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***Abstract*— It is expected that a lot of the new light vehicles in the future will be electrical vehicles (EV). The storage capacity of these EVs has the potential to complement renewable energy resources and mitigate its intermittency. However, EV charging may have negative impact on the power grid. This paper investigates the impact on a Danish distribution system when the EV charging aims to reduce the charging cost by charging at the cheapest hours. Results show that the charging based on the price signal only will have adverse effect on the grid. The paper also proposes an alternate EV charging method where distribution system operator (DSO) optimizes the cost of EV charging while taking substation transformer capacity into account.**

***Index Terms*— Electrical vehicle, smart charging, spot electricity price.**

I. Introduction

THE effort to reduce the carbon foot print of electrical power industry has resulted in significant increase in renewable generation in power industry. The USA has reported that the carbon dioxide emissions from electric power generation have declined by 2.1% in 2008, compared to 2007, mainly as a result of 50% increase (17.6 TWh) in generation from wind resources [1]. The power system in Denmark is characterized by a significant penetration of wind power. In Demark, wind accounted for 27.7% of total electricity generation capacity and produced 21.9% of total electricity in 2010 [2]. Furthermore, Demark aims for independence from fossil fuels by 2050. In order to achieve this target wind power has to account for more than 40% of total electricity consumption in 2020, almost double of the current figure, and even more in 2050 [3]. Despite being stochastic in nature, renewable energy sources like wind and solar are less dispatchable and controllable. Hence, in order to achieve its 100% fossil fuel free target in 2050, Denmark not only need smart grid, but also a lot of energy storage. A significant share of the storage will come from Electrical Vehicles (EVs). EV has the potential to complement renewable resources like wind and solar and take care of their intermittency [4]-[6].

In Denmark, the transport sector accounts for roughly around 20% of the total CO_2 emissions and out of that approximately half comes from private vehicles. Another fact is that 75% of car drives less than 40 km per day in Denmark and an EV with a fully charged 20 kWh battery will be able to meet the driving requirement [7]. The incentives from the Danish government like the exemption from registration tax and vehicle excise duty until the end of 2012 and free parking in Copenhagen area is expected to increase the penetration of electrical vehicles in Denmark. The Danish power company, DONG Energy, has already signed a partnership with a Californian based EV service provider, Better Place, which is planning to build a nationwide grid across Denmark to support electric cars. That infrastructure will be composed of thousands of charging stations in towns and cities, as well as so called “switching stations” along the highways, where depleted batteries can be replaced with fully charged ones on long trips. All this suggests that Denmark is preparing for huge EV penetration in future. According to Danish Energy Association, it is expected that 25% of petrol car (around 600,000) could be replaced by electrical car by the year 2025 [8]. It is predicted that EVs will make 64-86% of new light vehicle sales by 2030 in the USA [9]. This huge penetration of EV in future will have an impact on power grid. Impact of EV charging on Portuguese grid and Indian grid has been presented in [10] and [11], respectively. Impact of EV charging on transformer life and total harmonic distortion is presented in [12],[13]. Hence, it is necessary to devise EV charging algorithms to reduce the impact on the power grid.

An EV charging algorithm that takes the hosting capacity of the lines has been presented in [14]. Another EV charging method based on the availability of power from renewable sources is presented in [15]. But the EV owners will probably charge their vehicles when the electricity price is low. An EV charging based on time-of-use tariff is presented in [16]. In this paper, two charging algorithms for EVs, based on real time pricing, are presented. The real time electricity price depends on spot price of the electricity and some fixed taxes. The first charging algorithm charges the EVs in the cheapest hours to minimize the charging cost of individual EVs. In the second algorithm, DSO minimizes the cost of EV charging by taking transformer loading into consideration.

Section II gives a brief explanation of price based EV charging. Section III gives an account of the test system where EV charging methodologies are tested. Section IV explains

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the simulation cases. Section V presents the results and analysis of price based charging. Section VI presents an alternative algorithm to price based algorithm to overcome the issues with price based EV charging. Some conclusions are drawn in Section VII.

II. Price Based EV Charging

A simple smart charging algorithm is to charge an EV in the cheapest hours. In this paper, it is assumed that there are algorithms that can forecast the price with greater accuracy. The spot price of the electricity is shown in Fig. 1. When an EV is connected to the grid, the charging algorithm generates the charging schedule based on the forecasted price and state of charge to minimize the charging cost. In other word, the algorithm will charge the EV in cheapest hour. It can be seen from Fig. 1 that even though the prices may fluctuate with days, the cheapest hours for charging are usually the early morning when the system is lightly loaded.

III. System Description

The smart charging algorithm is tested in a test distribution system in Aalborg, Denmark, which was previously owned by a local distribution system operator "AKE El-Net Forsynings virksomhederne i Aalborg". It consists of 7 feeders and 231 end users supplied though a 400 kVA transformer. This paper assumes EV penetration of 25% (58 EVs). This paper also assumes that the EV battery size is 24 kWh. DIgSILENT PowerFactory has been used to model the test system, EVs, and test the impact of smart charging. Electric vehicles are modeled as constant power loads. It is difficult to determine the availability of EVs for charging. Hence, the paper has classified them in 5 different categories for simplicity:

- Type 1 comprises of 60% of total EVs and is available for charging from 16:00 till 6:00.
- Type 2 comprises of 10% of total EVs and is available for charging from 18:00 till 4:00. They may be owned by people working 12 hours a day.
- Type 3 comprises of 20% of total EVs and is available for charging from 18:00 till 6:00, from 11:00 till 14:00, and from15:00 till 17:00. They may be owned by mothers with children.
- Type 4 comprises of 5% of total EVs and is available for charging from 19:00 till 07:00 and 12:00 till 14:00. They may be owned by workers working in 2 shifts.
- Type 5 comprises of remaining 5% EVs and is available for charging from 8:00 till 22:00. They may be owned by night shift workers.

IV. Simulation Cases

The vehicles are charged via a household mains supply (230 V phase to neutral and 16 A in Danish cases). Three phase supply is used to charge the EVs. Three different loading conditions have been considered. The first one considers average hourly loading of the system in summer. The second one considers average hourly loading of the test system in spring. The loading of system in autumn is similar to that of the spring and hence only spring loading condition has been chosen. The last case considers the loading of system in the Christmas day. The loading of the 400 kVA substation transformer for these three different cases are shown in Fig. 2. In Denmark, electricity price consists of spot price and various other taxes that are fixed irrespective of the consumption [17]. Average hourly spot electricity price for summer and spring and the hourly spot electricity price for Christmas day are shown in Fig. 1. As mention above, this price is forecasted, with an acceptable accuracy, a day ahead and used to determine EV charging hours.

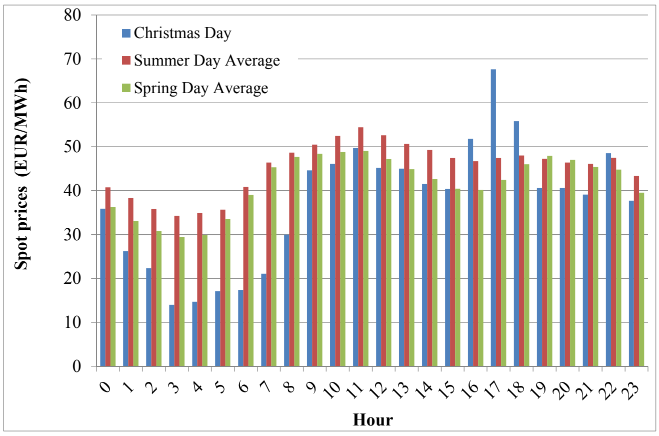

Fig. 1. Spot price of the electricity for three cases

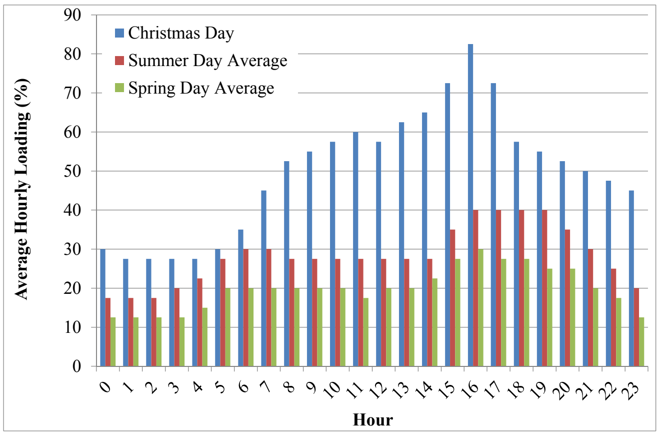

Fig. 2. Average hourly loading of the system

Two different scenarios have been considered. The first scenario assumes that the EVs are distributed randomly whereas the second scenario assumes that EVs are connected to the buses with the lowest voltages. The availability of EVs and their state of charge are generated randomly using the user classification mentioned in section II. Fig. 3 shows the number of EVs available for charging during the different hours of the day for two scenarios. State of charge of the EVs each time they are available for charging for scenarios 1 and 2 are shown in Fig. 4 and Fig. 5, respectively. Note that, Type 3 EVs are available for charging in three time slots and hence have three connection times. Also, in Scenario 1, there are no Type 5 EVs and hence all the 58 EVs are available for charging during night.

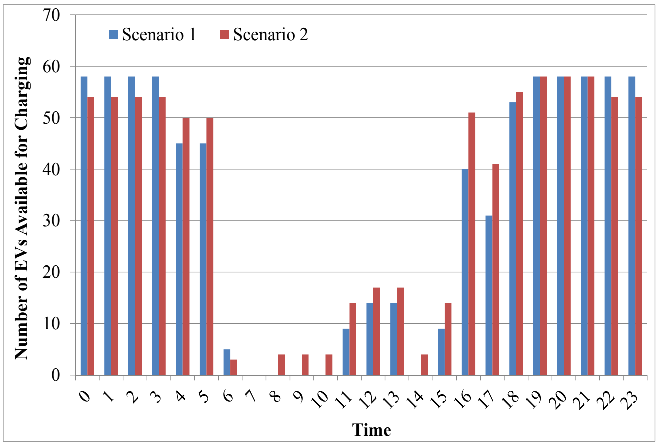

Fig. 3. Number of EVs available for charging

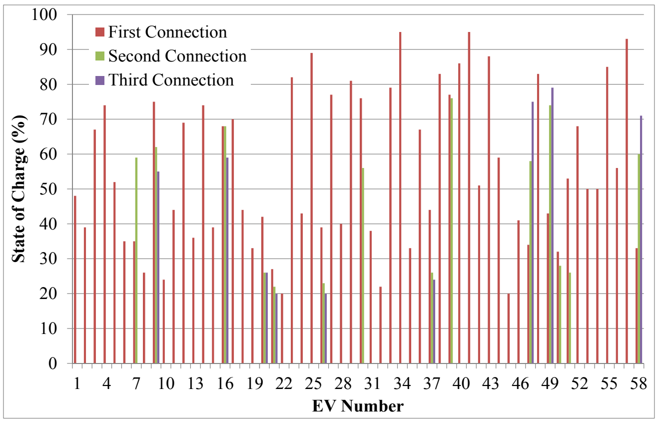

Fig. 4. State of charge of EVs at each connection for scenario 1

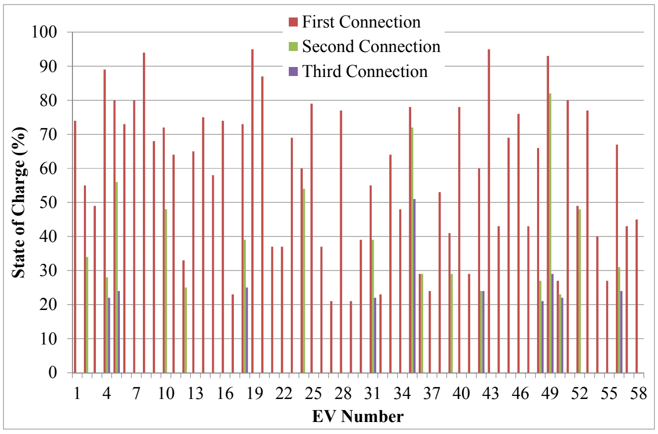

Fig. 5. State of charge of EVs at each connection for scenario 2

The distribution of the EVs in test distribution system in scenarios 1 and 2 are shown in Fig. 6 and Fig. 7, respectively. The red circles with number represent the location of specific electrical vehicle in the test distribution system.

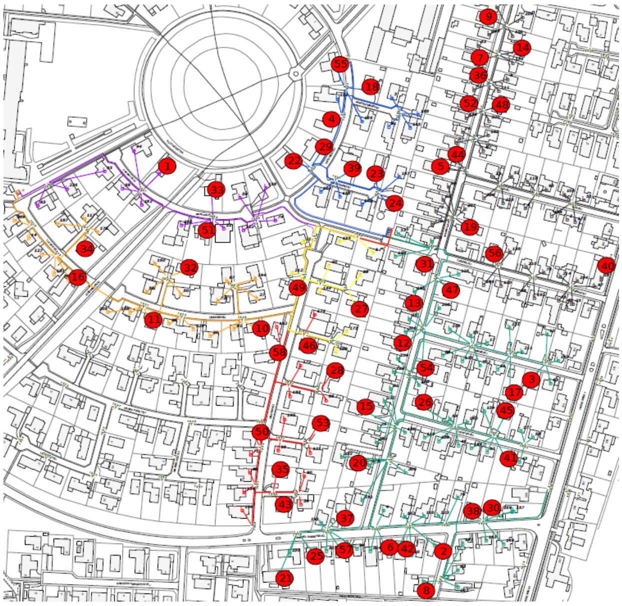

Fig. 6. EV distribution is scenario 1

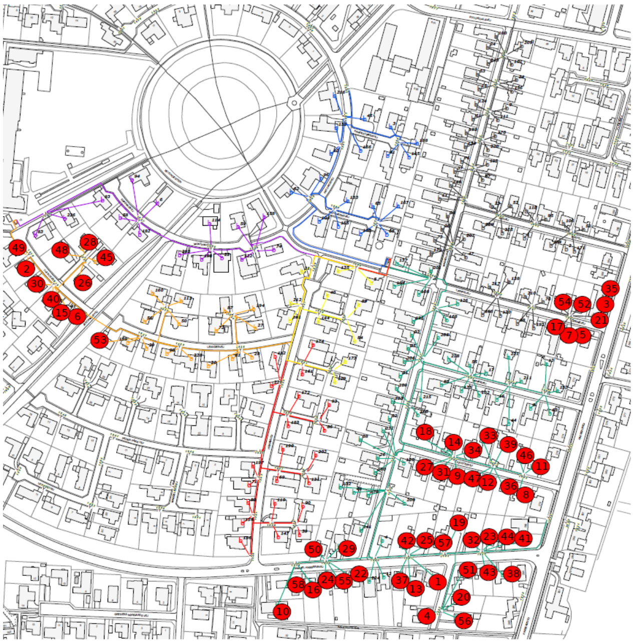

Fig. 7. EV distribution is scenario 2

V. Analysis of Price Based EV Charging

Table I and Table II show the charging hours of individual EV, for Christmas, summer and spring days, to achieve the minimum charging cost in scenarios 1 and 2, respectively. The EVs are charged 100% each time they are available for charging. The cheapest hours among the available hours, for charging, are chosen to charge EVs. Each cell in the tables represents the hour(s) in which an EV is charging. The first row and first column, under each case, denotes the EV index from which the EV number is found. As an example, index numbers 3 in the first column and 5 in the first row corresponds to EV no 35. The EV charges in hour 02 and 03.

TABLE I
CHARGING TIME OF INDIVIDUAL EVS FOR SCENARIO 1

Christmas Day

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3,4	3,4	3	3	2,3	2,3	3,4,13	3,4	3,13,15
1	3,4	3,4	3	3,4	3	2,3	3,13,15	3	2,3	3,4
2	3,4,12,13,15,16	3,4,12,13,15,16	3,4	3	3,4	3	3,4,12,13,15,16	3	3,4	3
3	3,13	2,3	3,4	3	3	2,3	3	3,4,12,13,15,16	3	3,13
4	3	3	3,4	3	3	3,4	3,4	3,4, 13,15	3	3,4, 13,15
5	3,4,12,13	3,4,12,13	3	3,4	2,3	3	3	3	3,4,13,15	

Spring

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3,4	3,4	3	3	2,3	2,3	3,4,13	3,4	3,13,16
1	3,4	3,4	3	3,4	3	2,3	3,13,16	3	2,3	3,4
2	3,4,12,13,15,16	3,4,12,13,15,16	3,4	3	3,4	3	3,4,12,13,15,16	3	3,4	3
3	3,13	2,3	3,4	3	3	2,3	3	3,4,12,13,15,16	3	3,13
4	3	3	3,4	3	3	3,4	3,4	3,4,13,16	3	3,4,13,16
5	3,4,12,13	3,4,12,13	3	3,4	2,3	3	3	3	3,4,13,16	

Summer

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3,4	3,4	3	3	2,3	2,3	3,4,13	3,4	3,13,16
1	3,4	3,4	3	3,4	3	2,3	3,13,16	3	2,3	3,4
2	3,4,12,13,15,16	3,4,12,13,15,16	3,4	3	3,4	3	3,4,12,13,15,16	3	3,4	3
3	3,13	2,3	3,4	3	3	2,3	3	3,4,12,13,15,16	3	3,13
4	3	3	3,4	3	3	3,4	3,4	3,4,13,16	3	3,4,13,16
5	3,4,12,13	3,4,12,13	3	3,4	2,3	3	3	3	3,4,13,16	

TABLE II
CHARGING TIME OF INDIVIDUAL EVS FOR SCENARIO 2

Christmas Day

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3	3,4,12,13	3,4	3,12,13 15,16	3,13 15,16	3	3	3	3
1	8	3	8,21	3	3	3	3	3,4	3,12,13,15,16	3
2	3	3,4	3,4	3	3,13	3	3,4	3,4	3	3,4
3	3,4	3,4,12,1315,16	2,3	3	3,4	3,12,15	3,4, 12,13	3,4	3,4	8,21
4	3	3,4	3,12,13,15,16	3	3,4	3	3	3,4	3,12,13,15,16	3,13,15,16
5	3,4,2,13, 15,16	3	8,21	3	3,4	3,4	3,12,13 15,16	3,4	2,3	

Spring

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3	3,13,12	3,4	3,13,12 16,15	3,13 16,15	3	3	3	3
1	16	3	16,15	3	3	3	3	3,4	3,13,12,16,15	3
2	3	3,4	3,4	3	3,13	3	3,4	3,4	3	3,4
3	3,4	3,4,13,12,16,15	3,2	3	3,4	3,13,16,15	3,4,13,12	3,4	3,4	16,15
4	3	3,4	3,13,12,16,15	3	3,4	3	3	3,4	3,13,12,16,15	3,13,16,15
5	3,4,13,12,16,15	3	16,15	3	3,4	3,4	3,13,16,15	3,4	3,2	

Summer

EV No.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0		3	3,13,12	3,4	3,13,12 16,15	3,13 16,15	3	3	3	3
1	21	3	21,20	3	3	3	3	3,4	3,13,12,16,15	3
2	3	3,4	3,4	3	3,13	3	3,4	3,4	3	3,4
3	3,4	3,4,13,12,16,15	3,2	3	3,4	3,13,16,15	3,4,13,12	3,4	3,4	21,20
4	3	3,4	3,13,12,16,15	3	3,4	3	3	3,4	3,13,12,16,15	3,13,16,15
5	3,4,13, 12,16,15	3	21,20	3	3,4	3,4	3,13,16,15	3,4	3,2	

Figs. 8 and 9 show the transformer loading with EVs in scenarios 1 and 2, respectively. As it can be seen from the figures that when all the EVs are charged in the cheapest hours, generally during the night when the system is lightly loaded, it can easily cause overloading in the system. The transformer is loaded around 200%, in all the cases, at the cheapest hour when all the available EVs are charging.

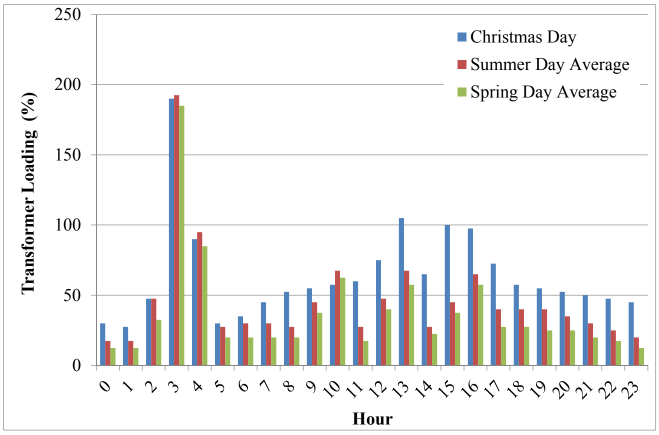

Fig. 8. Transformer loading with optimal electric vehicle charging in scenario 1

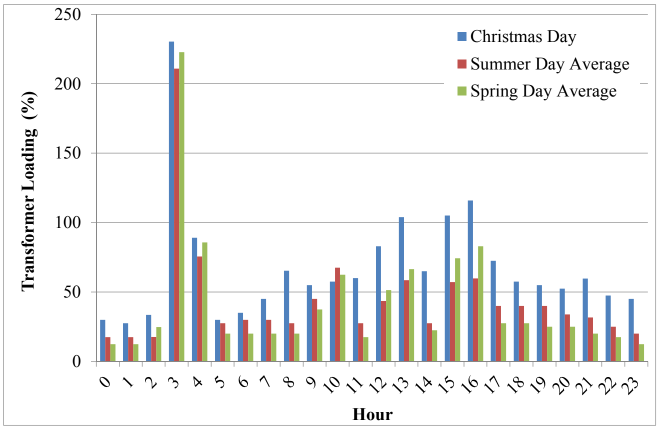

Fig. 9. Transformer loading with optimal electric vehicle charging in scenario 2

In Denmark, transformers are generally loaded at around 50-60% even during the pick hours. In the current test system, the transformer is loaded by not more than 40% except for the Christmas day. Despite of that, the transformer is overloaded when all EVs are charged during the cheapest hours. But in many utilities, the transformers are undersized assuming that they can cool down during the night [18]. Thus overloading the transformer in off-peak hours, as well, may lead to transformer breakdowns. Apart from the overloading of the transformer, severe voltage problem are also encountered. It can be seen from Fig. 10 that when all EVs are charging, the voltages at some of the buses can easily go below the power quality limit of 0.9 p.u. The voltages can go even further below in the worst case scenario (Scenario 2) as shown in Fig. 11.

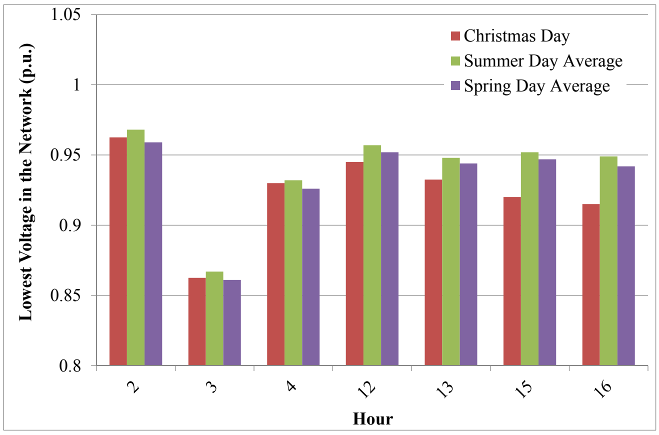

Fig. 10. The lowest voltages in the network with electric vehicle charging in different hours in scenario 1

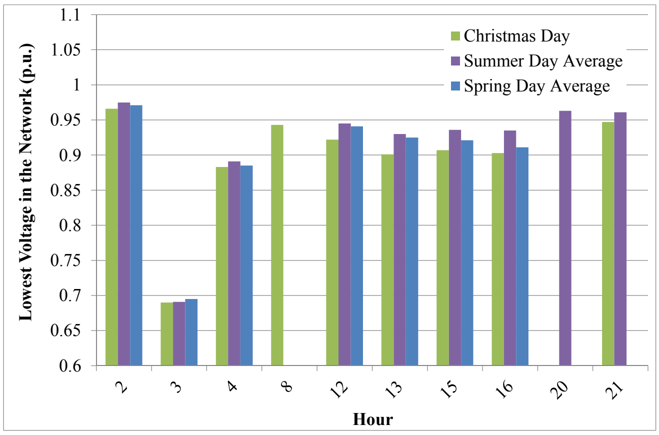

Fig. 11. The lowest voltages in the network with electric vehicle charging in different hours in scenario 2

VI. Proposed Smart Charging

As it can be seen from the above section, the charging of EVs, based on the electricity price only, leads to severe over loading and under-voltage problems. The solution to the above problems can be the smart grid where a lot of information about the power grid will be available. This paper proposes a method for charging of the electric vehicle in smart grid environment. In this method, the EVs are classified into two categories; namely Class A and Class B. Class A EVs are the ones who want to get charged faster by using the highest power possible. In the studied case, it is 11.04 kVA (3x230Vx16A). Rest of the EVs is classified as Class B. The Class B electric vehicle has to submit their availability for the next 24 hours. Then, the distribution system operator (DSO) calculates the charging power available to each Class B EVs, for each hour, based on the load forecast so as not to overload the substation transformer. If all the EVs are Class B, the available power for charging each available EV, for different cases in scenarios 1 and 2, are shown in Fig. 12.

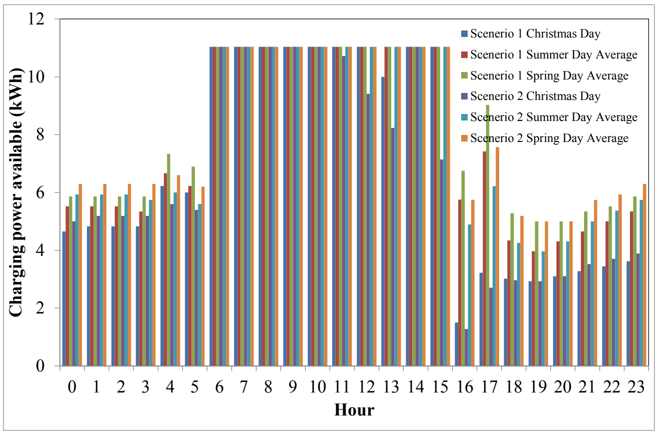

Fig. 12. Charging power available to each Class B EVs for different cases

In this proposed method, when the EVs are connected to the supply, their state of charge is communicated to the DSO. Based on this and EV's availability, the DSO develops the charging schedule of the EV. To explain the proposed methodology, two new scenario have been created; namely Scenario 3 and Scenario 4. In scenarios 3 and 4, EVs are distributed according to the scenarios 1 and 2, respectively. However, the charging power available to EVs will be limited by the DSO; unlike the scenarios 1 and 2 where each EV charges with maximum power (11.04 kW). All the EVs are considered as Class B.

The percentage change in the cost of charging individual EV in scenarios 3 and 4 compared to scenarios 1 and 2 are presented in Fig. 13 and Fig. 14, respectively. As expected the cost increases in most cases. However, there are some cases where cost decreases. This is basically due to the EVs, which connect in the midday but are not able to charge fully due to the scarcity of the power.

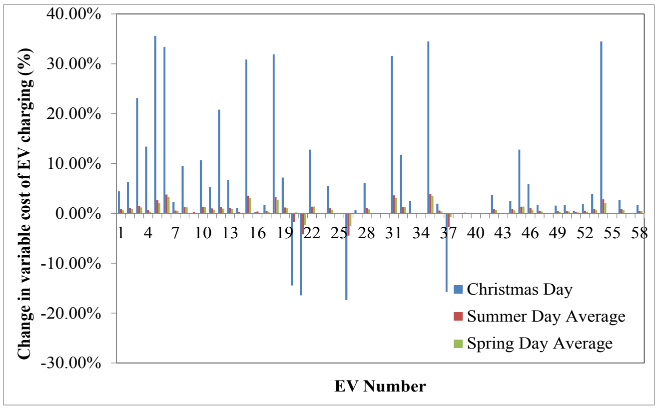

Fig. 13. Percentage change in price in scenario 3 compared to scenario 1

Scenarios 3 and 4 are ideal cases, where all the EVs are Class B. But there can be cases where some of the EVs may be Class A. Also, all the class B EVs may not be able to follow the availability they submitted to the DSO. In that case, they can change themselves to Class A.

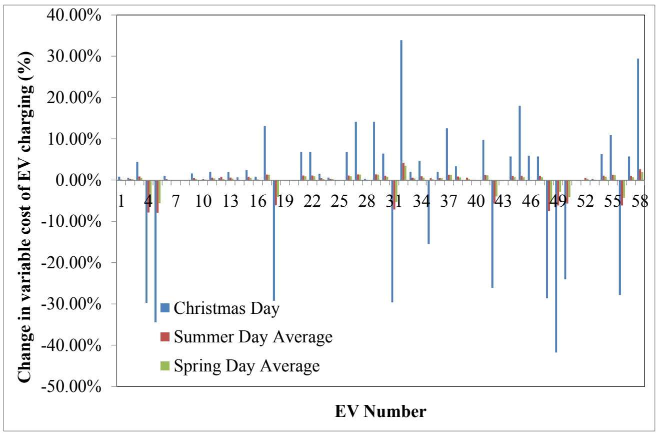

Fig. 14. Percentage change in price in scenario 4 compared to scenario 2

As mentioned earlier, Class A vehicle can charge at the rate of 11.04 kWh per hour if the capacity is available. As an example, if there are 4 Class A EVs and the substation transformer capacity reserve is only 20 kVA, then the EVs are charged at 5 kWh per hour. If some Class A vehicles want to get charged and some Class B vehicles are also charging, Class B vehicles are charged with lower power and some of the charging may be moved to later hours. However, this does not apply to the Class B EV which is in its last hour of charging before disconnection. At this point, it should be noted that the entire Class B vehicles will pay according to original schedule. Any extra cost of charging incurred by Class B EVs due to the change in schedule, as a result of Class A vehicles, is passed to Class A vehicles.

To explain the proposed technique, average summer loading of Scenario 2 is considered as an example. EV No. 57 and 58 are considered to be Class A and they connect at 02:00 for charging. The remaining 56 EVs are Class B vehicle. They submit their availability to the DSO. The DSO develops the charging schedule for these 56 EVs, which are presented in Table III. Again, the first row and first column, under each case, denotes the EV index from which the EV number is found. Each cell in the tables represents the hour(s) in which an EV is charging. The charging power in each hour in kWh is given in parenthesis. As an example EV No. 7 charges at hour 03 and takes 4.8 kWh. However, when Class A EVs (EV No. 57 and 58) connect, some of the charging of Class B electric vehicle have to be shifted to later hours. The new charging time of individual EV and charging power in each hour are given in Table IV. The EV No. 57 and 58 will have their charging cost increased as they have to incur the cost as result of shifting other EV charging time. The other 56 Class B EVs pay their charging cost as per the original schedule.

TABLE III

ORIGINAL CHARGING SCHEDULE OF INDIVIDUAL EVS BASED ON PROPOSED METHOD

EV No.	0	1	2	3	4	5	6	7	8	9
0		3(5.96),4(0.28)	3(5.96),4(4.84) 13(11.04),12(4.80)	3(5.96) 4(6.12) 5(0.16)	3(2.64),13(11.04) 12(6.24),16(4.60) 15(11.04)	3(4.80),13(10.56) 16(4.60),15(11.04)	3(5.96) 4(0.52)	3(4.80)	3(1.44)	3(5.96) 4(1.72)
1	21(4.82) 20(1.90)	3(5.96)4(2.68)	21(4.82),20(4.46) 16(4.60),19(2.19)	3(5.96) 4(2.44)	3(5.96),4(0.04)	3(5.96),4(4.12)	3(5.96),4(0.28)	3(5.96),4(6.12) 5(5.71),2(0.68)	3(5.96),4(0.52) 13(11.04),12(3.60) 16(4.60),15(11.04)	3(1.20)
2	3(3.12)	3(5.96) 4(6.12),5(3.04)	3(5.96),4(6.12) 5(3.04)	3(5.96) 4(1.48)	3(5.96),4(3.64) 13(11.04)	3(5.04)	3(5.96),4(6.12) 5(3.04)	3(5.96),4(6.12) 5(5.71),2(1.16)	3(5.52)	3(5.96),4(6.12) 5(5.71),2(1.16)
3	3(5.96), 4(6.12),5(2.56)	3(5.96),4(4.84), 13(11.04),12(3.60) 16(4.60),15(11.04)	3(5.96),2(6.15) 1(6.15),0(0.21)	3(5.96) 4(2.68)	3(5.96),4(6.12) 5(0.40)	3(5.28),13(6.72) 16(4.60),15(7.16)	3(5.96),4(6.12) ,5(4.96) 13(11.04),12(6.00)	3(5.96),4(6.12) 5(5.71),2(0.44)	3(5.96),4(5.32)	21(4.82),20(4.46) 16(4.60),19(0.27)
4	3(5.28)	3(5.96),4(6.12) 5(4.96)	3(5.96),4(3.64) 13(11.04),12(7.20) 16(4.60),15(11.04)	3(1.20)	3(5.96),4(6.12) 5(1.60)	3(5.96),2(1.48)	3(5.76)	3(5.96),4(6.12) 5(1.60)	3(5.96),4(2.20) 13(11.04),12(6.48) 16(4.60),15(11.04)	3(1.68),13(4.32) 16(4.60),15(11.04)
5	3(5.96),4(6.12),5(5.44) 13(11.04),12(7.44) 16(4.60),15(11.04)	3(4.80)	21(4.82),20(4.46) 16(2.95)	3(5.52)	3(5.96),4(6.12) 5(2.32)	3(5.96),4(6.12) 5(5.44)	3(5.96),4(1.96) 13(11.04),12(5.52) 16(4.60),15(11.04)			

TABLE III

ACTUAL CHARGING TIME AND POWER OF INDIVIDUAL EVS BASED ON PROPOSED METHOD

EV No.	0	1	2	3	4	5	6	7	8	9
0		3(5.87),4(0.37)	3(5.87),4(4.93) 13(11.04),12(4.80)	3(5.87) 4(6.12) 5(0.25)	3(2.64),13(11.04) 12(6.24),16(4.60) 15(11.04)	3(4.80),13(10.56) 16(4.60),15(11.04)	3(5.87),4(0.61)	3(4.80)	3(1.44)	3(5.87),4(1.81)
1	21(4.82),20(1.90)	3(5.87),4(2.77)	21(4.82),20(4.46) 16(4.60),19(2.19)	3(5.87) 4(2.53)	3(5.87),4(0.13)	3(5.87),4(4.21)	3(5.87),4(0.37)	3(5.87),4(6.12) 5(5.71),2(0.77)	3(5.87),4(0.61) 13(11.04),12(3.60) 16(4.60),15(11.04)	3(1.20)
2	3(3.12),	3(5.87),4(6.12) 5(3.13)	3(5.87),4(6.12) 5(3.13)	3(5.87) 4(1.57)	3(5.87),4(3.73) 13(11.04)	3(5.04)	3(5.87),4(6.12) 5(3.13)	3(5.87),4(6.12) 5(5.71),2(1.25)	3(5.52)	3(5.87),4(6.12) 5(5.71),2(1.25)
3	3(5.87),4(6.12) 5(2.65),	3(5.87),4(4.93) 13(11.04),12(3.60) 16(4.60),15(11.04)	3(5.87),2(5.73) 1(6.15),0(0.73)	3(5.87) 4(2.77)	3(5.87),4(6.12) 5(0.49),	3(5.28),13(6.72) 16(4.60),15(7.16)	3(5.87),4(6.12) 5(5.05),13(11.04) 12(6.00)	3(5.87),4(6.12) 5(5.71),2(0.53)	3(5.87),4(5.41)	21(4.82),20(4.46) 16(4.60),19(0.27)
4	3(5.28)	3(5.87),4(6.12) 5(5.05)	3(5.87),4(3.73) 13(11.04),12(7.20) 16(4.60),15(11.04)	3(1.20)	3(5.87),4(6.12) 5(1.69)	3(5.87),2(1.57)	3(5.76)	3(5.87),4(6.12) 5(1.69)	3(5.87),4(2.29) 13(11.04),12(6.48) 16(4.60),15(11.04)	3(1.68),13(4.32) 16(4.60),15(11.04)
5	3(5.87),4(6.12),5(5.53) 13(11.04),12(7.44) 16(4.60),15(11.04)	3(4.80)	21(4.82),20(4.46) 16(2.95)	3(5.52)	3(5.87),4(6.12) 5(2.41)	3(5.87),4(6.12) 5(5.53)	3(5.87),4(2.05) 13(11.04),12(5.52) 16(4.60),15(11.04)	2(11.04) 3(2.64)	2(11.04) 3(2.16)	

VII. Conclusion

Power industry contributes significantly to global greenhouse gas emission. It is looking for renewable energy to reduce its carbon footprint. However, the stochastic nature of renewable energy sources couple with less controllability and dispatchabilty demand for huge energy storage. Electric vehicles are pointed out as the possible solution. However, the charging of the electric vehicle can have negative impacts on the grid. This paper shows that the charging of electric vehicle, based on the price signal only, can result in significant overloading of the system as well as severe under-voltage problems in the electrical grid. These problems demand for smart EV charging algorithms that are not only based on price signals. An EV charging algorithm based on the price signal and transformer capacity is presented in this paper. The DSO, based on EV availability, devises the optimal EV charging strategy to minimize the cost for the EV owner and, at the same time, avoid any overloading problem.

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