Power Loss Reduction for Electric Vehicle Penetration with Embedded Energy Storage in Distribution Networks

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***Abstract*—Electric vehicles (EVs) are becoming more popular in modern society. These vehicles can be charged at home or in public areas with standard outlets. However, the extra power demand affects the distribution network (DN) in terms of power losses. If these vehicles are connected into the DN during peak times, it increases the power losses. One effective methods to solve this issue would be the introduction of energy storage systems (ESSs). Therefore, both active and reactive power dispatch combined with different charging periods, off peak and peak, for the ESS is proposed in this paper. The research provides both uncoordinated optimal active-reactive power flow (UA-RPF) of the ESS and the coordinated optimal active-reactive power flow (CA-RPF) of the ESS, which improves the performance of the DN. Results for the IEEE-33 distribution system are presented. It is demonstrated that 1.43MW total power losses (TPL) and 1.64MW of imports from the transmission network (TN) can be reduced by using the proposed approach.**

Keywords: Power losses, optimization algorithm, ESS.

I. INTRODUCTION

With modern technological development, and raising awareness of environmental protection, EVs will become cheaper and less environmentally damaging alternatives, to traditional vehicles. Customers can charge their EVs either using electric outlets in their homes, working places or public stations with charging plugs. These EVs can only be driven over a limit range, some of the EVs may have larger batteries and better drive systems, but their range is still limited[1][2].

The charging process can greatly affect the DN, especially when a large number of the EVs are connected to the DN at the same time. These vehicles use considerable amounts of energy, so that if this scenario happens at peak time, it worsens the insecurity level of the DN, and cause a great deal of active power loss. Meanwhile, this puts lots of pressures on the system operators in terms of keeping the system secure. It has been shown that, if EV penetration increases by 10% between 18:00-21:00 hours, energy losses raise by almost 3.7%[3].

From the system operator's point of view the power losses are an economic concern and need to be reduced. One the reduction methods is to add ESS into the DN. Usually ESSs in the DN are combined with any available renewable energy sources in order to accommodate variations in these sources, thus making the system more stable. Some areas do not have sufficient sources of renewable energy generation, and therefore to address this situation, the concern of this paper is how to use ESS to improve the system performance, for example by reducing the power losses. From the EV owner's point of view, they want to use cheaper electricity when they charge their EVs and, this is also considered in the paper.

Previously, active and reactive power dispatches were considered separately for loss reduction. Some researchers concentrate on installing capacitors for reactive power optimization[4]. Some researchers use an algorithm for optimal location selection to reduce active power losses[5], others to remove load imbalances in the radial network for loss reduction [6]. Alternatively, the methods proposed in this paper consider the reduction of both active and reactive power losses. Also, two optimization methods, both based on the ESSs were used and compared for losses reduction caused by the different levels of EV penetration.

Renewable energy sources were also implemented in the model for this research, including wind power generation and photovoltaic generation. In this optimization problem, only active, and reactive power losses and the power imported from the TN are considered.

This article emphasizes the improvements and the differences when using the two charging methods, which are UA-RPF of the ESS and the CA-RPF of the ESS. It also indicates how much active power can be reduced from the TN.

II. ASSUMPTION AND MODLING

A. Load scenarios

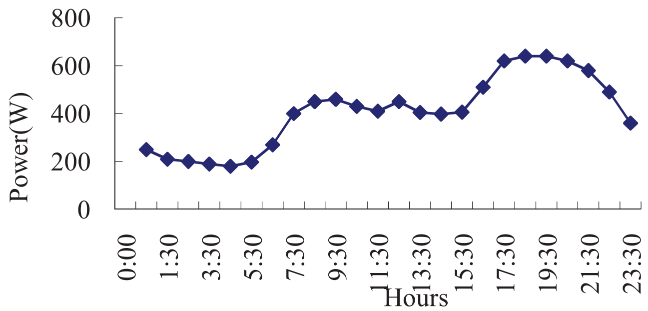

Fig.1. Daily electricity demand in a UK residence excluding heating

From the available household load measurements data[7], a daily electricity demand (excluding heating) in the UK residence has been drawn above.

B. Specifications and modeling of EVs

Recent market data shows that, EV sales are lead by the Chevrolet Volt plug-in hybrid with 48,218 units, followed by Nissan Leaf all electric cars with 35,588 units. The Toyota Prius Plug-in Hybrid occupies the third largest market with 20,724 units, with the fourth being the Tesla Model S with over 15,000 units[8][9][10][11]. Accordingly, it can be seen that the Chevrolet Volt plug-in hybrid occupies the 41% of the whole electric vehicle market, the Nissan Leaf all-electric car account for 30%, the Toyota Prius Plug-in Hybrid takes up 17%, while the Tesla Model S shares the rest of the market which is 12% . Therefore, an assumption is made, each load feeder, 41 people use Chevrolet Volt Plug-in Hybrid cars, 30 people use Nissan Leaf all-electric cars, 17 people buy Toyota Prius Plug-in Hybrid cars, and 12 people use the Tesla Model S. The characteristics of the different electric vehicles are shown below[12].

TABLE I. CHARACTERISTIC OF THE EV

	Load Type	Type	Pd(MW)	BatterySize(KWh)
12	**Tesla Roadster**	**Battery**	0.0168	53
30	**Nissan leaf**	**Battery**	0.06	24
41	**Chevrolet Volt**	**Hybrid**	0.003	16
17	**Toyata Prius**	**Hybrid**	0.003	4.0

In order to analyze the impacts of EVs on the distribution system, these vehicles are connected in the feeder 22, 25, 32, and 14 of the IEEE 33-bus distribution system[13]. Comparisons are made, to see the differences in terms of active power losses in some specific buses.

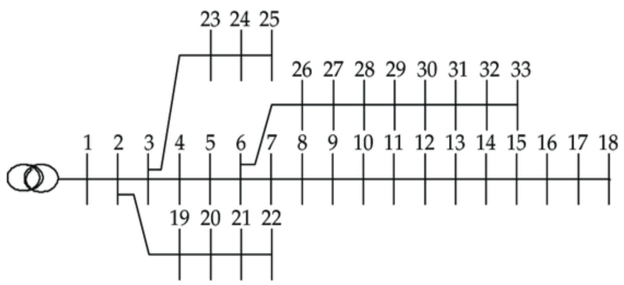

Fig.2.The tested DN

The maximum power demand (PD) for all 41 Tesla Roadsters is 0.688MW, for all 30 Nissan leafs is 1.8MW, for all 17 Chevrolet Volts is 0.051MW, and for all 12 Toyota Prius is 0.036MW. The total power demand (TPD) is
2.1756 2.575MW, and it is added into the node 22, node 25, node 32, and node 14 respectively which is chosen randomly. The load feeder data is shown in the Table II .

Each EV has a battery and, the charging characteristic can be seen in Table.I. For the Tesla Roadster 0.0168 MW power are needed to be fully charged, for the Nissan Leaf it is 0.06 MW, for the Chevrolet Volt is 0.003MW, and for the Toyota Prius it is 0.003MW. The battery can only be charged during the charging time, which means energy flow is unidirectional, so the concept of EVs to grid is not considered here. Fast charging is taken into consideration, but requires a higher short-circuit power. Customers can purchase an electrical outlet to fit the high short-circuit power from the auto-supply shop. Extra costs are needed to install the high voltage connection equipment, but it can charge the EV faster than others. The scenario studied up to 40% EVs penetration in 10% increments, based on the 20% penetration. For example at 20% EVs penetration, it is assume that there are 20 EVs, Chevrolet Volt occupies the 41% which is 8 Chevrolet Volts, 6 Nissan Leafs, 3 Toyota Prius, and 2 Teslas.

TABLE II. LOAD FEEDER DATA

Load feeder	PD(MW)	TPD(MW)	PD'(MW)
22	0.09	2.575	2.675
25	0.21	2.575	2.785
32	0.42	2.575	2.995
14	0.12	2.575	2.695

C. Charging period and place

Although the EV is becoming more popular, charging stations are not as common as petrol stations, therefore, EVs are assumed to be charged at home or at the work place. Fig.3 shows the percentage of vehicles arriving at home[14]. From Fig. 3 periods are proposed. The first one is from the 8:30 t to 14:30 people arrive home and plug their EVs in to the charging station nearby or their garage. The second charging period takes place between 14:30 and to 19:30 and, this period coincides with the peak load during the day and also more EVs arriving home. These penetrations can lead to more power losses in the DN. The last charging period is from 19:30 to 23:30, with less people arriving home and charging their EVs during the night. This assumes that, there is only one EV per house and that the charging places are usually either at home, at the office or in the centre of town.

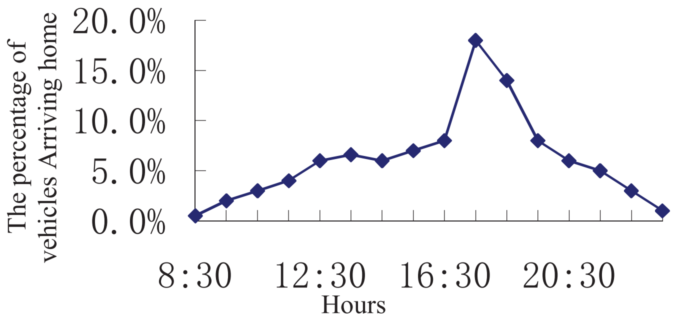

Fig.3.Percentage of vehicles not under way

D. The method of load flow analysis

A load flow analysis in terms of total power losses(TPLs), total generation, and PD was performed by the matpower using the IEEE 33-bus tested distribution system, combined with different EVs penetration levels, different load profiles, and different charging periods. Two scenarios are chosen to be analysed, depending on the different penetration levels. The first case for each scenario is taken as the base value, which is without adding any EVs into the distribution grid, but different load profiles in three different charging periods. The next cases are with the EVs penetration 20%, 30%, 40%, respectively in three charging periods. The charging feeders of the EVs are randomly chosen in the IEEE 33 node system.

TABLEIII. PERCENT BETWEEN TOTAL POWER LOSSES AND TOTAL POWER

Penetration level / Charging period	0%	20%	30%	40%
8:30-14:30	3.16%	4.39%	5.07%	5.92%
14:30-19:30	3.25%	4.41%	5.23%	6.03%
19:30-23:30	3.24%	4.15%	4.92%	5.69%

E. Result

The results of the power losses in terms of the uncoordinated charging are shown in Table 3 below. The numbers of EVs used were 100, as this is a reasonable number of EVs for a medium size community. The results show the percentage of TPLs to the total power received from TN.

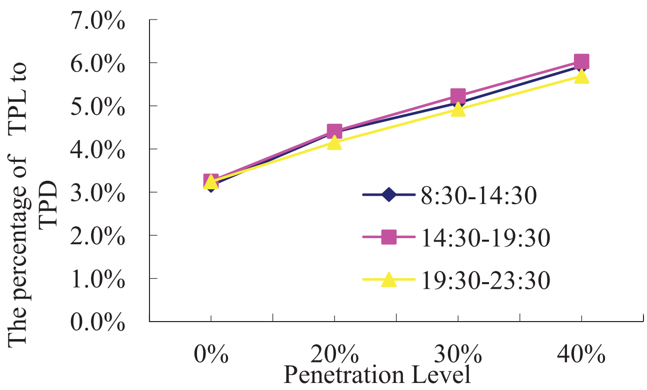

Fig.4.Difference of the total power demand of three methods

In all cases with the EV penetrations increase, the percentage of the TPL increase. The highest power losses take place between 14:30 and 19:30. Two reasons for it, one is the load during that period is higher than the other periods, the other is more EVs arrive at home during that period. Knowledge of these power losses are vital to the system operators, in order to them to compensate for the system losses and choosing the appropriate methods to do this.

III. THE METHODS OF POWER LOSSES REDUCTION IN THE TEST NETWORK

A. *Objective function and constraints*

The previous section illustrates power losses in the IEEE 33 tested network. For reducing these losses, the ESS was embedded into the DN as shown in the Fig. 2, meanwhile, the objective function Min $P_L = \sum_{\forall k,m}^{k,m \in S_B} I_i^2 R_i$,based on the power flow analysis was built.

In order to analyse the power losses in the DN, a π model combined with ESS and DN of a particular distribution line between nodes k and m was modelled, with real and the reactive power flow through node k (the sending point) and m (the receiving end) as given by bellows.

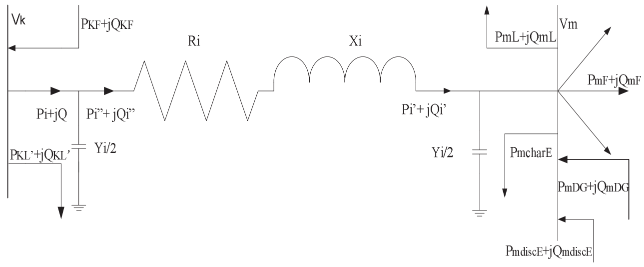

Fig.5.The model of a distribution network branch between node p and q

From Fig .5. it can be seen that

$$P_i' = P_{mL} + P_{mcharE} + P_{mF} - P_{mDG} - P_{mdiscE} \quad (1)$$

$$P_i = P_i'' = P_i' + R_i \frac{P_i'^2 + Q_i'^2}{V_m^2} \quad (2)$$

$$Q_i' = Q_{mL} + Q_{mF} - Q_{mDG} - Q_{mdiscE} - V_m^2 \frac{Yi}{2} \quad (3)$$

$$Q_i = Q_i'' - V_k^2 \frac{Yi}{2} = Q_i' + X_i \frac{P_i'^2 + Q_i'^2}{V_m^2} - V_k^2 \frac{Yi}{2} \quad (4)$$

Where P_i and Q_i are the sending active and reactive power through nodes k and m, the series impedance and shunt admittance between node k and m are $(R_i + j X_i)$ and $\frac{Yi}{2}$ respectively, P_{mDG} and the Q_{mDG} are the real and reactive power injected by the distribution generation, the P_{mDG} and the Q_{mDG} are not considered in the optimization. P_{mL} and the Q_{mL} are the total active and reactive power load at bus m. P_{mF} and Q_{mF} are the sum of active (reactive) power flows through all the downstream branches connected to bus m . P_{mcharE} , P_{mdisE}, Q_{mdisE}, are the active and reactive power charging and discharging of the ESS respectively.

$$V_m = V_k - I_i Z_i = V_k - \frac{S_i''^*}{V_k^*}(R_i + j X_i) \quad (5)$$

$$V_m = V_k - \frac{P_i'' - jQ_i''}{V_k}(R_i + j X_i) = \left(V_k - \frac{P_i'' R_i + Q_i'' X_i}{V_k}\right) - j\left(\frac{P_i'' X_i - Q_i'' R_i}{V_k}\right) \quad (6)$$

$$V_m = \sqrt{V_k^2 - 2(P_i'' R_i + Q_i'' X_i) + \frac{(P_i''^2 + Q_i''^2)(R_i^2 + X_i^2)}{V_k}} \quad (7)$$

V_k and V_m are the voltage at bus k and m, I_i is the current through the branch, where S_i'' =P_i''+Q_i'', P_i''=P_i, Q_i''= Q_i+$V_k^2 \frac{Yi}{2}$, so the value of the current flow through the branch connected between nodes k and m can be calculated by[15].

$$I_i = \sqrt{\frac{P_i^2 + Q_i^2}{V_k^2}} \quad (8)$$

Mathematically, objective function of the power losses is given as

$$Min\ P_L = \sum_{\forall k,m}^{k,m\in S_B} I_i^2\, R_i = \sum_{\forall k,m}^{k,m\in S_B}\left(\frac{P_i^2+Q_i^2}{\mathrm{V_k}^2}\right)R_i \quad (9)$$

$\mathrm{P_L}$ is subject to the equality and inequality constrains as bellows

The active and reactive power flow in branch must satisfy the equations below

$$\mathrm{P_i} - \mathrm{P_i'} - \mathrm{R_i}\frac{\mathrm{P_i'^2+Q_i'^2}}{\mathrm{V_m^2}} = 0 \quad (10)$$

$$\mathrm{Q_i} - \mathrm{Q_i'} - \mathrm{X_i}\frac{\mathrm{P_i'^2+Q_i'^2}}{\mathrm{V_m^2}} + \mathrm{V_k^2}\frac{\mathrm{Yi}}{2} = 0 \quad (11)$$

The voltage magnitudes at the sending point and receiving point must be satisfy the equation below for all branches in the distribution networks

$$V_m^2 - \left\{V_k^2 - 2(P_i''R_i + Q_i''X_i) + \frac{(P_i''^2+Q_i''^2)(R_i^2+X_i^2)}{V_k}\right\} = 0 \quad (12)$$

The power factor of the DG connected to the bus m must be satisfy the flowing equation

$$\frac{P_m^{DG}}{\sqrt{\left(P_m^{DG}\right)^2+\left(Q_m^{DG}\right)^2}} = \cos\alpha_m \quad (13)$$

The hourly energy balance in each ESS can be written as

$$E_{(h+1)} - E_{(h)} + {}_{char}P_{mcharE} - \frac{P_{mdiscE}}{disc}\,\Delta t = 0 \quad (14)$$

Where $\mathrm{E_{(h)}}$ is the energy level in ESS during the hour, efficiency $_{\mathrm{char}}$ and $_{\mathrm{disc}}$ are the charge and discharge efficiency[16].

The active power charging should be zero during the on-peak time, the discharging should also be zero during the off-peak time.

$\mathrm{P_{mcharE\ (h1)}} = 0, \qquad \mathrm{h_1} \in \text{on} - \text{ peak time}$

$\mathrm{P_{mdiscE\ (h2)}} = 0, \qquad \mathrm{h_2} \in \text{off} - \text{ peak time}$

The inequality constrains the line current flow the each branch should be within the thermal limit

$$I_i \le I_i^{rated}, \quad \forall\ \mathrm{m} \in S_B \quad (15)$$

The bus voltage at each bus should not exceed maximum and minimum voltage

$$V_m^{min} \le V_m \le V_m^{max}, \quad (16)$$

$$V_k^{min} \le V_k \le V_k^{max} \quad (17)$$

The distribution generation's capacity must not exceed the total load of the network

$$\sum_m^{S_B}\sqrt{(P_m^{DG})^2+(Q_m^{DG})^2} \le \sum_m^{S_B}\sqrt{(P_m^{L})^2+(Q_m^{L})^2} \quad (18)$$

B. *The model of the ESS*

The BSS is the most commonly used in the ESS. It consists of many power conditioning systems (PCS), which can provide both active and reactive power to the DN[17]. When the PCS discharges to the network it can be seen as an inverter, whereas when it charges from the system can be regarded as the rectifier. A simple PCS, consists of a capacitor, diode as well as transformer. The active and reactive power discharge of the ESS should not exceed the maximum apparent power $\mathrm{S_{PSCmax}}$ of ESS[18].

$$P_{mdiscE}^2 + Q_{mdiscE}^2 \le S_{PSCmax}^2$$

The active power in terms of charging and discharging must be the positive values

$$P_{mcharE} \ge 0, \qquad P_{mdiscE} \ge 0$$

Moreover the upper and the lower bound of the storage units should be satisfied

$$E_{min} \le E \le E_{max}$$

The apparent power of the ESS should be larger than the maximum power demand which is 2.995MW, as can be seen from the Table II, and the installed capacity of the ESS also needs to be exceeded than the total install battery capacity of the total EVs which is 3217.8 KWh, the configuration can be seen in Table I. Therefore, the whole capacity is chosen to be 3.3MWh.

C. *Methodology*

The minimizing of power losses which are treated as nonlinear minimization problem, can be tackled as a sequential optimization[19], and dealt with using matlab optimization programming. Two optimization methods, UA-RPF ESS and CA-RPF of the ESS are proposed for the power losses reduction based on that programming. For the UA-RPF the active, reactive power discharge and the active power charge of the ESS are optimized, by using the matlab nonlinear programming without considering the peak and off peak load periods. H, for the CA-RPF, the minimization not only relates to the optimization of active, reactive power discharge of the ESS, but also two charging time (off peak charging and peak charging) is taken into consideration

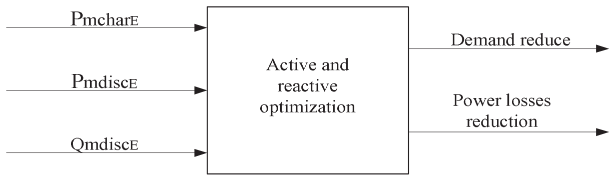

Fig.7.Input and output chart

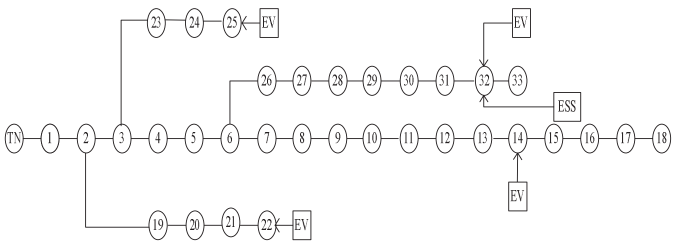

Fig.8.The tested DN

It is assumed that the ESS needs to be fully charged before it provides the active and reactive power to the DN, or before it is first installed into the networks active and reactive power to the DN, or before it is first installed in the networks. The figures for charging in terms of power losses are shown in the Table V, and these are 0.53MW and 0.50MW for the latter case.

IV. Results and Analysis

From the above section, power losses in terms of two different optimization methods were obtained by using the matlab optimization programming. In general, the losses are reduced when the ESS adds into the IEEE 33 tested DN.

TABLE IV. LOAD DEMAND FOR THE IEEE 33 TESTED NETWORK

Charging Period	EVs Penetration	0%	20%	30%	40%
8:30-14:30	LD (MW)	3.7	[illegible].13	4.33	4.57
14:30-19:30	LD (MW)	3.9	4.33	[illegible].56	[illegible].77
19:30-23:30	LD (MW)	3.3	3.73	[illegible].96	4.17

bus load+penetration ratio*2.1756

The table of load demands (LD) was built and can be seen above, based on the daily household load and the demand of the EV at different penetration levels. From the table above, 3.7MW is the load of the IEEE 33 tested system. This load is regarded as the base load for the period 8:30 – 14:30. Then according to the ratio between 8:30 – 14:30 and 14:30 19:30 in terms of daily household load which is 1.053, the load for 14:30-19:30 is calculated 3.7 × 1.053 = 3.9MW. The Same method is used to calculate the load between 19:30 and -23:30. 4.13 MW is calculated by 3.7 + 0.43MW=4.13MW where 0.43MW is the total power demand of 20% EVs penetration for 4 different types of EV.

.2*2.1756

TABLE V. THE ACTIVE POWER LOSSES WITH ESS AND WITHOUT ESS

Charging period	Penetration level	0%	20%	30 %	40%
8:30-14:30	Without ESS WithESS(MW)	0.12 0.53	0.25 0.09	0.34 0.13	0.45 0.18
14:30-19:30	Without ESS WithESS(MW)	0.05 0.13	0.26 0.10	0.36 0.25	0.47 0.32
19:30-23:30	Without ESS WithESS(MW)	0.11 0.50	0.22 0.08	0.31 0.22	0.41 0.27

TableV. shows the differences of total active power losses (APL) in the tested DN with and without A-RPF ESS for UA-RPF case, during the different periods with different EV penetrations. From that table, the APL reduced dramatically when adding ESS to the DN. The total active power (TAP) reductions are 0.64MW, which is calculated by the sum of the difference of APL between the pattern with ESS and without ESS in terms of three different EVs penetration levels, for the period between 8:30-14:30. During the period 14:30-19:30 it is 0.42MW, whereas, for the period 19:30-23:30 it is 0.37MW. Therefore, the TAP can be reduced 1.43MW between 8:30 and 23:30.

It also needs to be noticed that the APLs increase by installing the ESS during the charging period from 8:30-14:30 and 19:30-23:30 with 0% EV penetration. The reason for is that for these two periods the ESS needs to be fully charged. So it raises the loads when it charges from the DN. Whereas, when the EVs connect to the DN, the active power losses are significantly reduced by using the A-RPF ESS.

The charging period between 14:30 and-19:30 is chosen to see the differences between the two methods which are UA-RPF and CA-RPF. For the CA-RPF ESS, during the off peak periods of 8:30-14:30 and 19:30-23:30, the ESS has to be charged, but for the peak period between 14:30 and-19:30, the ESS has to discharge to the DN, without charging. However for the UA-RPF these factors are not taken into account.

Table VI. below indicates these two different methods in terms of APL, reactive power losses (RPL), and the TAP from the TN during the period between 14:30 to 19:30. The gaps can be seen by comparing the UA-RPF ESS and CA-RPF ESS. As shown in that table, the active and reactive power losses are decreased by using the UA-RPF and CA-RPF. Meanwhile, under the different EVs penetrations, large amount of active power from the TN can also be reduced by using the proposed method.

TABLE VI. THE APL,RPL,TAP WITHOUT ESS BETWEEN 14:30-19:30

Power / Penetration	APL	RPL	TAP
0%	0.13	0.09	4.03
20%	0.26	0.19	5.88
30%	0.36	0.27	6.89
40%	0.47	0.35	7.84

TABLE.VII. THE APL,RPL,TAP BETWEEN 14:30-19:30

Pattern / EVs penetration	With ESS UA-PRF(MW)			With ESS CA-PRF(MW)		
	APL	RPL	TAP	APL	RPL	TAP
0%	0.05	0.04	2.42	0.11	0.11	1.01
20%	0.10	0.08	3.85	0.10	0.08	3.84
30%	0.25	0.19	5.91	0.25	0.19	5.90
40%	0.32	0.24	6.64	0.32	0.24	6.61

Fig.8 is drawn, in order to make the APL more clear as to the three different charging patterns, the black one is without ESS, the green one is CA-RPF ESS, and the red one is UA-RPF ESS. It can be seen that APL is much lower by using the proposed methods than by not using it.

It is very interesting to notice that, the APL is a little bigger at the beginning of the coordinated charging compare with the uncoordinated one. The reason for this is in this scenario loads of the DN are not increased, ESS has to use active and reactive power which are already stored in the ESS during the off peak times. So it generates more active and reactive power than the situation in terms of UA-RPF ESS. However, with the loads raise, the active power losses are almost the same as for the UA-RPF ESS.

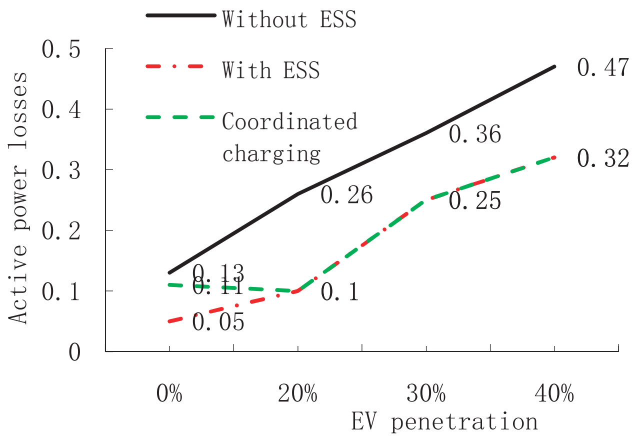

Fig.8. The comparison the between the 3 different charging methods

TABLE VIII. FEEDER'S LOAD

Feeder / Time	14 (MW)	22 (MW)	25(MW)	32(MM)
14:30	0.0556	0.0516	0.0946	0.066
15:30	0.0622	0.0582	0.1062	0.0762
16:30	0.0701	0.0702	0.123	0.095
17:30	0.1428	0.1370	0.2042	0.1615
18:30	0.1174	0.1114	0.1814	0.1364
19:30	0.0778	0.0713	0.1418	0.0968

Although, by using the CA-RPS ESS charging method power losses are slightly higher than the UA-RPF ESS charging method, the charging price of ESS is much lower than the UA-RPF ESS, in terms of using the peak and off peak electricity price. During the same period, the active power can be decreased from the TN by installing the ESS in the DN. In the UA-RPF ESS pattern, 1.61MW power can be reduced which is calculated by 4.03-2.42=1.61MW. In the CA-RPF ESS pattern, 3.0 MW power calculated by 4.03-1.01 can be reduced for 0% EV penetration. For the 20% EV, the power reductions are 2.03MW and 2.04MW respectively. For the 30% they are 0.98Mw, 0.99MW, for 40% the power from TN that can be reduced are 1.2MW, 1.23MW.

Fig.10 is made for comparing the TPL of the CA-RPF ESS and the TPL without ESS during the period between 14:30 and 19:30 at the 30% EV penetration. According to the Fig. 9 at 14:30, 6% EVs are not under way, the total power demand for the EVs at this time is $6\% \times 0.66 = 0.0039$ MW, and 0.66 MW is the total power demand (TPD) of 30% EV for the 100 EVs. At 15:30 the TPD is $7\% \times 0.66 = 0.00462$ MW, 16:30 is $8\% \times 0.66 = 0.0039$ MW, 17:30 is $18\% \times 0.66 = 0.1188$ MW, 18:30 is $14\% \times 0.66 = 0.0924$, 19:30 is $8\% \times 0.66 = 0.0528$ MW. These loads are connected to the feeder 14, 22, 25,and 32 respectively, for each time.

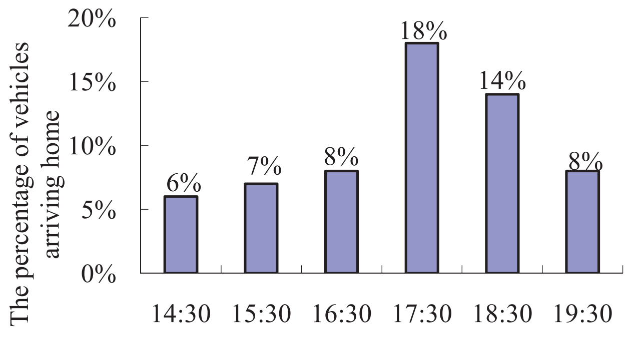

Fig.9. Percentage of vehicles arriving at home between 14:30 to 19:30

Adding these demands into the tested DN is shown in the table below. At 14:30 for the feeder 14 the power demand including EVs and daily loads is 0.016 + 0.0039 = 0.0556MW, 0.016 MW is the house hold loads at feeder 14.

From Fig .10 below the TPLs increases from 14:30 to 18:30 and then decreases from 18:30 to 19:30. One of the main reasons of this is that demands for the electricity raises and then declines. It is worth noticing that, the maximum TPL which is 0.058 MW with the ESS is much less than the TPL 0.053MW without the ESS.

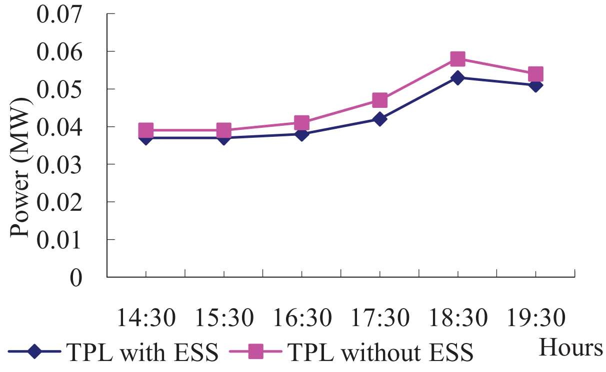

Fig.10.The total power losses of the tested network in terms of different charging pattern

TABLE IX.THE TOTAL POWER LOSSES OF THE TESTED NETWORK IN TERMS OF DIFFERENT CHARGING PATTERN

Pattern \ Time	14:30	15:30	16:30	17:30	18:30	19:30
TPL with ESS	0.037	0.037	0.038	0.042	0.053	0.051
TPLwithout ESS	0.039	0.039	0.041	0.047	0.058	0.054

The active power and reactive power discharge of the ESS is shown in Fig.11. Below. During the period between 14:30-17:30 the active and reactive power increases all the time, at 17:30 it reaches the highest point and then decreases for the rest of the time. The gap between the active and reactive power discharge is very high, because the EV doesn't need the reactive power and, the householders do not need lots of reactive power, moreover it also does not change a great deal during time as it goes by.

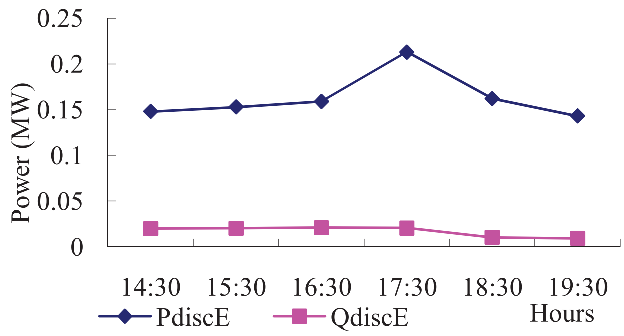

Fig.11. PdiscE and QdiscE during the time between 14:30 -19:30

TABLE X. PDISCE AND QDISCE DURING THE TIME BETWEEN 14:30 -19:30

Pattern \ Time	14:30	15:30	16:30	17:30	18:30	19:30
P discE (MW)	0.015	0.152	0.159	0.213	0.162	0.143
Q discE (MW)	0.019	0.020	0.020	0.020	0.102	0.090

Fig.12.shows that the TAP receives from the grid with the ESS without ESS, and the TAP provides by the DN with ESS.

It can be seen that from the period 14:30 to 18:30 (for the DN with ESS) with power demand increases the TAP from the TN rise from 0.59MW at 14:30 to 1.75MW, then declined to a low of 1.63MW at 19:30. It is noticeable that the ESS reduces a great deal of active power from the network compare with the one without ESS, at 18:30, 0.13MW active power reduced, at 17:30 0.19MW active power does not need to import from the TN. Moreover the total 0.75MW active power can be reduced by using the ESS.

TABLE XI. THE TAP FROM THE TN

Time / Pattern	14:30	15:30	16:30	17:30	18:30	19:30
TAP from TN with ESS(MW)	0.59	0.62	0.74	1.08	1.75	1.63
TAP from TN without ESS(MW)	0.69	0.73	0.87	1.27	1.88	1.72
TAP provides by DN with ESS (MW)	0.74	0.77	0.90	1.29	1.92	1.77

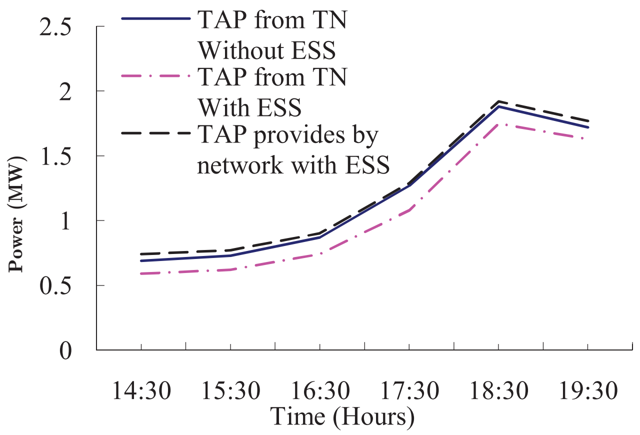

Fig.12.The TAP from the TN with and without ESS

III Conclusion:

Previously, many studies used optimization methods based on either active or reactive power dispatch in terms of capacitor placement, and network reconfiguration, as well as charger design for power loses reduction caused by EVs within in the DN. The power losses were compared with, and without, optimization methods. However, unlike these methods, in this paper we proposed, and compare, two different methods both based on the active, and reactive power optimization dispatch of the ESS for power loss reduction. In addition, the power imported from the TN has also been reduced.

In the first part of the paper, by using historical data for daily load, charging demand for EVs was analysed. Meanwhile, EVs were added into the IEEE 33 nodes test networks, the percent between total power losses and total power generated raises from 3.16% at 0% EV penetration to 5.69% at 40% penetration between 8:30-23:30 hours. Therefore, when EV penetration levels increase, the power losses increase dramatically, the trend of losses is almost linear from Fig.4, so that with more EVs penetration, losses will rise predictably.

In the second part of the paper, using the combined problem formulation for the active and reactive power dispatch of the ESS lowers the active power losses. 1.43MW of total active power losses can be reduced. Moreover two novel charging and discharging methods, which are coordinated active-reactive power flow of the ESS and uncoordinated active-reactive power flow of the ESS, were used in the IEEE 33 node test network during the peak time between 14:30 and-19:30 hours. Although for the former method the active power losses are a little higher, compare with the latter method, 1.64MW does not need to be imported from the TN, making the charging price of the ESS lower for the first method. Overall, adding ESS is an efficient method for the DN to achieve power loss reduction.

The results were obtained by using the optimization algorithms described in this paper, the applied methodologies and techniques can also be applied to other objective functions, for instance to reduce the voltage drop, reactive power balancing or coordination of the wind power and the ESS operation

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