.

2.1 Forecasting module

The forecasting module proposed in this paper was built to provide reasonably close predictions up to the last EV's departure time, within the six EVs. The process begins with the collection of essential input data, which includes the forecast horizon, historical export pricing data from the Iberian market [12], and historical weather data [13] based on geographic coordinates (latitude and longitude). This data forms the basis for creating features that reflect time-based and environmental patterns.
In the feature engineering stage, the raw inputs are turned into meaningful variables. These include datetime details, weather conditions, and lag variables that help the model understand trends and dependencies over time. These features are then used by our forecasting models to make predictions.
For the forecasting itself, a combination of advanced machine learning algorithms is used, specifically *XGBoost Classifier*, *XGBoost Regressor*, and *Random Forest Regressor*. They allow the system to generate precise short-term forecasts based on both historical patterns and future weather conditions.
Once the initial predictions are made, a post-processing step ensures that the outputs meet operational requirements. This stage includes eliminating negative forecast values, which are physically meaningless in many energy applications, and applying improvements tailored to photovoltaic (PV) performance metrics.
The final output of the module consists of detailed predictions for the next hours. These forecasts serve as an input for the optimisation module, which uses them to support real-time control strategies, improve overall system performance, and contribute to more efficient and sustainable energy management.

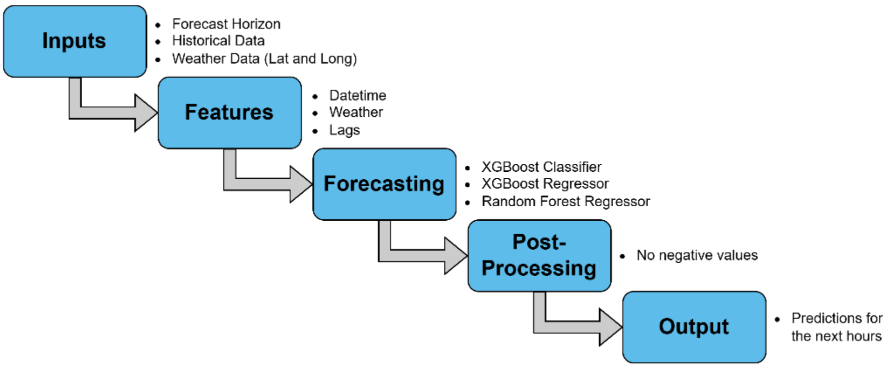

Figure 2: Forecasting module schema.

2.2 User interface application

The user interface serves as the principal interaction point between EV users and the CEMS, facilitating the collection of key input parameters. These include the EV's battery capacity, maximum charging and discharging power limits, round-trip efficiencies, the user's intended departure time, and the desired target SoC.

2.3 Optimisation module

The optimisation module of the CEMS takes as input the forecast data, company infrastructure specifications from the installation site, and user-specific information collected via a mobile application, which includes EV availability, battery status, and user preferences. Using this data, the module employs a solver to compute the most efficient charging and discharging schedules, balancing energy costs, user demands, and grid constraints. Although the company operates on a three-phase electrical system, it utilizes only single-phase connectors. As a result, the optimisation process treats each phase independently, ensuring that EVs assigned to different phases do not interfere with one another.

2.3.1 Operational constraints of EVs

The set of equations (1) – (8) represents the operational constraints of EVs. These constraints are necessary to ensure that the EVs operate within their physical and technical limits, respecting the battery's energy capacity, the charging power limits of both the EV and the connectors, and the charging and discharging efficiencies. The limit for power consumption required for EV operation is established on equation (1), according to the maximum EV charger power ($\overline{p}_{ev}^{ch}$), considering the binary decision variable $a_{ev,t}$ that define, under the optimal decision, if it is adequate to schedule EV charging or not taking into account that the EV is connected to the connector related ($place_{con} = id_{ev}$). Similarly, equation (2) establishes the corresponding limit for discharging power, considering the binary decision variable $b_{ev,t}$ that define, under the optimal decision, if it is adequate to schedule EV discharging or not and only when the V2X technology is available in the EV, defined by the binary parameter $v2g_{ev}$, and taking into account that the EV is connected to the connector related ($place_{con} = id_{ev}$). The binary decisions variables, that indicate whether the EV is charging, discharging, or idle, cannot be equal to 1 at the same time, ensuring that an EV cannot charge and discharge simultaneously, as represented by equation (3).

The energy stored in the initial period of the optimisation horizon, as expressed in equation (4), depends on the initial SoC of the EV's battery ($E_{ev,t=0}^{ev}$), the power consumption of the EV ($P_{ev,t}^{evch}$), and the charging efficiency of both EV (η_{ev}) and connector (η_{conn}), the discharging power of the EV ($P_{ev,t}^{evdch}$), and the discharging efficiency of both EV (η_{ev}) and connector (η_{conn}). Equation (5) models the evolution of energy stored in each EV battery for all time steps after the initial one. The EV minimum capacity constraint (6) ensures that the battery of each EV does not discharge below a predefined minimum energy level, essential to protect the battery's health, and comply with manufacturer-imposed restrictions. Equation (7) ensures that the energy stored in the EV battery reaches the target SoC defined by the user, while Equation (8) guarantees that this energy does not exceed the battery's maximum allowable capacity.

$$P_{ev,t}^{evch} \leq \overline{p}_{ev}^{ch}.a_{ev,t}, \qquad \forall ev,t \;\&\; place_{con} = id_{ev} \tag{1}$$

$$P_{ev,t}^{evdch} \leq \overline{p}_{ev}^{dch}.b_{ev,t}.v2g_{ev}, \qquad \forall ev,t\& \; place_{con} = id_{ev} \tag{2}$$

$$a_{ev,t} + b_{ev,t} \leq 1, \qquad \forall ev,t \tag{3}$$

$$E_{ev,t}^{ev} = E_{ev,t=0}^{ev} + P_{ev,t}^{evch}.\eta_{ev}.\eta_{conn}.\Delta_T - P_{ev,t}^{evdch}\Delta_T.\frac{1}{\eta_{ev}.\eta_{conn}}, \qquad \forall ev,conn,t = 0 \tag{4}$$

$$E_{ev,t}^{ev} = E_{t-1}^{ev} + P_{ev,t}^{evch}.\eta_{ev}.\eta_{conn}\Delta_T - P_{ev,t}^{evdch}\Delta_T.\frac{1}{\eta_{ev}.\eta_{conn}}, \qquad \forall ev,conn,t > 1 \tag{5}$$

$$E_{ev,t}^{ev} + E_{ev,t}^{minsocrelax} \geq E_{ev}^{min}, \qquad \forall ev,t \tag{6}$$

$$E_{ev,t}^{ev} + E_{ev,t}^{targetrelax} \geq E_{ev}^{target}, \qquad \forall ev,t = last \tag{7}$$

$$E_{ev,t}^{ev} \leq E_{ev}^{max}, \qquad \forall ev,t \tag{8}$$

2.3.2 Operational constraints of connectors and EVSE

The set of equations (9)–(14) represents the operational constraints of connectors and EVSE. These constraints are essential to ensure that the charging and discharging operations of all connectors are executed safely, efficiently, and within technical limits imposed by EVSE. Equation (9) defines the power consumption associated with each connector, reflecting the charging and discharging activity of the EV connected to it. Constraints (10) and (11) define the charging power behaviour for smart charging connectors ($type_{conn} = 1$) and non-controllable connectors ($type_{conn} = 2$), also known as on-off sockets. For controllable connectors, the charging power can vary between zero and maximum limit, denoted by $\overline{p}_{conn,t}^{conn}$ respectively. This means the system has flexibility to set the charging power based on optimisation needs, without necessarily using the maximum available power. In contrast, non-controllable connectors operate in an on/off manner, charging at the maximum power $\overline{p}_{conn,t}^{conn}$ or not charging at all. Equations (12) and (13) ensure that the charging and discharging power of each connector, respectively, does not exceed the limit allowed by the EVSE on the specific phase to which it is connected. Equation (14) states that the total charging power of the EVSE is equal to the sum of the charging powers of all its connected connectors.

$$P_{conn,t}^{conn} = (P_{ev,t}^{evch} - P_{ev,t}^{evdch}), \qquad \forall ev, conn, t \ \& \ place_{conn} = id_{ev} \tag{9}$$

$$P_{conn,t}^{conn} \leq \overline{p}_{conn,t}^{conn} . evconnected_{ev,t}, \qquad \forall ev, conn, t \ \& \ place_{conn} = id_{ev} \ \& \ type_{conn} = 1 \tag{10}$$

$$P_{conn,t}^{conn} = \overline{p}_{conn,t}^{conn} . evconnected_{ev,t} . x_{conn,t}, \qquad \forall ev, conn, t \ \& \ place_{conn} = id_{ev} \ \& \ type_{conn} = 2 \tag{11}$$

$$\sum_{conn \in CONN} \sum_{f \in F} P_{conn,t}^{conn} \leq \overline{p}_{evse,f}^{evse}, \qquad \forall conn, f, t, evse \ \& \ conn \ in \ evse \ \& \ conn \ in \ phase = f \tag{12}$$

$$\sum_{conn \in CONN} \sum_{f \in F} P_{conn,t}^{conn} \geq -\overline{p}_{evse,f}^{evse}, \qquad \forall conn, f, t, evse \ \& \ conn \ in \ evse \ \& \ conn \ in \ phase = f \tag{13}$$

$$P_{f,evse,t}^{evse} = \sum_{conn \in CONN} \sum_{f \in F} P_{conn,t}^{conn} , \qquad \forall conn, f, t, evse \ \& \ conn \ in \ evse \ \& \ conn \ in \ phase = f \tag{14}$$

2.3.3 **Operational constraints of power system**

The set of equations (15) – (18) represents the operational constraints of the company system. These constraints ensure that the system does not simultaneously import and export power, while also respecting the limits imposed by the installed power and transformer ratings. Equation (15) represents the energy balance in the system, considering three-phase unbalanced load consumption, and three-phase unbalanced EVSE. Constraints (16) and (17) ensure that the power flow respects the limits imposed by the transformer. The binary variable y_t indicates that the system is importing power at time t, while z_t indicates that it is exporting at time t. Equation (18) guarantees that both operations do not occur simultaneously, since the system cannot import and export power at the same time.

$$P_{f,t}^{import} - P_{f,t}^{export} = \sum_{cs \in CS} P_{f,evse,t}^{evse} + P_{f,t}^{l} , \qquad \forall f, t \tag{15}$$

$$P_{f,t}^{import} \leq \ P_{f,t}^{t} \, y_t, \qquad \forall f, t \tag{16}$$

$$P_{f,t}^{export} \leq \ P_{f,t}^{t} \, z_t, \qquad \forall f, t \tag{17}$$

$$y_t + z_t \leq 1, \qquad \forall t \tag{18}$$

2.3.4 **Objective Function**

The objective function (OF) focuses on minimizing costs. As expressed in Equation (21), the OF integrates four critical components that reflect the energy dynamics within the system. These components are detailed in subsequent equations: EVs (22), and the broader system operations (23).

$$\min f = EV + S \tag{21}$$

$$\begin{aligned} EV = \textstyle\sum_{t \in T} \sum_{ev \in EV} (P_{ev,t}^{evdch} . eprice_t^{import} . degcost \, . \varDelta_t + \ (E_{ev}^{target} - E_{ev\,,t}^{ev}) . mpriofactor) + \\ E_{ev\,,t}^{targetrelax} . penalty1 . priofactor + E_{ev\,,t}^{minsocrelax} . penalty2 \end{aligned} \tag{22}$$

$$S = \sum_{f \in F} \sum_{t \in T} (P_t^{Imp} \varDelta_t C_t^{buy} - P_t^{Exp} \varDelta_t C_t^{sell} + P_t^{Imprelax} p) \tag{23}$$

2.4 Real-time control module

The real-time control module is responsible for managing the charging and discharging of EVs, all within an integrated system that supports V2X technology. This logic operates based on three key factors. First, it uses real-time measurements, that are captured and formatted by an agent (Python code based) before being stored in a real-time database. Second, it relies on charging schedules that are generated based on planned events by the optimisation module. Finally, the control logic also considers static information from both the devices and the installation infrastructure, ensuring that operational constraints and system capabilities are fully accounted for. This control module monitors the import and export power values and determines how much current is available for EV charging on each phase. It manages the EVs separately by phase, since control actions affect only the cars connected to the same phase. Based on EV priorities, the module checks whether the charging schedule can be followed. If necessary, it temporarily reduces or stops charging for lower-priority EVs within that specific phase. Additionally, if more power becomes available, the system reallocates it to increase charging power where possible. Charging is also stopped automatically once an EV reaches its energy target as defined in the mobile application. The output of this module is the current setpoint delivered to each EV.

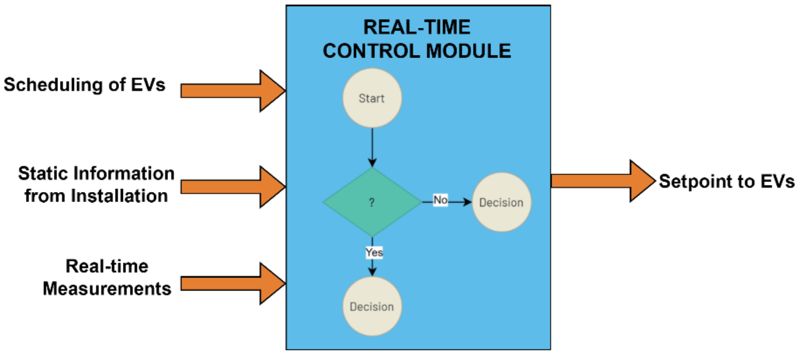

Figure 3: Real-time control module schema.

3 Numerical Results

3.1 Case study

To evaluate the proposed optimisation approach, a case study was developed based on a company system consisting of one EVSE with six available connectors, a typical corporate load profile, and a transformer with a 75 kVA operational limit. Four scenarios were analysed: first, a baseline scenario, in which EVs begin charging immediately upon connection with no control strategy; a second, in which the proposed CEMS is implemented to optimize the charging schedule according to system constraints and objectives, aiming to minimize energy costs, a third in which no control is implemented and the systems is stresses with power transformer limitation and a four, in which the proposed CEMS is also implemented, but under power constraints, i.e., the company system experiments a transformer rating limitation. The technical specifications of the connectors are detailed in Table 1 below, while the information about EVs and end-users is on Table 2.

Table 1: Technical specification of connectors.

ID	Phase	V2X Availability	Connector Type	Connector maximum charging power (kW)	Connector maximum discharging power (kW)	Connector charging efficiency (p.u.)	Connector discharging efficiency (p.u.)
1	1	False	1	7.4	0.0	0.92	1.00
2	2	False	1	7.4	0.0	0.92	1.00
3	3	True	1	7.4	7.4	0.92	0.92
4	1	False	2	2.3	0.0	0.92	1.00
5	2	False	2	2.3	0.0	0.92	1.00
6	3	False	2	2.3	0.0	0.92	1.00

All EVs have a maximum charging power of 11 kW and charging efficiency of 0.92. Vehicles with V2X availability also have a discharging efficiency of 0.92 and discharging power of 11 kW.

Table 2: Technical specification of EVs and end-users' behaviour.

Assigned connector	**Arrival Time**	**Departure Time**	**V2X Availability**	**Initial SoC (p.u.)**	**Target SoC (p.u.)**	**Role**	**EV maximum capacity (kWh)**
1	08:00	16:00	True	0.30	0.90	Director	40
2	08:00	21:30	True	0.50	0.90	Director	60
3	08:00	15:00	True	0.60	0.90	Employee	50
4	08:00	23:00	False	0.40	0.90	Visitor	20
5	08:00	22:15	False	0.60	0.90	Visitor	40
6	08:00	12:30	False	0.15	0.90	Fleet	80

The tariff used by this installation can be seen on Table 3, in which three tariff levels was considered based on the energy market implemented in Portugal [14]. The company demand can be observed in Figure 4.

Table 3: Company imports tariff.

Tariff Type	**Time Intervals**	**Electricity Price (€/kWh)**
Off – Peak	00:00 – 08:00; 22:00 – 23:59	0.0901
Peak	08:00 – 09:29; 11:00 – 17:29; 20:00 – 21:59	0.1558
Super Peak	09:30 – 11:00; 17:30 – 19:59	0.2232

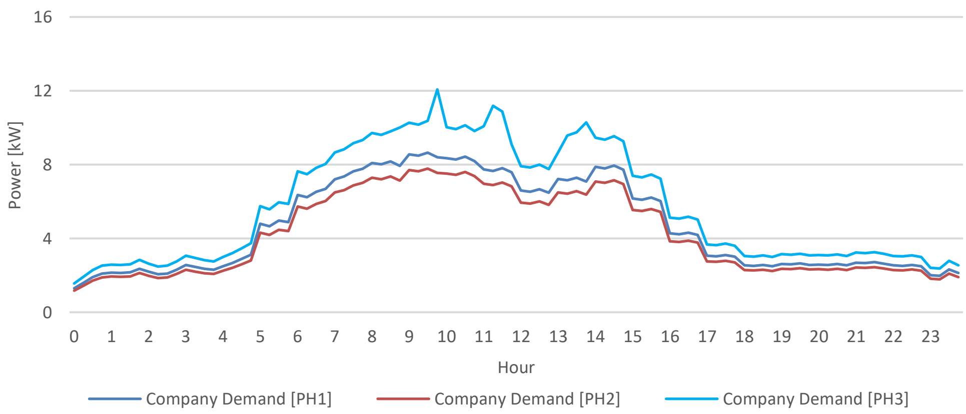

Figure 4: Company demand per phase.

3.2 Results

To validate the proposed case study, the CEMS was implemented in Python [15] using the Pyomo library and solved with the commercial solver CPLEX [16]. It is important to highlight that to facilitate the analysis of the results, only the Phase 3 of the company system is considered in which connectors 3 and 6 are located, this because phase 3 (PH3) is overloaded.

3.2.1 Case 1 – Standard System Without Intelligence (PH3):

In this scenario, the system operates under normal conditions without any smart energy management. The company's power limit remains, for each phase, constant at 25 kW throughout the entire optimisation horizon. Without intelligent control, the EVs begin charging immediately upon connection, aiming to reach full charge as quickly as possible, even during super peak energy price (9:30 – 11:00). Consequently, the total energy charged by both EVs plugged in connectors 3 and connector 6 amounts to 138.22 kWh, resulting in a total cost of €25.45. On the other hand, the company demand and the EV total power never exceeded the company power limit.

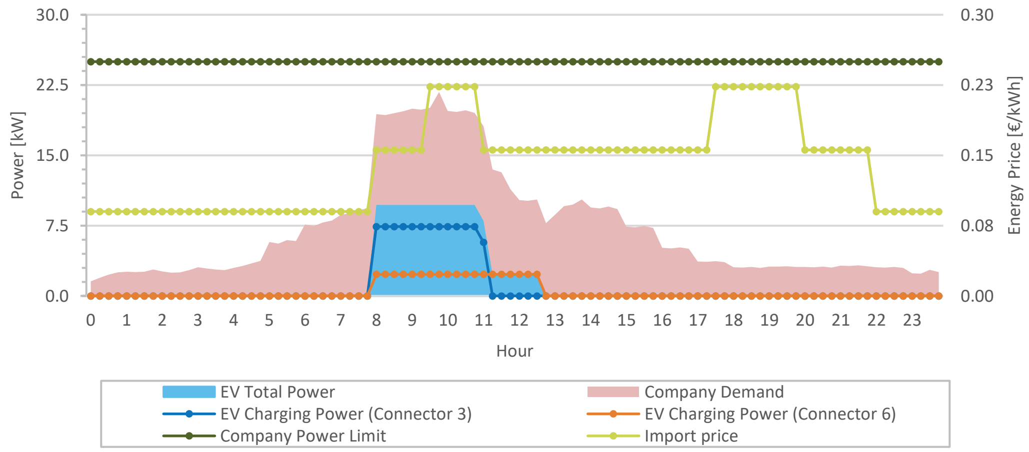

Figure 5 – System's behaviour on normal conditions and without CEMS algorithm.

3.2.2. **Case 2 – Standard System CEMS optimisation algorithm (PH3):**

In this scenario, the system operates under normal conditions with the proposed CEMS optimisation algorithm. The company's power limit remains, for each phase, constant at 25 kW throughout the entire optimisation horizon. Thanks to the intelligent control, EV connected connector 3, is scheduled to charge during periods with the off-peak tariff, aiming to minimize total costs, as can be observed in Figure 6, since during the super peak hours this EV is managed for not charge. As a result, the total energy charged by both EVs is 112.28 kWh, with a total cost of €18.42.

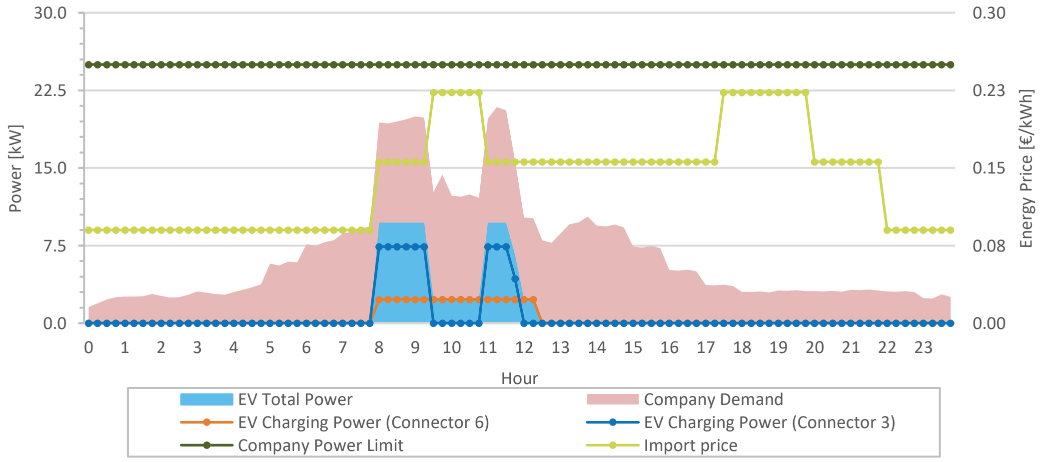

Figure 6 – System's behaviour on normal conditions and with CEMS algorithm.

Additionally, in Case 1, the system fails to adhere to the battery health constraints specified by the user of Connector 3 as can be observed in Figure 7. Specifically, the SoC exceeds the 90% target, with batteries reaching 100%, which may negatively affect long-term battery health. In contrast, Case 2 complies with the defined constraints, maintaining the SoC within the 90% limit. This behaviour is illustrated in Figure 7, where it is evident that only Case 2 respects the target SoC. Connector 6 is unable to reach the target SoC in any of the cases due to its high energy demand of 60 kWh. Given the limited 4.5-hour charging window and the use of a non-controllable (on/off) connector, that has a maximum charging power rate of 2.3 kW, meeting this demand is not feasible, moreover, due to this fact, the EV #6 cannot be managed to avoid super-peak energy tariff, as can be observed in Figure 6.

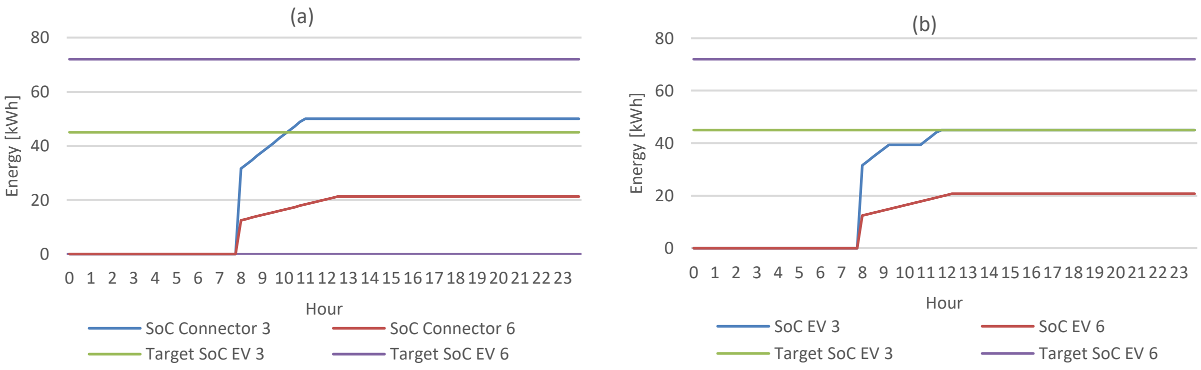

Figure 7 – Final SoC for Case 1 (a) and Case 2 (b).

3.2.3 Case 3 – Stressed System without intelligence (PH3):

In this scenario, the system operates under stressed conditions without intelligent control. The company's power limit, in each phase, is reduced to 12.5 kW between 08:00 – 12:00, after which it returns to a constant 25 kW for the remainder of the optimisation horizon. During the initial four-hour period of connection (08:00 – 12:00), the EV connected to connector 3 is forced to discharge a total of 7.47 kW to help meet the demand of the vehicle on connector 6. However, this behaviour is not related to EV prioritization, since the system lacks intelligence, but rather occurs because of both vehicles attempting to charge as quickly as possible, regardless of role or hierarchy. Due to the absence of intelligent scheduling, the EVs begin charging immediately upon connection, aiming to reach full charge without consideration for energy cost or system constraints. As a result, the total energy charged by both EVs amounts to 141.17 kWh, with a total cost of €24.08.

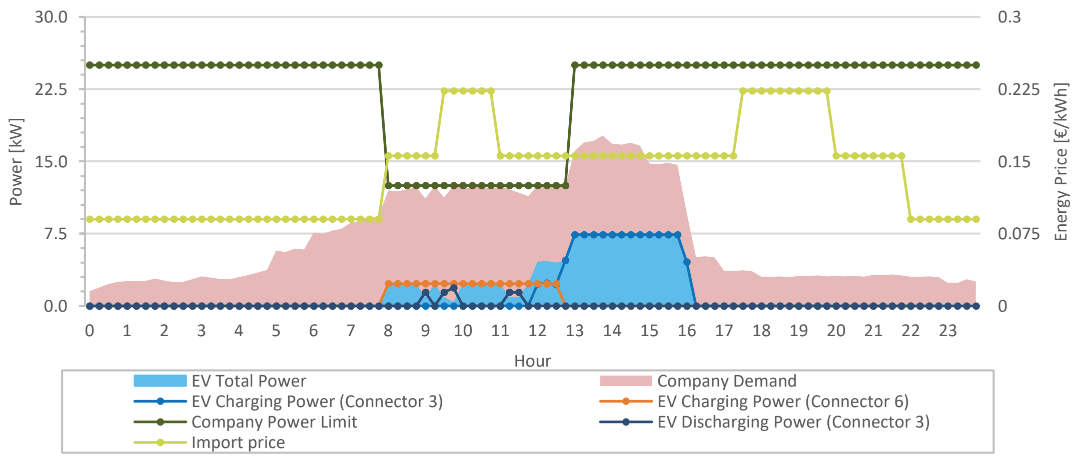

Figure 8 – System's behaviour on stressed conditions and without CEMS algorithm.

3.2.4 Case 4 – Stressed System with CEMS optimisation algorithm (PH3):

In this scenario, the system operates under stressed conditions using the proposed CEMS optimisation algorithm. The company's power limit is reduced to 12.5 kW between 8:00 – 12:00, after which it returns to a constant 25 kW for the remainder of the optimisation horizon. During this constrained period, the EV connected to connector 3 (Visitor) is forced to discharge 7.47 kW to help supply the demand of the EV on connector 6 (Director), which has higher charging priority within the system. The EV on connector 6 remains connected only until 12:30; therefore, despite the high energy tariff during that period, it still needs to charge to meet the required energy demand before disconnection. Although this behaviour resembles that observed in Case 3, the prioritization of the Director vehicle directly influences the charging schedule. Thanks to the CEMS's intelligent optimisation, charging is primarily shifted to periods with lower tariffs whenever possible. Under these conditions, the total cost is €20.04, with a total energy charge of 115.24 kWh.

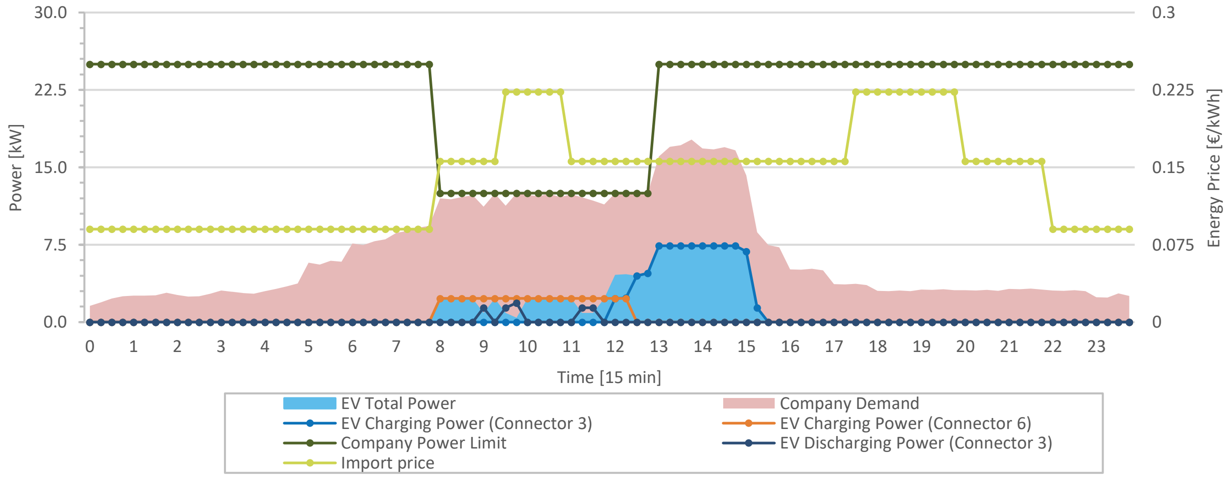

Figure 9 – System's behaviour on stressed conditions and with CEMS algorithm.

Due to the absence of an intelligent control system, Case 3 does not respect the target SoC of 90% for Connector 3, with EV reaching 100%, which may impact battery health. In contrast, Case 4, which implements the proposed CEMS algorithm, maintains the target SoC for both connectors, both can be observed in Figure 10. In addition, Connector 6 fails to reach the target SoC in any case, due to its high energy demand of 60 kWh. This demand cannot be met within the 4.5-hour window when using a non-controllable (on/off) connector.

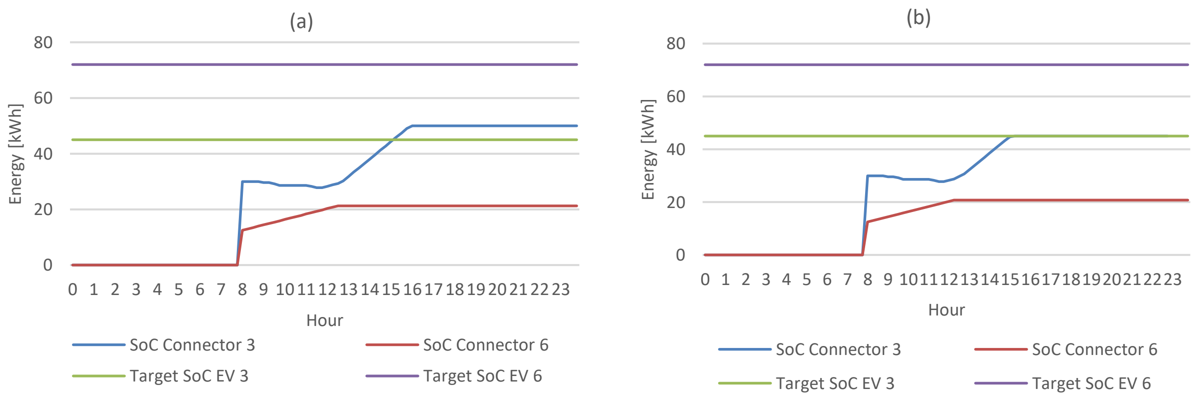

Figure 10 – Final SoC for Case 3 (a) and Case 4 (b).

4 Conclusion

In this paper, a company energy management system (CEMS) is presented for a company equipped with an electric vehicle supply equipment (EVSE) featuring six connectors with different properties, including both controllable and non-controllable (on/off) types. The main results show that the CEMS effectively meets user demands by prioritizing super priority and high-priority users during peak demand and efficiently allocating power to medium and low-priority users based on availability. The CEMS optimization algorithm effectively reduces energy consumption during periods of super-peak tariffs. In a standard system setup, the implementation of the CEMS algorithm resulted in a 27.62% reduction in tariff costs. The algorithm also operates effectively under stressed system conditions, with the power transformer limit reduced by half. In this scenario, during the stress condition, the energy attended to the users was managed to hours without power limitation to avoid not meet users' requirements. Additionally, the algorithm ensures that the target state-of-charge (SoC) for both EVs is not exceeded, thus protecting battery health. The integration of V2V technology enhances system flexibility, redistributing energy between EVs and reducing reliance on the grid. The priority-based system ensures equitable energy distribution, while the optimisation model minimizes costs by leveraging real-time energy prices.

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