Electric Vehicle in Distribution Grids

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Abstract—With the presence of Electric Vehicles (EV's) in the distribution grid as a load, grid losses increase dramatically, which can have adverse effects on parameters such as deployment, cost, profit, etc. But if EV's are connected to the grid, by managing their charging and discharging, positive effects can be created in the load curve and grid losses can be reduced. In this paper, the effect of the presence of different types of EV's with different capacities and the absence of EV's on grid losses have been compared with each other considering the daily load curve. The simulation in DIGSILENT software has been done on a 74-bus distribution grid with IEEE standards considering and with 1000 vehicles. The results show well the effect of EV's charging and discharging on grid *losses*.*

Keywords—losses, charging stations, electric vehicle (EV), daily load curve

I. Introduction

With the ever-increasing use of vehicles in various industries, the need for energy sources to move them is strongly felt, and currently, fossil fuels are the most important source of energy for vehicles. Therefore, the most important reasons why EV's are being considered are the increase in concerns about environmental pollution, the reduction of fossil fuel reserves, the low safety of fossil fuels, and the issue of global warming and efforts to reduce greenhouse gas emissions. It should also be paid attention that along with the expansion of the use of EV's, the use of renewable sources for the production of electric energy should also be developed [1-2].

Since the transportation industry is one of the most important fuel-consuming industries, the replacement of EV's and electric motors with internal combustion vehicles is on the agenda of countries. Today, various industries are looking for alternatives to energy supply sources with new technologies. Rechargeable EV's are one of the best candidates for replacing fossil fuels-based vehicles due to their low emissions and high efficiency, and for this reason, we are witnessing tremendous progress in the battery industry and charging facilities for these vehicles in countries. The countries of the world are moving towards the electrification of vehicles, and even in European countries, a period has been considered to end the sale of gasoline and diesel cars.

On the other hand, the energy required for EV's with the same performance is about half of the energy of internal combustion vehicles. This issue causes a movement towards a healthier environment, and also in these cars, the need to consume oil, water, and metals is much less, and there are no atmospheric pollutants and environmental pollution such as damage to the ozone layer. The use of EV's can be an effective factor in reducing pollution caused by fossil fuels, but with the increase in the number of these vehicles, charging stations must be created in the grid. Therefore, the presence of more EV's in the network has created new needs, including the construction of charging stations, which should be considered in the operation and planning of the grid. For this reason, one of the important points about electric vehicles is that at the same time as the penetration rate of these types of vehicles increases, the necessary infrastructure to supply the electric energy they need should also be expanded, and in other words, the use of EV's will become more widespread and the need for The possibility of traveling long distances creates the need for charging stations that can provide the necessary conditions for supplying electric energy to these cars. In a short definition, it can be said that a charging station means a public or private space where equipment is installed that can receive electrical energy then provided this energy in a form of acceptable and safe EV's [3].

In recent years, the electricity industry in the world has faced huge changes and with the aim of increasing economic productivity and improving the quality of energy, the traditional and exclusive structure of the electricity industry has been changed to a competitive structure. that Losses in the distribution grid reduce the quality of delivered energy and also spend heavy costs to supply energy to consumers. In the discussion of EV management, by managing the power stored in EV's, it is possible to partially compensate for the required power during peak and critical hours by injecting the power of these vehicles into the grid [4].

In other words, the network can be managed in such a way that power is injected from the grid to EV's during non-peak times, and power is injected from vehicles to the network during peak times [5].

With this management, operators of distribution companies receive some of the power they need through vehicles during peak times when the price of electricity is high. Of course, plans should be considered in order to encourage consumers to cooperate with distribution company operators so that car users can park their cars at these stations during peak hours [6]. Therefore, there must be control over the hours and the charging rate of vehicles. Since these types of vehicles are in the garage most of the day, it is possible to use as convenient their batteries. In fact, EV's provide the possibility of financial profit for themselves and the network managers by providing their charging process to the power grid management. Experts believe that one of the most important and influential factors in the development of electric transportation in any country is the attitude of the government in that country and the establishment of relevant laws. In other words, the global experience of producing EV's shows that simultaneously with the activities of car manufacturers regarding the design and production of EV's, governments must provide the necessary infrastructure for these vehicles to enter the market, and after that, in order to create demand for the products of car companies, incentives be considered financially. The energy that an electric vehicle alone can inject into the grid is very small on the scale of the grid and can have a negligible effect on the power system. But if these vehicles are collected in groups in large numbers, the effect they can have on the power system will be very significant and in megawatts.

In this paper, the effect of the presence of different types of EV's with different capacities and the absence of EV's on grid losses have been compared with each other considering the daily load curve. The simulation in DIGSILENT software has been done on a 74-bus distribution grid with IEEE standards considering 1000 vehicles. The results clearly show the effect of EV charging and discharging on grid losses.

II. Mathematical Modeling

According to the penetration rate of EV's in the grid and the number of charging units in each station, the objective function of the problem from the point of view of the power company is defined as functions of grid losses and uniform voltage profile.

The grid losses function: includes the total grid power loss, taking into account EV charging stations, and is shown by Loss:

$$f_1 = \sum_{i=1}^{Nbr} loss = \sum_{i=1}^{Nbr} R \times |I_{br,i}| \qquad (1)$$

1) The function of the voltage profile indicator: includes is to improve the grid voltage profile by considering EV charging stations and is expressed as the following equation:

$$f_2 = dev = max\{|1 - max(v)|, |1 - min(v)|\} \qquad (2)$$

In this paper, the objective function is as the following equation:

$$f_t = f_1 + f_2 \qquad (3)$$

A. *Limitations of the problem*

The objective functions in this paper are always minimized under the following conditions:

1) The total number of charging units assigned to the stations must be equal to the number of units required in the grid.

$$\sum_{i=2}^{n} h(i) = N_{unit} \qquad (4)$$

2) The number of charging units in each station cannot be less than a minimum value because it is not economical considering the fixed costs of each station. The number of charging units can be the amount of zero, meaning that a charging station should not be built at this point.

$$h(i) = 0 \quad or \quad N_{min} \leq h(i) \leq N_{max} \qquad (5)$$

3) load flow equations:

$$p_i = \sum_{i=1}^{N_{bus}} |v_i||v_j||Y_{ij}| \cos(\theta_{ij} - \delta_i - \delta_j) \qquad (6)$$

$$Q_i = \sum_{i=1}^{N_{bus}} |v_i||v_j||Y_{ij}| \sin(\theta_{ij} - \delta_i - \delta_j) \qquad (7)$$

4) The voltage limit for all system buses should be within the acceptable limits of v_{max}‘v_{min} (of course, in some studies, this is not possible with a detailed knowledge of the scenario. Although the voltage profile will certainly improve, the voltage may not be within this range):

$$v_{min} \leq v \leq v_{max} \qquad (8)$$

III. Main grid modeling

In this section, the system model for the main grid is introduced and the grid losses are observed in DIGSILENT software.

A. *IEEE 69 bus grid*

To show the performance and effectiveness of the proposed method, the IEEE 69 bus grid has been studied in this section. This grid has been evaluated as a test network in investigating possibilities and determining the capacity of EV charging stations in distribution systems in numerous papers. The grid configuration is shown in Fig.1.

In this grid, the rated voltage is 12.66 volts, the bus voltage is 12.66 volts, the rated mixed power is 10 megavolts, the rated current is 1 KA, and the length of each line is 1 kilometer.

Fig.2 shows the simulation results in DIGSILENT software.

As shown in the output of the software, the grid loss is 230 kW.

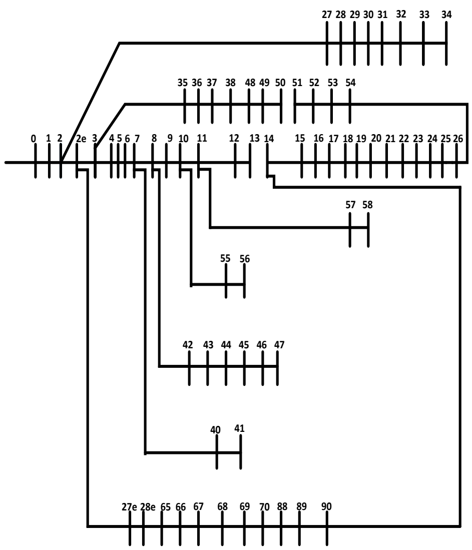


Fig.1 Test network of 69 buses

Load Flow Calculation	Total System Summary
Ac Load Flow, balanced, positive sequence Automatic Tap Adjust of Transformers No Consider Reactive Power Limits No	Automatic Modal Adaptation for Convergence No Max. Acceptable Load Flow Error for Nodes 1/00 KVA Moel Equations 0/10 %

Total System Summary	Study Case:Study Case	Annex: /1

No. of Substations 0	No. of Busbars 0		No. of Terminals 108	No. of Lines 69
No. of 2-W Trfs. 0	No. of 3-W Trfs. 0	No. of syn. Machines 0	No. of asyn.Machines 0	
No. of Loads 80	No. of 3-W shunts 0	No. of SVS 0		

Generation	=	0/00 MW	0/00 Mvar	0/00 MVA
External Infeed	=	4/03 MW	2/80 Mvar	4/90 MVA
Load P(U)	=	3/80 MW	2/69 Mvar	4/66 MVA
Load P(Un)	=	3/80 MW	2/69 Mvar	4/66 MVA
Load P(Un-U)	=	0/00 MW	0/00 Mvar	
Motor Load	=	0/00 MW	0/00 Mvar	0/00 MVA
Grid Losses	=	0/23 MW	0/10 Mvar	
Line Charging	=		0/00 Mvar	
Compensation ind.	=		0/00 Mvar	

```
Compensation cap.   =                   0/00  Mvar

Installed Capacity  =      0/00 MW
Spinning Reserve    =      0/00 MW

Total Power Factor:
eneration       =       0/00  [-]
Load/Motor       =  0/82 / 0/00  [-]
```

Fig.2 Main network output

IV. MODELING THE GRID WITH PENETRATION OF DIFFERENT TYPES OF VEHICLES WITH DIFFERENT CAPACITIES AND CHARGING AND DISCHARGING TIME

This grid includes 1000 EV's. The first bus is considered a base bus. Buses 1 to 69 each have 15 EV's and the rest of the buses have 14 vehicles. In TABLE I, the types of vehicles are given according to the variety of their battery capacity, and the charging and discharging time of the vehicles is determined by the charging and discharging rate of 3.3 kW.

The location of the number and types of vehicles in each bus after the simulation is obtained in TABLE II. bus number one is a Slack bus and no vehicle is placed on it.

TABLE I. DIFFERENT TYPES OF VEHICLES ACCORDING TO THE VARIETY OF THEIR BATTERY CAPACITY

Type	**Charging and discharging time (h)**	**Vehicle capacity (kWh)**
First	4.8	16
Second	7.27	24
Third	5.75	19
Fourth	8.48	28
The fifth	6.66	22

TABLE II. LOCATION OF THE NUMBER AND TYPES OF VEHICLES IN EACH BUS AFTER SIMULATION

Numbers Of Buses	**Battery Capacity (kWh)**				
	22	***28***	***19***	***24***	***16***
1	2	3	2	2	6
2	3	2	4	3	3
3	3	2	4	3	3
4	2	4	5	1	3
5	1	2	3	4	4
6	1	5	2	2	4
7	1	3	4	3	4
8	4	2	4	1	4
9	2	5	3	4	1
10	5	4	4	2	0
11	2	4	3	4	2
12	3	5	1	1	5
13	5	3	2	4	1
14	1	5	5	2	2
15	2	3	3	5	2
16	1	4	4	3	3
17	3	4	5	0	3
18	2	3	4	4	2
19	2	7	1	4	1
20	2	4	1	3	5
21	6	3	0	4	2
22	5	3	3	1	3
23	3	5	4	1	2
24	1	3	5	3	3
25	2	6	2	3	2
26	4	4	0	4	3
27	3	5	3	0	4
28	0	2	4	7	2
29	4	3	1	4	3
30	4	4	2	0	5
31	1	2	6	2	4
32	1	5	5	3	1
33	6	2	4	2	1
34	5	3	4	1	2

35	3	4	3	1	3
36	1	4	4	3	2
37	4	3	3	4	0
38	3	1	1	3	6
39	3	2	5	1	3
40	2	4	2	4	2
41	5	1	1	5	2
42	2	5	1	1	5
43	3	1	4	3	3
44	7	3	0	2	2
45	0	4	2	2	6
46	5	1	1	3	4
47	1	6	6	0	1
48	3	2	1	6	2
49	1	3	4	2	4
50	4	1	1	7	1
51	2	8	2	1	1
52	2	2	0	5	5
53	2	2	2	2	6
54	6	2	2	2	2
55	5	4	3	1	1
56	1	1	3	4	5
57	4	1	2	3	4
58	3	2	1	4	4
59	4	4	3	2	1
60	4	1	4	3	2
61	3	2	4	2	3
62	4	3	2	3	2
63	6	0	2	2	4
64	5	1	1	1	5
65	1	4	1	3	5
66	6	1	1	1	5
67	2	2	5	5	0
68	3	2	1	2	6
69	6	4	2	1	1

According to the 3% probability of vehicles not being present at the time of charging and the 10% probability of not being present at the time of discharging in this simulation, 970 vehicles out of 1000 vehicles have been charged and 900 vehicles have been discharged. These are the optimal charging hours for 970 vehicles to minimize losses. several 200 vehicles at hour 1, 200 vehicles at hour 2, 200 vehicles at hour 3, 150 vehicles at hour 4, 150 vehicles at hour 5, and 100 vehicles at hour 6 start charging. At the end of the allowed time for charging, there are fewer vehicles, and the vehicles that start charging during these hours are usually the type of vehicles whose charging time is shorter than others.

Several 900 vehicles out of 1000 vehicles participate in the discharge. 200 vehicles at 3:00 p.m., 200 vehicles at 4:00 p.m., 200 vehicles at 5:00 p.m., 200 vehicles at 6:00 p.m., and 200 vehicles at 7:00 p.m., started to discharge. Fewer vehicles were present in the discharging of vehicles during the last hours allowed for discharging too.

V. Modeling in Two Modes of the Main Grid and the Presence of Vehicles, as Well as Multiplying the Daily Load Curve

To obtain the main losses of the grid and the losses with the presence of EV's, first, the main loads of the grid (both Active power and Reactive power) in the coefficient of the daily load curve (Fig.3) multiplied per hour, then the main losses of the grid in the DIGSILENT software are determined every hour and then the loads that are listed in TABLE II of the previous section And only their Active power is known, for each bus, in every hour these Active powers multiply in the load curve factor to get the desired Active power, then the reactive power is obtained from the equations:

$$P = S \times \cos \emptyset \quad (9)$$

$$Q = P \times \tan \emptyset \quad (10)$$

In these equations, the power factor, i.e. cos0.9, is lagging into consideration. Further, after P and Q are obtained, they are added to the main grid in such a way that P and Q are positive in charging mode and negative in discharging mode. after load flow in the DIGSILENT Losses are obtained when EV's are on the grid. In Fig.4 active and reactive power obtained after calculations can be seen.

Fig.5 also shows the results of the load flow in the software.

A. *Daily load curve*

In the main grid, the load that enters is the base Active and Reactive power, it is understandable that the electricity consumption will not be the same in 24 hours, for example, in the middle of the night when most consumers are outage, the electricity is consumed less. And on the contrary, in the afternoon and evening, when the coolers also enter the circuit, more power is sinking from the grid. The daily load curve is shown in Fig.3. In this daily load curve, it is determined how many percent of this amount of basic power has been consumed. For example, in hours 1-8, the load curve coefficient is 0.8 which is multiplied by the base power, which is the load power in 24 hours, then the charging or discharging power is added to it EV's, then in the per hour the losses are calculated and in the following, its is congregated with each other that the total losses are being calculated in 24 hours.

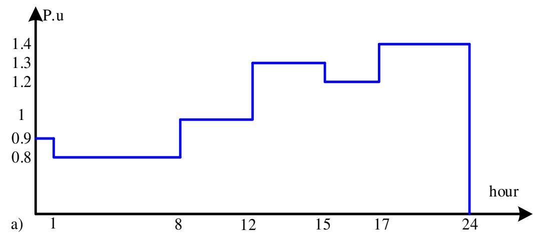


Fig.3 Daily load curve

Fig.4 An example of loads after applying the daily load curve

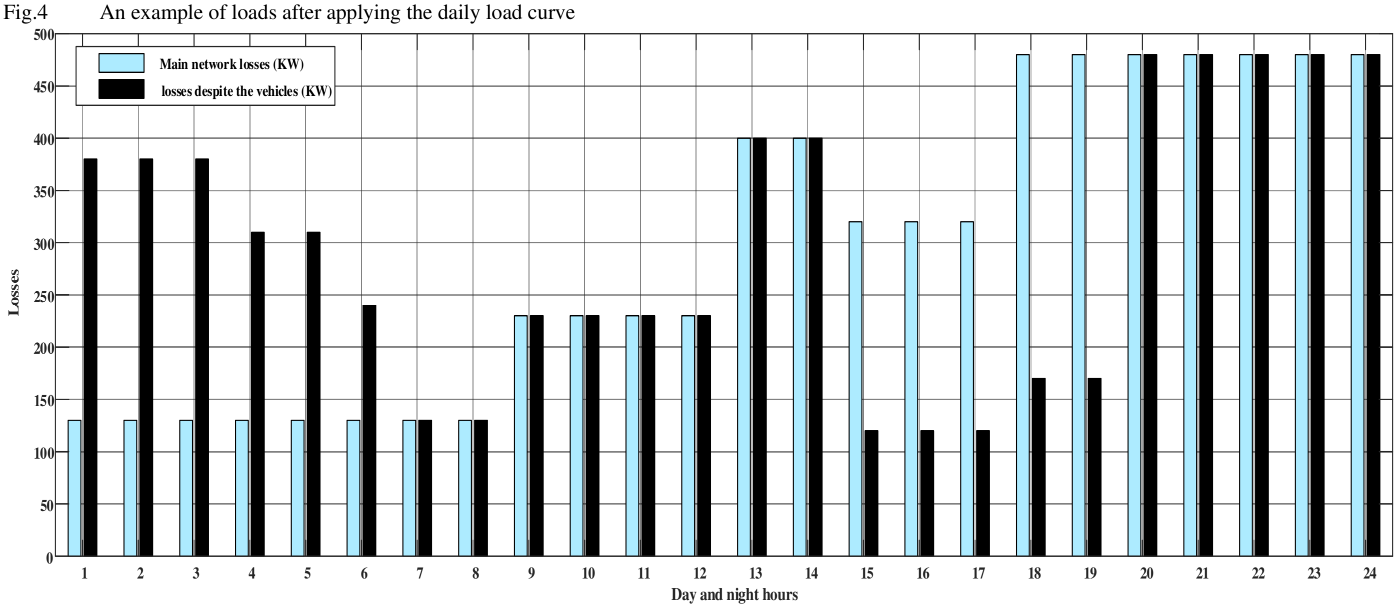
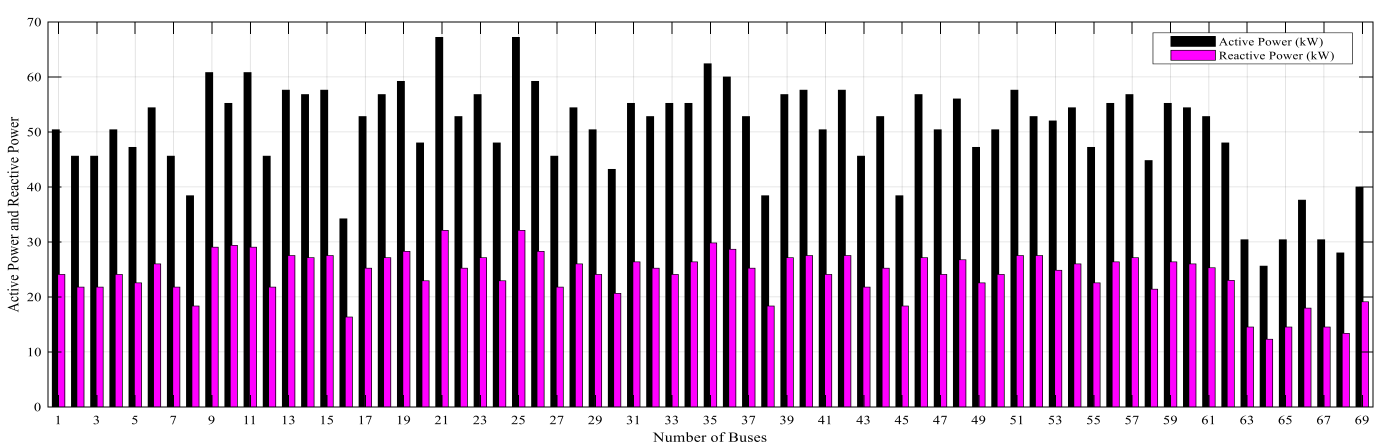


Fig.5 Results of the paper



VI. CONCLUSION

Abstract—With the presence of Electric Vehicles (EV's) in the distribution grid as a load, grid losses increase dramatically, which can have adverse effects on parameters such as deployment, cost, profit, etc. But if EV's are connected to the grid, by managing their charging and discharging, positive effects can be created in the load curve and grid losses can be reduced. In this paper, the effect of the presence of different types of EV's with different capacities and the absence of EV's on grid losses have been compared with each other considering the daily load curve. The simulation in DIGSILENT software has been done on a 74-bus distribution grid with IEEE standards considering and with 1000 vehicles. The results in Fig.5 confirm our proposed method well that the charging and discharging of EV's at different hours of the day and night and their energy exchange with the grid and management of its can achieve reduction losses in the grid and costs for the production company.

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