INTRODUCTION

Increased demand for transportation demanded the use of more oil, leading to an increase in carbon dioxide (CO2) emissions, a significant contributor to air pollution. Electrification is a key technological strategy for reducing air pollution, as well as a viable option for countries seeking to diversify their energy sources and minimize greenhouse gas (GHG) emissions. EVs (electric vehicles) that offer zero tailpipe emissions are more economical than internal combustion engines and have an enormous potential to reduce GHG emissions. The rapid development of electric vehicles (EVs) has increased the power demand, which has caused an extra burden on the public grid increasing the load fluctuations, therefore, hindering the high penetration of EVs. As a result, there has been a great deal of interest in partially or completely replacing the grid with renewable energy sources such as solar energy.[1] In this project, we devised an optimum approach for charging a pool of electric cars (EVs) in an industrial-like microgrid, where the electricity can originate from the grid, PV panels, or both.

EXPRESSION OF CHARGE EFFICIENCY AS A FUNCTION OF TIME

We know,

$$S_e^{t+\Delta t} - S_e^t = \eta \times P_{charge} \times \Delta t$$

$$\frac{S_e^{t+\Delta t} - S_e^t}{\Delta t} = \eta \times P_{charge}$$

$$\lim_{t \to 0} \frac{S_e^{t+\Delta t} - S_e^t}{\Delta t} = \eta \times P_{MAX}$$

$$\frac{{ds}/{dt}}{P_{MAX}} = \eta \quad => \quad \frac{{ds}/{dt}}{\overline{P}} = \eta \quad \text{……………………..} \ (1)$$

Lets assume, ${ds}/{dt}$ = y

Now, for y_1,

$$y_1 = 0.8 \times 0.1P = 0.08P \quad \text{……………..(2) where } 0 \leq y_1 \leq 0.1\overline{P}$$

for y_2,

$$\frac{y_2 - y_1}{x_2 - x_1} = 1$$

$$\frac{y_2 - 0.08P}{0.7\overline{P}} = 1$$

$$y_2 = 0.78P \quad where\ 0.1\overline{P} \leq y_2 \leq 0.8\overline{P}$$

and y_3,

$$\frac{y_3 - y_2}{x_3 - x_2} = 0.7$$

$$\frac{y_3 - 0.78P}{0.2\overline{P}} = 0.7$$

$$y_3 = 0.92P \quad where\ 0.8\overline{P} \leq y_3 \leq \overline{P}$$

Now, for any point (p,y) we can write,

$$y = 0.08p \;\; for\; 0 \le p \le 0.1\overline{P}$$

$$y = p - 0.02\overline{P} \;\; for\; 0.1\overline{P} \le p \le 0.8\,\overline{P}$$

$$y = p + 0.22\overline{P} \;\; for\; 0.8\overline{P} \le p \le \overline{P}$$

$$\eta\, P = \int_{0}^{0.1\overline{P}} 0.08p + \int_{0.1\overline{P}}^{0.8\overline{P}} p - 0.02\overline{P} + \int_{0.8\overline{P}}^{\overline{P}} p + 0.22\overline{P}$$

$$\eta \;= 0.92$$

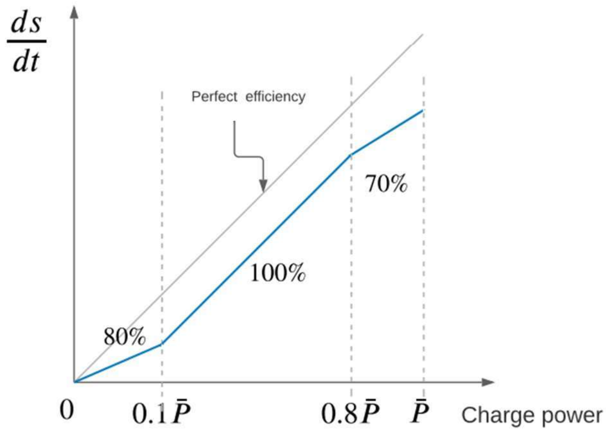

Figure 1: Variation of the state of charge of an EV per unit of time as a function of the charge power.

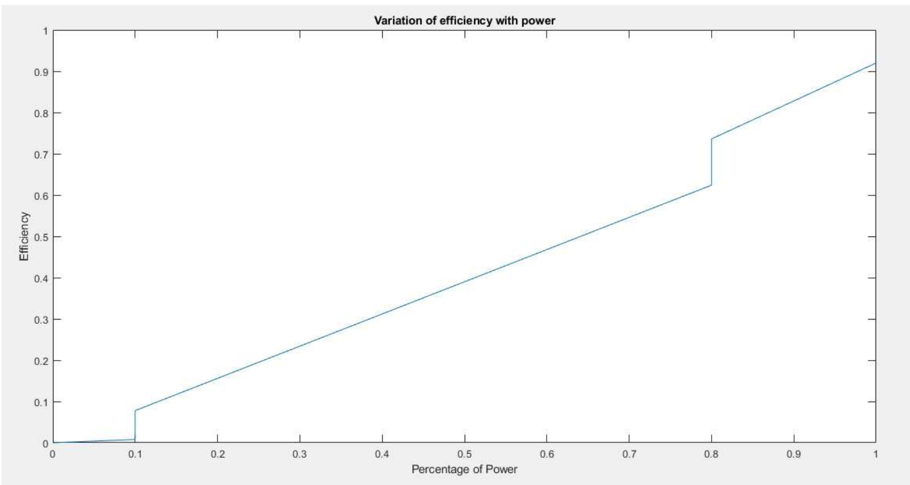

Figure 2: Charge Efficiency (η) as a function of Power (P)

OBJECTIVE FUNCTION

min [sum (P_{import}[e] Import_Price[e] – P_{export}[e]×Export_price[e]) for e as each time step] + $\sum_{i=1}^{n} \frac{T_i^d - T_i^a}{C_i}$ X π_i) k for i as each vehicle]

where, k = Trade-off Coefficient

The objective function is defined to minimize the cost of charging the EV by considering multiple constraints related to the exchange of power between the grid as well as the utilization of PV power from the solar array. Priority index of each EV is defined along with the trade-off coefficient to ensure the minimal cost and optimal EV charging strategy. The constraints are formulated and described in the following section.

CONSRAINTS:

The following are the constraints for this objective function

1- **Power Balance Constraint**
The power imported from the grid and PV used by the electric vehicles should be equal to the power exported and the powers charged of the electric vehicles.

import_power[i] + PV_used_by_EVs[i] = export_power[i] + sum((actual_charge_powers[e,i]) for i as each time step and e as each vehicle

2- **PV used for Charging**

The PV forecasted should be equal to the power exported plus the PV used by the electrical vehicles.

forecast_PV[i] = export_power[i] + PV_used_by_EVs[i] for i as electrical vehicle

3- **Avoid Import_Export_1**
When we have import of power, there should not be any export. Also, the imported power should be less than the grid capacity.

$$\begin{cases} P_{import} \le P_{grid} \times z \\ P_{export} \le P_{grid} \times (1-z) \end{cases} \quad where, z = 0 \; or \; 1$$

Where on_off_import_export is a binary variable such that when import is on the export will be off.

4- **Avoid Import_Export_2**

$$\begin{cases} P_{import} \le P_{grid} \times z \\ P_{export} \le P_{grid} \times (1-z) \end{cases} \quad where, z = 0 \; or \; 1$$

It is combined with the constraint 3, it makes sure that maximum power exported it less than or equal to the grid capacity and when there is export, it makes import as null.

5- **Charging of EVs**
This constraint makes sure that each vehicle is charged only when it is inside the parking side. It counts the departure and arrival times for each of the electrical vehicles. It takes into account the current time and arrival time for each electrical vehicle and charges accordingly.

6- **Charging Power Constraint**
This constraint makes sure that actual charging power of the vehicle is less than or equal to the maximum charging power of that vehicle.
actual_charge_powers[e,i] < = EV5[e].max_charging_power) for i time steps and e electrical vehicles

A binary variable z is introduced to avoid import and export of power to the grid at same time. This constraint ensures while the microgrid is receiving power from the grid, it cannot initiate an export operation. This constrain works as a modification of the first two constraints.

CHECK OF THE CONTROLLERS WITH ARBRITARY VALUES

We tested our controller code for different values of the tradeoff coefficient. When we had set the value to 0, we noticed that there was no charging of the EV. And this is completely obvious, because when the tradeoff coefficient is set to zero, there is no trade-off between the charging of EV and the Export of electricity. Therefore, as exporting the electricity is more profitable, all the electricity is exported to the grid.

However, when we changed the value to 1, we noticed that the EV had started to charging and also exporting some power to the grid. Which means there is sufficient power to charge the EV as well as exporting to the grid. Therefore, the imported power is zero.

CONTROLLER OUTPUT

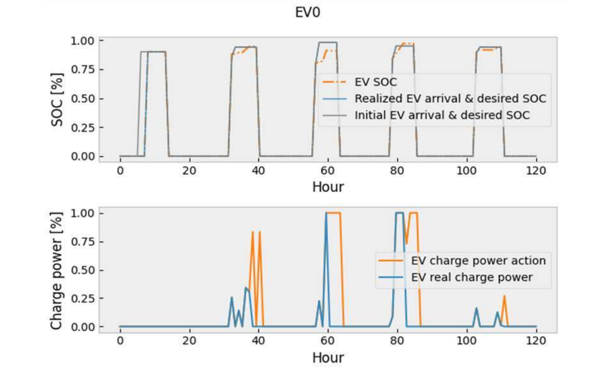

Figure 3: Charge Power (%) and SOC(%) of EV1 over time

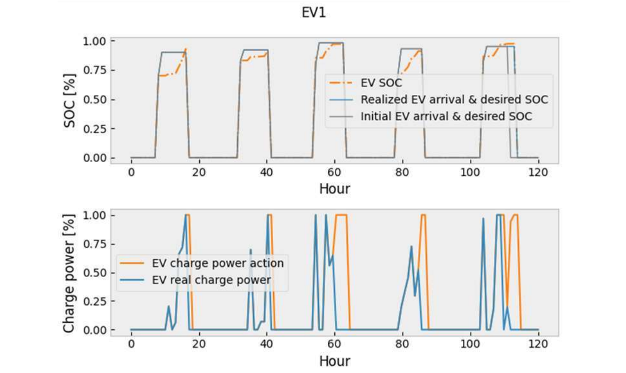

Figure 4: Charge Power (%) and SOC(%) of EV1 over time

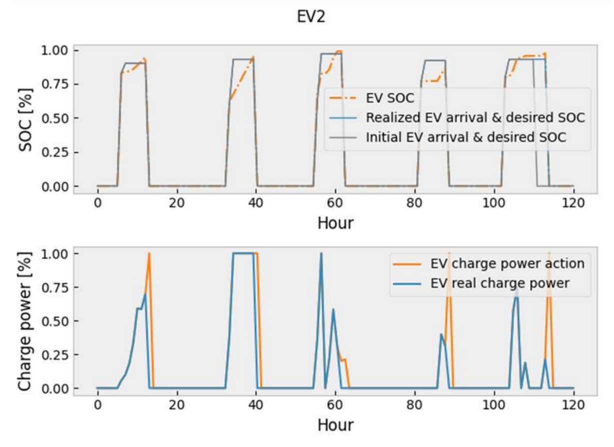

Figure 5: Charge Power (%) and SOC(%) of EV1 over time

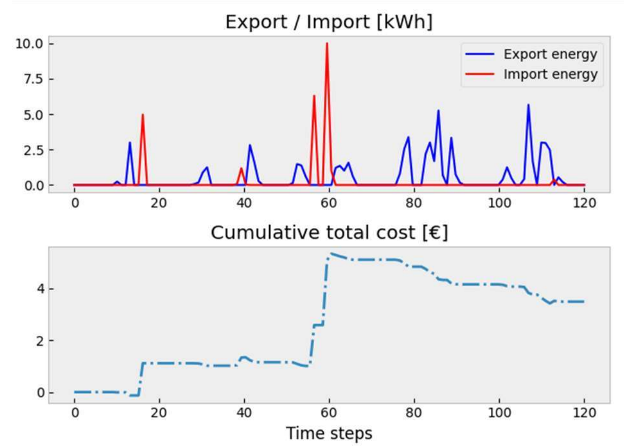

Figure 6: Charge Power (%) and SOC(%) of EV1 over time

REFERENCES

[1] Dian Wang. Microgrid based on photovoltaic energy for charging electric vehicle stations: charging and discharging management strategies in communication with the smart grid. Electric power. Université de Technologie de Compiègne, 2021. English. ffNNT : 2021COMP2584ff. fftel-03292806