Hammersmith & Fulham will have 5 SHBS charging stations, while Richmond upon Thames will have 14, based on the existing number of petrol stations in these boroughs. Among these stations, Richmond generally exhibits the highest EV charging load, reaching a peak value of 2.8 MW. To cater to this peak charging load, 8 chargers are required in the charging stations. The calculation assumes that a 360 kW charger is needed to charge an EV with a 60 kWh battery. Hence, by employing 8 chargers, the peak charging load in Richmond can be met. On the other hand, the SHBS charging station in Hammersmith & Fulham experiences the lowest charging load, which remains below 1000 kW. Consequently, 3 chargers with a capacity of 360 kW each are sufficient for this station.

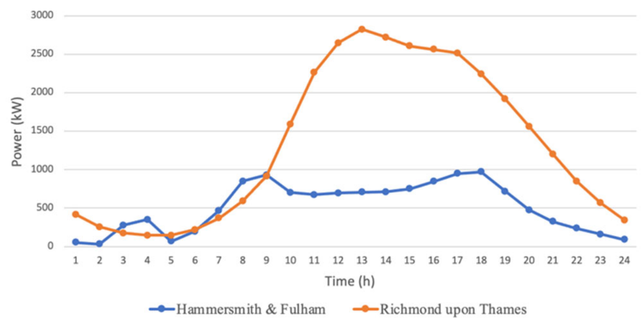

Fig. 3: Case studies in two London boroughs for SHBS charging stations

Table 1 displays the primary technical and economic parameters of each station. For the case study, a 24-hour scheduling period was employed, with an hourly energy dispatch solution used on a summer reference day. The common parameters of the charging stations include:

- Charging capacity (kW): 360.
- PV capital cost (£/kW): 1112.
- PV O&M cost (£/kW): 0.01.
- Battery capital cost (£/kW): 331.55.
- Battery O&M cost (£/kW): 0.01.
- Battery initial state of charge (%): 40.
- Rated charge and discharge power of battery (kW): 500.
- Minimum battery state of charge (%): 25.
- Maximum battery state of charge (%): 100.
- Battery charge and discharge efficiency (%): 85.
- Initial capacity of gas tank (%): 30.
- Hydrogen tank cost (£/kW): 27.63.
- Hydrogen tank O&M cost (£/kW): 0.01.
- Tank storage efficiency (%): 95.
- Fuel cell generator capacity (kW): 600.
- Fuel cell generator capital cost (£/kW): 705.9.
- Fuel cell generator O&M cost (£/kW): 0.15.
- Electric to gas efficiency (%): 75.
- Electricity-to-gas coefficient (kWh/m^3): 0.2.
- Gas-to-electric efficiency (%): 65.
- Gas-to-electricity coefficient (m^3/kWh): 0.295.
- Renewable energy feed-in tariff (£/kW): 0.03.

Table 1: The parameters of SHS-EV charging station.

Parameter	**Hammersmith & Fulham**	**Richmond upon Thames**
Number of chargers per station	3	8
PV installed capacity (kW)	500	1000
Battery capacity (kW)	1000	800
Hydrogen tank capacity (m^3)	1000	1000
Fuel cell generator capacity (kW)	800	1500

IV. Simulation Results

Fig. 4 shows that the solar energy is the main source of energy output between the hours of 7 am and 7 pm, with a maximum output capacity of up to 500 kW. This means that during this period, the charging station is heavily reliant on solar energy to meet the energy demands required for charging EVs. To ensure that there is enough energy to power the charging station during this time, both hydrogen energy storage and electric energy storage work in conjunction with one another. This coordinated effort helps to guarantee that the charging station can fulfil the energy demands required for charging during each time.

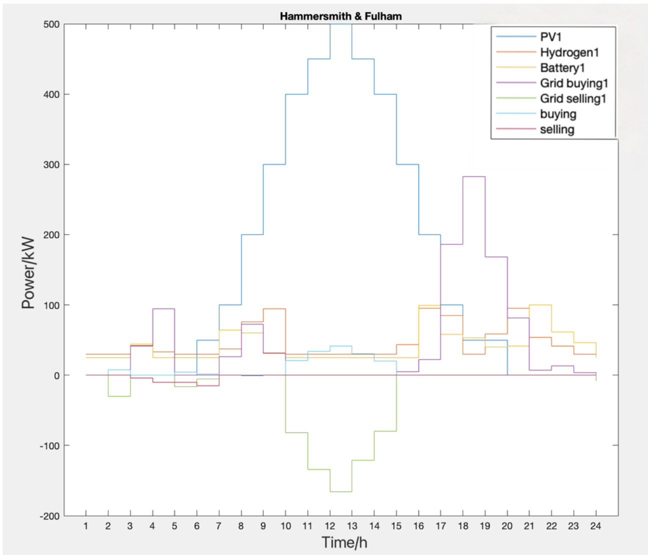

Fig. 4: Hammersmith & Fulham optimal energy dispatch solution.

Furthermore, it is observed that during the time when electricity prices are at their highest, from 10:00 to 15:00, the charging station interacts with the power grid to guarantee a sufficient electricity supply. During these peak hours, the charging station may have to rely on the power grid to meet the energy demands for charging, which can be costly. However, by leveraging the time-of-use pricing strategy, the charging station can potentially save money by purchasing electricity during off-peak hours when prices are lower and storing it for use during peak hours. Overall, by optimizing the energy flow between different sources of energy and taking advantage of different pricing strategies, the charging station can ensure a cost-effective and efficient energy supply.

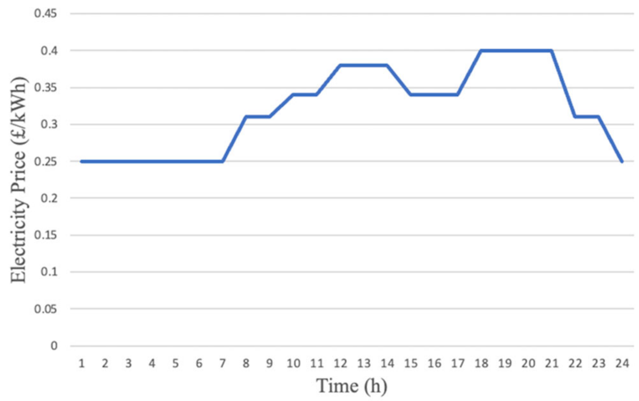

Fig. 5: Electricity price for a day.

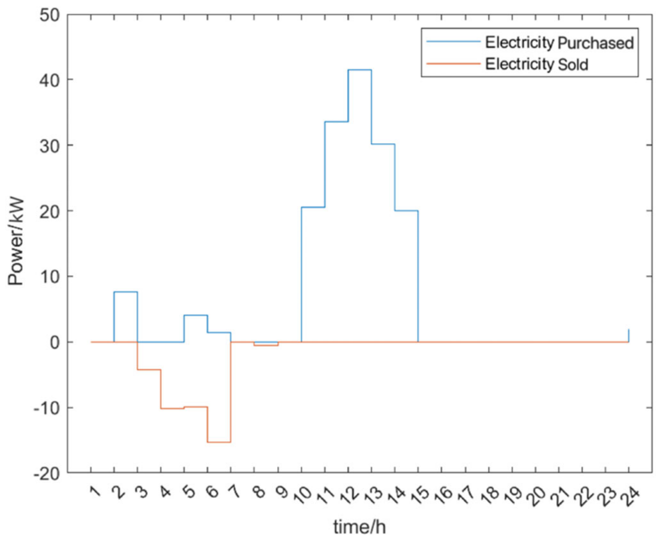

Fig. 6: Energy exchange between two SHBS charging stations (H&F).

Fig. 6 displays the energy exchange between the two charging stations during the specified time periods, which is limited to a maximum of 50 kW. The energy exchange is carefully analyzed by implementing Genetic Algorithm to achieve the lowest cost. As per the results depicted in Fig. 5, the energy exchange between two charging stations is insignificant when an autonomous energy generation system is installed in the charging stations and connected to the grid. This indicates that energy exchange does not have a significant impact on achieving the minimum cost of the charging stations, and therefore the energy exchange between two charging stations can be neglected in somehow. This observation is critical as it helps in designing the charging stations to be energy-efficient and cost-effective. By analyzing and optimizing the energy exchange between two charging stations, the overall cost of operating the charging stations can be minimized while maintaining optimal energy supply.

Table 2: SHBS charging station minimum capital and O&M cost.

Cost	Hammersmith & Fulham	Richmond upon Thames
Capital cost for initial years (£) C_m^0	1,338,720	1,828,410
Discounted capital cost (£) C_0	181,889.15	248,422.33
Grid electricity purchase per day (£)	575.09	1994.36
Energy exchange per day (£)	77.12	30.25
O&M cost per day (£)	205.65	232.79
Minimum daily cost (£) *minF*	1273.32	2887.81

Table 3: EV charging station cost only buy electricity from grid.

Cost	Hammersmith & Fulham	Richmond upon Thames
Daily cost (£)	4,195.88	11,225.81

Table 2 presents important information regarding the economic aspect of two SHBS charging stations, outlining both their capital and O&M costs. It is notable that if the SHBS charging station's lifespan is 10 years, and it undergoes daily maintenance while replacing each component every 10 years, the cost allocated per day would only be £4163.13. Comparing this to Table 3, it is evident that the daily cost for the two charging stations is three times higher than the SHBS charging station. Utilizing energy conversion between SHBS charging stations not only optimizes energy utilization but also reduces operational expenses. To integrate these stations with the large power grid, certain adjustments must be made. It is crucial to consider these costs and benefits when making decisions regarding the establishment and maintenance of charging stations, especially in the context of promoting sustainable transportation practices.

V. Conclusion

The primary focus of this paper is on the economic analysis of two SHBS charging stations energy exchange, and each charging station's power distribution involves various energy production equipment, energy conversion equipment, and energy storage equipment. The paper systematically conducts an economic analysis of the system, considering the electric load demand of charging stations in Hammersmith & Fulham and Richmond upon Thames during different time periods and the energy interaction between two charging stations. A mathematical model of SHBS power generation is constructed, considering the energy-flow coupling relationship between equipment and the factors of time-of-use electricity price. Furthermore, the paper studies the operation optimization of the system under grid-connected electricity sales.

During the coordinated planning process, considering the interplay among charging stations, and power lines can enhance the capacity of distributed generation usage while diminishing the need for grid investment. In SHBS charging station's coordinated planning, the charging stations can conduct flexible interaction with other smart devices, which can efficiently increase the utilization of equipment and overall economic gain.

Expanding further, the SHBS charging stations with the power grid can optimize the allocation of renewable energy resources and reduce the reliance on traditional power sources. By leveraging the flexibility of smart devices, the charging stations can coordinate their operation with other energy-consuming devices, such as home appliances and electric vehicles, to maximize the utilization of available resources. This coordinated planning approach can also enable demand response mechanisms, where the charging stations adjust their energy consumption based on the grid's needs, leading to more efficient and cost-effective energy use. Overall, a holistic approach to charging station planning that considers the interplay among various devices and the power grid can lead to a more sustainable and resilient energy system.

Future modelling will not only consider the capital costs of charging stations but also other factors like their distance and location. This will enable a more holistic evaluation of the costs and benefits associated with setting up and maintaining charging stations. These enhancements will improve the effectiveness and efficiency of renewable energy electric vehicle charging stations and promote the adoption of sustainable transportation practices.

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