Evaluation of Well-Being Criteria in Presence of Electric Vehicles Consumption Increase and Load Shifting on Different Load Sectors

Abdol-Baset Badakhsh *, Mohammad Naseh Hassanzadeh*‡,

* Department of Electrical Engineering, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran

(baset.badakhsh@gmail.com, noandishan.sanat@gmail.com)

‡ Corresponding Author: M.N.Hassanzadeh, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran , Tel: +98 912 541 4593, Fax: +98 873 362 4564, noandishan.sanat@gmail.com

Received: 20.07.2016 Accepted:19.07.2017

Abstract- By the development and progress of electrical systems and considering the environmental issues, the use of electric vehicles has increased, which leads to changes in the system load profile as well as the peak load of the distribution network. These changes affect the reliability criteria of the power system. A method to maintain the system's reliability criteria in an acceptable range while increasing the penetration of this type of loads could be the use of the demand side potential. By changing the rate and duration of different consumption loads, demand side management (DSM) can pave the way for further penetration of the new loads through improving the system reliability criteria and reducing the peak load. In this research, by investigating the behavior of the electric vehicles' load and applying the potential and flexibility of different segments of the load, effects of further penetration of the electric vehicles, as the consumption load, on the system' reliability criteria as well as effects of the response of different sectors of the load on further penetration of these loads were investigated. Simulation was performed using the Well-being Model, which divides all the system performance states in to three states of health, marginal, and risk with sequential Monte Carlo method. The simulation was conducted on the RBTS test system using MATLAB software. With regard to the results of the simulation, penetration of the electric vehicles increased the risk probability of the system. However, by applying the load shifting, the adverse effects of the presence of the electric vehicles on reliability were compensated it.

Keywords- Electric vehicles, Load Shifting, reliability, Well-Being Model.

1. Introduction

The increasing progress of human life and necessity of having reliable electrical energy require reliable generation, transmission and distribution. One of the most fundamental objectives of power systems is continuous supply of inexpensive electrical energy with favorable quality. Hence, evaluation of the reliability of the power systems is considered as a very important issue. The distribution system is the most extensive part of the power system in terms of the covered area. Further, this system is an interface between the consumers and the power system which receives the energy from the transmission and super-distribution network and delivers it to the consumer. Moreover, since the structure of the distribution networks, despite its simplicity, has a major share in the investments in the power system, evaluation and investigation of the reliability of the distribution networks seem to be essential. In the past few decades, the electrical systems have undergone changes in terms of the generation resources, electrical loads such as renewable energies, electric vehicles, etc. Due to the expansion of electrical systems and environmental advantages, use of electric vehicles has been increasing. The increasing use of electric vehicles can reduce the reliability of the system. This issue, regarding the capacity of the transmission lines and distribution transformers, can impose negative effects such as increased loss, increased voltage fluctuations, decreased reliability of the system, and so on. Applying the demand side management to distribution systems can significantly influence the improvement of the system reliability parameters. Extensive studies have been conducted on the effects of the penetration of electric vehicles and demand side management programs in electrical systems. These studies have investigated various subjects such as system stability, reliability, and improvement of exploitation reserve (storage) in the presence of electric vehicles.

In [1], stability of power systems and changes of reliability components in the distribution network were evaluated by the penetration of electric vehicles. Various types of electric vehicles, with regard to the battery's chargeability and energy restoration, were introduced in to the network and the effect of the presence of electric vehicles on the environmental and economic components was also investigated. In [2], be sides pointing to the expansion of smart grids as well as the importance of the presence of batteries in these networks, the Monte Carlo method was used to investigate the network reliability parameters. In [3], the effects of demand response on the performance of the power systems were investigated, which show reducing the system losses in addition to reducing the customer costs. Further, the network's reliability was improved by reducing the load in peak hours. In order to investigate the effects of penetration of electric vehicles in the network, the penetration percentage was determined from 10% through 100% of the network consumers accordingly. In[4-5], in addition to investigating and explaining this issue, the management of charging the electric vehicles entered in to the network has been determined with regard to the constraints such as electrical energy prices at different hours of the day, charging time of the vehicles, and the remaining capacity. Penetration of the electric vehicles as the new load should be done with accurate planning so that considerable negative effects on the power system parameters could not be imposed. On this basis. In [6], the development of test equipment for the electric car charger has been addressed. In [7], Energy Pocket Base method for an electric vehicle charger has been presented in comparison with traditional charging methods in Smart Grade. In [8], a methodology is presented that enables an estimation of required energy storage characteristics for future storage technologies that can be compared to conventional ones. In [9], Paper deals with different power trains of electric hybrid and electric vehicles which diminish the fuel consumption by giving to the internal combustion engine (ICE) better working conditions with respect to ICE revolutions and demanded power. In [10], as a cardinal objective, the voltage and frequency stability is achieved by power balancing technique using load shaving and load shifting method. In [11-12], the appropriate planning for charging the electric vehicles has been done in such a way that the system losses are minimized besides considering the capacity of distribution networks. The use of the renewable energy sources in the power systems is expanding however, the power supplied by some of these resources is not absolutely predictable investigating the effects of penetration of the electric vehicles in the systems including such resources is inevitable thus. In [13-14], the application and effects of charging the electric vehicles in the power systems in Denmark and the United States have been evaluated since a huge part of the electric power in Denmark is supplied by the wind turbines. In many of the studies, the load side management has been used to improve the reliability of the network.

In [15], due to the hourly prices of electricity and regarding the fact that the costumers, being aware of this fact, can transfer the consumption load from the expensive and peak hours to other hours and consequently reduce their costs, the effect of the demand response in Denmark was investigated and the obtained results indicated the reduction of the costumers' costs as well as reduction of the losses in the power system. The use of renewable energies by consumers, besides reducing the consumers' costs, could save fossil fuels. Thus, this solution can be used to compensate for the decreased reliability of the network through using the electric vehicles in the network [19]. In [18], the solar cell and battery have been considered for the consumers owning hybrid electric vehicles in order to achieve improvement of the intended reliability and reduce the peak load and cost by saving the energy during the day and in the off-peak hours and using this energy in the peak load hours. In[15],the reliability of the independent wind/photovoltaic/diesel and storage systems was investigated in the presence of the electric vehicles. This research was specific to the areas that cannot be connected to the power network scientifically or economically. Examination of the results indicated the greater impact of the electric vehicles on the reliability of these networks rather than the power network. In [21], Safadi et al. investigated the effect of demand side management on the reliability of the RBTS system. The energy and load loss expectation quantities of the reliability indices were investigated and then, improved by applying some load shift programs. Line congestion is another problem caused by the addition and non-smart charging of electric vehicles to the network. However, such line congestion was partly reduced in [22] by placing the charging stations in proper locations and smart positioning of these points. In this paper the model considers different sectors of load with different load shifting levels and penetration of electric vehicles in different levels and kinds. The risk evaluation is based on the well-being system where sequential Monte Carlo simulations are applied. The effectiveness of the proposed model is revealed by applying it to the RBTS.

2. Preliminary Basics

This section intends to briefly describe the major theoretical concepts applied in the developed model. In below, brief explanations over the considered model for Well-being model and electric vehicles model and well-being analysis are provided.

2.1. Well-Being Analysis

In this method, analytical techniques have been embedded in probabilistic criteria. The well-Being evaluates system in serving load via a set of probabilistic criteria as displayed in Figure 1. This framework has been designed in calculation of health, marginal, and risk criteria. The system is in health state if there is additional reserve to meet analytical criteria like largest unit loss. In reserve state, the system does not face problems, but it lacks sufficient reserve to face analytical criteria. In risk state, the load is higher than the generation capacity. The risk probability is the Loss Of Load Probability (LOLP) criterion. There are analytical and simulation methods to estimate the well-being system indexes. Due to the advantages of the simulation method, the sequential Monte Carlo method is used for estimating the well-being system indexes.

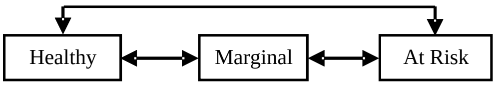

Fig.1. Well Being Model

Well-Being Indexes Calculation Procedure is as follow:

1. Each unit's capacity diagram is calculated separately, and then, all units are combined together, and the whole available capacity diagram for the whole system will be presented (capacity in).

2. In each time period of the diagram, the largest available generating unit will be calculated. Its corresponding capacity will be subtracted from the available capacity diagram obtained in the first step. Therefore, the available capacity is obtained without the largest unit in that time period (capacity in-CLUS).

3. In the next step, the load diagram is combined sequentially with the two diagrams above, and the system indexes are calculated as follows (Fig.2)

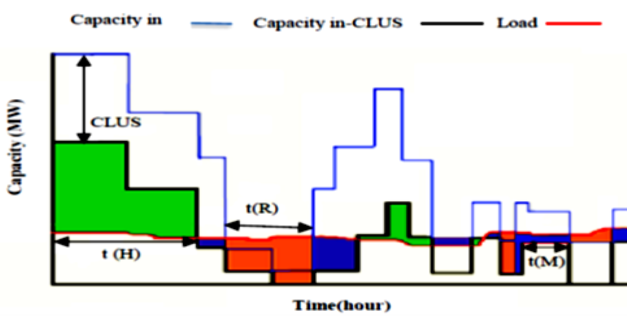

Fig.2. Combined generation and load

2.2. Electric vehicles

In general, electric vehicles are divided in to three categories.

- Electric vehicles (EV)
- Hybrid electric vehicles (HEV)
- Plug-in hybrid electric vehicles (PHEV)

Electric vehicles can be charged using transmission, induction, or battery charging stations. Charging through transmission is the simplest method for charging electric vehicles. This method means connecting the electric vehicles to the specific plugs in the network. Regarding the currently existing lines, this method might be the simplest method in terms of investment. Inductive charging requires no connection. This type of charging would be possible by merely parking the electric vehicles in the parking lots equipped with the inductive charging equipment. The battery exchange sites providea very fast method for charging. In these stations, the battery of the vehicle is replaced with fully charged batteries. However, promoting this method requires standardization of all the batteries produced by different producers. Since the present paper investigates the effect of the electric vehicles on the reliability of the power system, only the conduction mode charging is taken in to account.

2.3. Load Shifting

The demand management is defined as planning, implementation, and supervision on the electricity-related activities affecting the power consumption and causing favorable changes in the load form, time pattern of consumption, and energy consumption rate. As for the demand accountability, there are various methods, out of which, in this research, the load shift method is used. In this method, the load rate is reduced at peak hours and the same reduced rate is immediately supplied at the off-peak hours. Therefore, in this method, the load is shifted from the peak load hours to the off-peak load hours. This method is applied as follows [19]:

If the peak load rate is limited to a certain value such as p, the adjusted load rate at peak and off-peak hours will be shown as Equations (1) and (2):

$$\overline{L(t)} = \begin{cases} P & t \in \Omega \\ L(t) + A & t \in \Psi \end{cases} \quad (1)$$

$$A = a\left[\frac{\sum_{t\in\Omega}(L(t) - P)}{N}\right] \quad (2)$$

where

$\overline{(L(t))}$:Changed load

P: Predetermined peak load rate

L(t): Base load or main load rate

Ψ: Off-peak hours when the shifted loads are supplied

Ω: Peak load hours when the load should be shifted

A: Load rate added to the load at off-peak hours

a: Percentage of the decreased energy supplied at off-peak hours, i.e.100% in this study. It is supposed that the total energy which is not supplied in the peak load will be supplied at off-peak hours.

The load-shifting is conducted in various segments of the load and the energy rate is transmitted from the peak load to the off-peak hours based on the specified peak load. Also, it is assumed that the transmitted load is supplied immediatelyat off-peak hours.

2.4. RBTS test system

Roy Billinton Test System (RBTS) test system contains 6 buses and the generator units are located in buses 1 and 2.This system has 11 generator units in total. The transmission lines' voltage, total installed capacity, and system peak load are 230KV, 240MW, and 185 MW, respectively. Information of this system was presented in[16]. Figure 3. Shows the single-line diagram of the RBTS system.

3. Research Method

In order to determine the number of electric vehicles that can be added to the system, the number of the residential consumers of the system should be estimated. In this section, providing the information on the type and number of different loads of the test system, the number of residential consumers of the whole system is estimated and several different scenarios are presented for the penetration of the electric vehicles in to the system. The number of the electric vehicles added to the system and the speed and charging time of these vehicles are the criteria for determining different scenarios. By penetrating the electric vehicles based on different scenarios, the present paper is aimed to improve the reliability indices by the demand side management. Examination of various loads of the test system as well as their cooperative patterns in the demand response program is also investigated in this section.

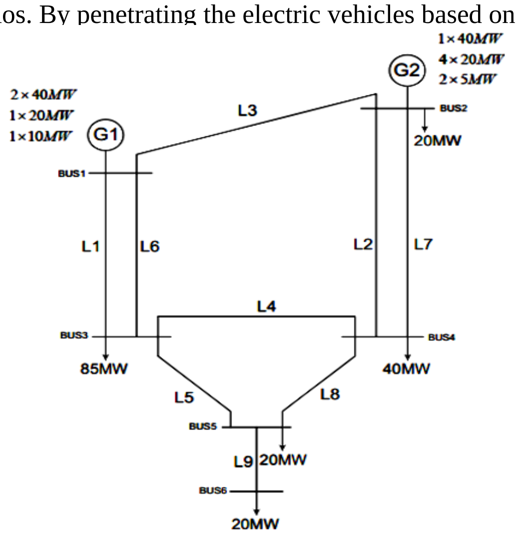

Fig. 3. Single-line diagram of RBTS system

3.1. Electric vehicles penetration plans

With regard to the information of the RBTS test system, the highest number of the electric vehicles which can be added to the system, based on the number of the residential consumers, is 15800 vehicles. In this article, numerous scenarios are considered for the penetration of the electric vehicles. These states are designed using the criteria of penetration percentage, duration and charge rate of the battery, and hours of the electric vehicles connection to the network.

Addition of the electric vehicles to the network can be conducted at various levels. In this paper, we consider four levels of penetration with different percentages of 10, 20, 30, and 40%.

For charging the electric vehicles, two fast and slow charging modes are brought in to consideration. The features of these two charging modes, based on the number of the charging hours of each vehicle and the power received by the vehicle during charging from the network, are shown in Table 1. [22].

Table 1. Battery charging time duration

Type of Charging	Approximate Charge Time to full capacity(Hrs)	Maximum Power during Charging(KW/h)
Slow Charging	6	3.7
Fast Charging	2	11

In previous studies conducted on electric vehicles, it has been mainly assumed that it is better to charge the electric vehicles at off-peak hours during night [12-14,17]. In this article, it is assumed that, at the mid-peak and peak load hours, some of the vehicles are connected to the network. To apply this assumption, three charge plans are considered:

- Time Plan 1: All the electric vehicles are charged during off-peak hours.
- Time Plan 2: 80% of the vehicles are charged at off-peak hours and 20% at mid-peak hours.
- Time Plan 3: 60% of the vehicles are charged at off-peak hours, 30% at mid-peak hours, and 10% at peak hours.

Regarding the criteria of the vehicles' penetration level in 4 plans, two charging modes and 3 plans introduced for the charging time of the vehicles, totally 24 modes in this article are considered to apply the electric vehicles.

3.2. Load Shifting plans

By adding the electric vehicles to the system and increasing the system's load, the load curve is changed and the reliability is decreased. Thus, the demand response program is used for its improvement. In the demand shift method, the reliability indices' influence from the demand response program depends on the amount of the load shifted from the peak to off-peak hours. Therefore, for a more accurate examination, the demand shift is conducted at four levels of 5%, 10%, 15%, and 20%. In the RBTS test system, have 7 different types of load sector with unequal combinations, each of which is separately incorporated in to the demand response program in order to investigate the effect of various segments of the load at each of the mentioned levels. Finally, all of the loads are incorporated simultaneously in to the program. In other words, at each level of the demand response program, there are 8 load combinations. Therefore, since four levels of demand shift are considered, totally, 32 examination modes of the effects of the demand side management are investigated in each of the scenarios presented for the penetration of the electric vehicles.

3.3. Developed Methodology

In this section, the project steps, including the demand response and combination of the electric vehicles, for calculating the measures of the public health model of the system at the generation level are described step by step.

Step 1: Inputting the test system data including generators, demand data in various segments, electric vehicles data, etc.

Step 2: Applying the simulation of the sequential Monte Carlo to determine the mode of each generation units. The output of this step will include the available generation capacity at each hour of the simulation period, which is 5000 years.

Step 3: Determining the load data of each segment, including residential loads, agriculture loads, and so on. The output of this step will include the hourly load of each segment of the load during the whole year.

Step 4: Determining the number of the residential loads in each bus with regard to their consumption power ratio in order to estimate the number of the vehicles existing in each bus. The output of this step will be the number and power of the load of the electric vehicles with regard to the percentage of their penetration in to each bus and in the whole system.

Step 5: In this step, the load profile will be determined with regard to the demand response in various segments of the load and the penetration percentage of the electric vehicles in different scenarios. The output of this step will be the annual load profile in various scenarios of the electric vehicles' penetration and the response of different segments of the load.

Step 6: Calculating the criteria of the public health model requires determining the largest available generation unit per hour, which will be calculated for each hour. Furthermore, the available generation rate minus the largest available unit will be also calculated. In other words, the output of this step will be the largest available generation unit per hour and total available capacity minus the largest unit.

Step 7: In this step, based on the total available hourly capacity, largest available hourly unit, total available capacity minus the largest available unit, and load profile, the criteria of the public health system model are calculated as follows:

Step 7.1: First, the hour is selected in the time range and the available capacity is compared with the hourly load. If the load is greater than the available capacity, the system will be at risk. Otherwise, the available capacity minus the largest available unit at that hour will be compared with the load and, if it is greater than the load, then the system will in the health mode. Otherwise, it is in the margin mode.

Step 7.2: At each hour, in sequence, the simulated time period of step (7.1) will be repeated and the time results will be recorded. In the meantime, at each hour, the criterion of stopping the calculations and the simulation will be investigated.

Step 7.3: If the stop criterion is met, the criteria of the public health system model will be determined and the program will be finished; otherwise, it will turn back to step (7.2).

4. Numerical Results

In this section, the results of the simulation in 5 scenarios are presented and then analyzed. First, in the base mode of the system in which the electric vehicles were not yet added to the system, the probability of risk, health, and margin modes was determined. By adding the electric vehicles at different levels, the system criteria were recalculated and then compared with the results of the base mode. Next, by applying the demand response to the load shift method, the load curve variations and the probability of the risk and health modes of the system were examined in order to investigate the effect of various levels of the demand response.

Scenario 1: Simulation results of base system

In the base mode in the absence of electric vehicles, by calculating the probability able of the disconnected capacity of the units as well as considering the load curve, the values of the probabilities in three modes of health, margin, and risk are obtained and the results are presented in Table 2.

Fig. 4 is indeed a part of a working / failed state obtained for the test system, which is resulted during the implementation of the base mode. The system's risk mode is related to the times when the load of the system is higher than the available capacity. Magnification of the following figure is related to this mode, in which the load curve is higher than the available capacity curve.

Table 2. Simulation results of system in base mode

Healthy Probability P(H)	Marginal Probability P(M)	Risk Probability P(R)
0.97004	0.028947	0.001012

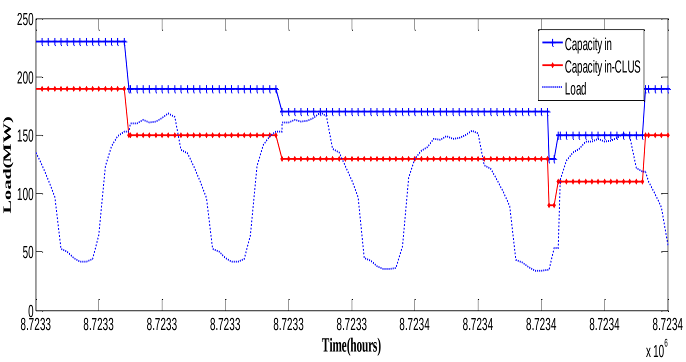

Fig. 4. Working/failed sequence of base model

Scenario 2: penetration of EV in fast charging mode

By adding the electric vehicles to the network, the load curve of the system as well as the values of the probability of the health, alert, and risk modes of the system is changed. In the fast charging mode, penetration of electric vehicles is based on two main parameters: vehicles penetration parentage and electric vehicles' charging time. Fig. 5 shows the load curve at different percentages of the penetration of the electric vehicles by assuming the speed and charge time of the vehicles as constant.

Table 3. shows the simulation results of the system with penetration of the electric vehicles in to the fast charging mode.

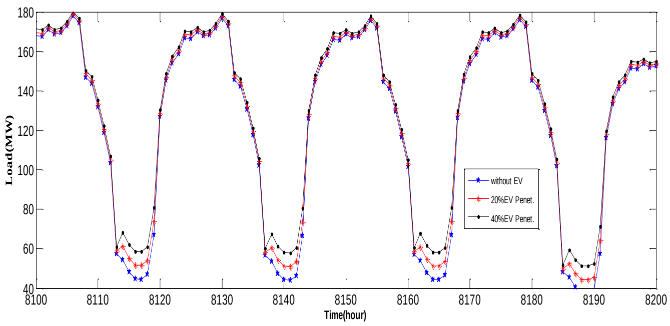

Fig. 5. Load curve with different penetration percentages of electric vehicles

Table 3. Simulation results of system with electric vehicles' penetration in fast charging mode

Penetratio parentage	charging time plan	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)
10%	1	0.970040	0.028947	0.001012
	2	0.970002	0.028985	0.001014
	3	0.968800	0.030124	0.001076
20%	1	0.970040	0.028947	0.001012
	2	0.969957	0.029028	0.001015
	3	0.967634	0.031223	0.001143
30%	1	0.970039	0.028947	0.001012
	2	0.969911	0.029074	0.001016
	3	0.966552	0.032245	0.001203
40%	1	0.970039	0.028948	0.001012
	2	0.969848	0.029134	0.001017
	3	0.965084	0.033633	0.001283

According to Table 3. the probability of the health mode of the system is decreased with the penetration of the electric vehicles, while the probability of the margin and risk modes of the system is increased. The increase in the probability of the system's risk becomes more intense with the increased penetration level of the electric vehicles. For example, with 20% penetration of the electric vehicles in plan 3, the probability of the system's risk is increased from 0.001012 to 0.001143, which indicates an increase of 12.9%.Now, if we assume the penetration of the electric vehicles in this plan as 40%, then it will be seen that the risk probability reaches 0.001283 by 26.8% increase. Fig. 6 shows changes in the probability of the system's risk mode caused by the increase in the percentage of the penetration of the electric vehicles.

According to Fig. 6. The more the number of the vehicles added to the system, the more the probability of risk in the system will be increased. The change in the charging time of the electric vehicles during the day affects the probabilities of health, margin, and risk modes as well as imposing various impacts on the load curve.

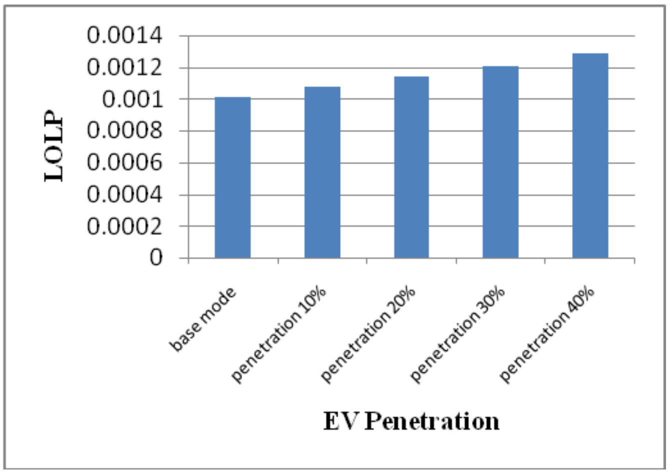

Fig.6. Diagram of risk probability variations in different penetration percentages of electric vehicles

Fig. 7 shows the total load curve of the system at three time plans simultaneously. In these curves, the percentage of the vehicles' penetration is constant at the 30% level.

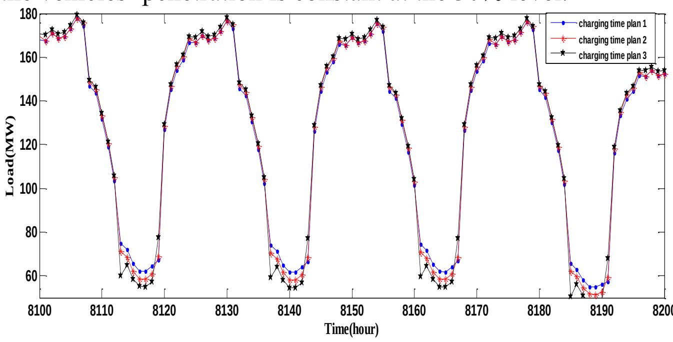

Fig. 7. Load curve considering electric vehicles with vehicle charging time plans

According to Table 3. the change in the charging time of the electric vehicles from off-peak to mid-peak and peak hours reduces the probability of the health mode and increases the probability of margin and risk modes of the system. Based on the simulation results, the higher the number of the vehicles charged at peak or mid-peak hours, the higher the risk probability would be. For example, with the 40% penetration of the electric vehicles in to Plan 2, the risk probability of the system goes from 0.001012 to 0.001017,indicating 0.5% increase, while if the same number of vehicles is charged with plan 3, the risk probability reaches 0.001283 with 26.8% increase. The following diagram shows the effect of charging the electric vehicles at various hours of the day in 3 defined plans.

Scenario 3: penetration of electric vehicles in slow charging mode

Addition of the electric vehicles to the network with slow charging, just like the fast charging mode, causes a change in the load curve of the system as well as the

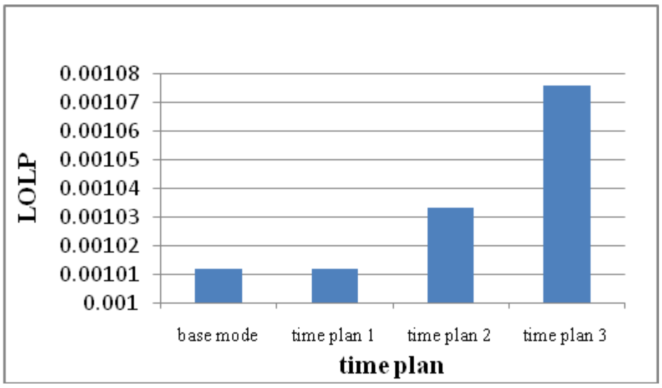

Fig. 8. Diagram of risk probability variations at different times of charging electric vehicles

probability of health, alert, and risk modes of the system. Table 4. shows the simulation results of the system with penetration of the electric vehicles in the slow charging mode. According to table 4. Probability of the health mode of the system is decreased with the penetration of the electric vehicles, while the probability of the margin and risk modes of the system is increased. Similar to the fast charging mode, the increase in the risk probability of the system becomes more intense with the increased penetration level of the electric vehicles. Furthermore, the change in the charging time of the electric vehicles from the off-peak to mid-peak and peak hours intensifies the decrease in the probability of the health mode and increase in the probability of the margin and risk mode of the system.

Table 4. Simulation results of system with electric vehicles' penetration in slow charging mode

penetration %	charging time plan	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)
10%	1	0.970040	0.028947	0.001012
	2	0.969564	0.029401	0.001035
	3	0.968754	0.030166	0.001080
20%	1	0.970040	0.028947	0.001012
	2	0.969192	0.029759	0.001049
	3	0.967617	0.031239	0.001143
30%	1	0.970039	0.028947	0.001012
	2	0.968852	0.030084	0.001064
	3	0.966541	0.032255	0.001203
40%	1	0.970039	0.028948	0.001012
	2	0.968484	0.030436	0.001080
	3	0.964998	0.033714	0.001288

According to Tables 3. and 4. both slow and fast charging has similar effects on the probability of the risk, alert, and health modes of the system. In the slow mode, a higher number of the electric vehicles is charged in a longer time period (6 h), but in the fast mode, a lower number of the vehicles is charged in a shorter time period (2 h). The effect of both modes on the risk probability is insignificant and variable. In plan 1, the risk probability is the same at both charging speeds as well as different penetration levels. Assuming the penetration level of 20%, the value of this probability in both fast and slow charging modes is equal to 0.001012. In plans 2 and 3, the risk probability in the slow charging mode is slightly higher than the one in the fast charging mode. With a change in the number of vehicles charged per hour, this result will be variable.

Scenario 4: Load shifting in presence of electric vehicles in fast charging mode

Fig. 9 shows the load curve of the system influenced by applying the demand response at various levels used in this article. According to this figure, by applying the demand response, the load curve is decreased at the peak load hours and the decreased load is transmitted to the off-peak hours, which causes an increase at the off-peak hours. Thus, the higher the percentage of applying the demand response, the more the variation of the curve would be.

The simulation program is implemented to apply the demand response method at the above-mentioned four levels, at each of which the seven loads are incorporated in to the demand response program, once separately and once simultaneously. These steps are applied to each plan of the penetration of the electric vehicles in order to analyze the effects of the demand side management at each penetration level of the electric vehicles.

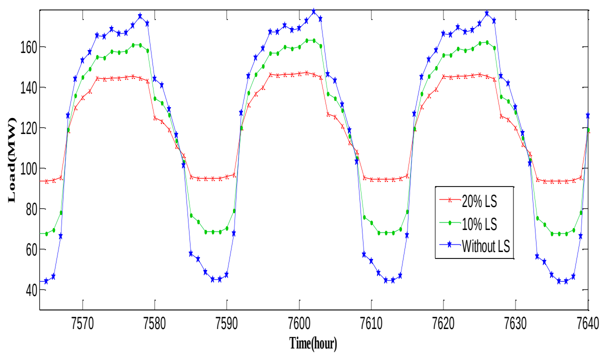

Figure.9. Load curve with different percentages of demand response

Table 5. shows the simulation results of the system by applying the demand response when the electric vehicles with the penetration level of 20% are charged quickly in plan 3. In Scenario 2, it is observed that the penetration of electric vehicles in this mode increases the risk probability of the system from 0.001012 to 0.001143. According to the above table, the probability of system risk mode is decreased using the demand response.

Table 5. System criteria with load shifting and 20% penetration of electric vehicles in plan 3 with fast charging

Load	Load Shifting	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)	Load	Load Shifting	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)
Agriculture	95%	0.967634	0.031223	0.001143	**Large users**	95%	0.972308	0.026806	0.000886
	90%	0.967634	0.031223	0.001143		90%	0.975320	0.023937	0.000743
	85%	0.967634	0.031223	0.001143		85%	0.977863	0.021494	0.000643
	80%	0.967710	0.031153	0.001137		80%	0.981588	0.017891	0.000521
Commercial	95%	0.968270	0.030628	0.001012	**Office space**	95%	0.967803	0.031067	0.001130
	90%	0.969106	0.029844	0.001050		90%	0.968029	0.030858	0.001113
	85%	0.970077	0.028922	0.001001		85%	0.968202	0.030697	0.001100
	80%	0.971438	0.027641	0.000921		80%	0.968494	0.030422	0.001084
Government	95%	0.967902	0.030976	0.001122	**Residen tial**	95%	0.967697	0.030903	0.001140
	90%	0.968367	0.030549	0.001084		90%	0.968913	0.030033	0.001054
	85%	0.968785	0.030161	0.001054		85%	0.970883	0.028205	0.000912
	80%	0.969269	0.029710	0.001021		80%	0.973051	0.026170	0.000779
Industria	95%	0.969872	0.029113	0.001015	**total**	95%	0.974521	0.024705	0.000774
	90%	0.972067	0.027033	0.000900		90%	0.980394	0.019050	0.000556
	85%	0.973756	0.025424	0.000820		85%	0.988815	0.010864	0.000321
	80%	0.974174	0.025024	0.000802		80%	0.996323	0.003590	0.000087

In many of the modes, besides compensating for the increased risk probability caused by the penetration of electric vehicles, the demand response is able to decrease the risk probability up to less than the base mode rate, which is 0.001012, and improve the reliability by increasing the probability of the health mode. Fig. 10 shows the effect of demand response level on risk probability. This diagram is related to the mode in which only the residential demand (household load) is incorporated in to the demand response program. According to Fig. 10, in the demand response program using the load shift method, the greater the value of the shift from peak demand to off-peak hours, the more the decrease in the risk probability and the higher the improvement of the system reliability would be.

For example, incorporation of the residential demand in to the demand response with 90% level causes the risk probability to decrease from 0.001143 to 0.001054,indicating 7.8% reduction. Now, if this type of demand is incorporated in to the demand response at the 80% level, the risk probability reaches 0.000779 with 31.8% reduction. Fig. 11 shows the system's risk probability variation in such case that the network's loads are incorporated, separately or simultaneously, in to the demand response with 80% level.

According to Fig. 11, each of the network loads has a different affection the value of the risk probability, but all of the loads reduce the system's risk probability. The agriculture load has the minimum effect, while the major users along with the industrial demand cause the maximum effects.

Scenario 5: Load shifting in presence of electric vehicles in slow charging mode.

Table 6. shows the simulation results of the system applying the load shifting when the electric vehicles with the penetration level of 20% are slowly charged in time plan 3 that 60% of the vehicles are charged at off-peak hours, 30% are charged at mid-peak hours, and 10% are charged at peak hours.

According to Table 6. The probability of the risk and alert modes of the system is decreased by applying the demand response, but the probability of the health mode is increased. In many of the modes, the demand response is able to reduce the value of the risk probability up to less than the base mode value and improve the reliability in addition to compensating for the increase in the risk probability caused by penetration of the electric vehicles.

Fig.12 shows the system's risk probability variations in case the network loads are incorporated, separately or simultaneously, in to the demand response with 90% level.

Each of the septet consumers is incorporated separately for 96 times in to the demand response. Fig. 13 shows the ability of different loads to compensate for the increase in the risk probability caused by penetration of the electric vehicles. This diagram is drawn with regard to the number of the modes in which each load improves the reliability of the system up to the base level of the system.

Using the demand management, the percentage of the electric vehicles' penetration in to the system can be increased such that the system's reliability has no unfavorable change and the risk probability is not increased. For further explanation, we assume that the vehicles added to the system are charged slowly with plan 3 and only the commercial load is used in the demand response.

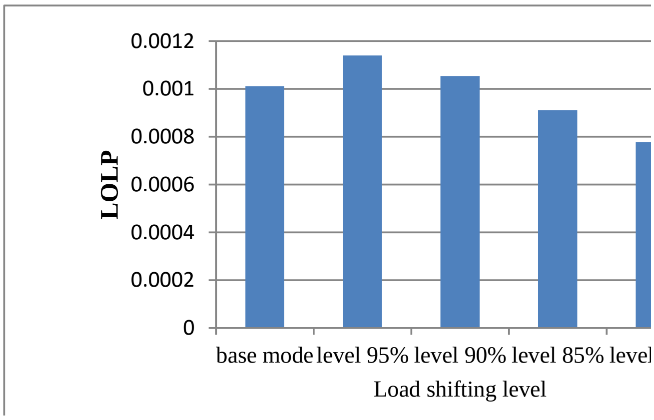

Fig.10. Diagram of risk probability variations with different levels of industrial demand response

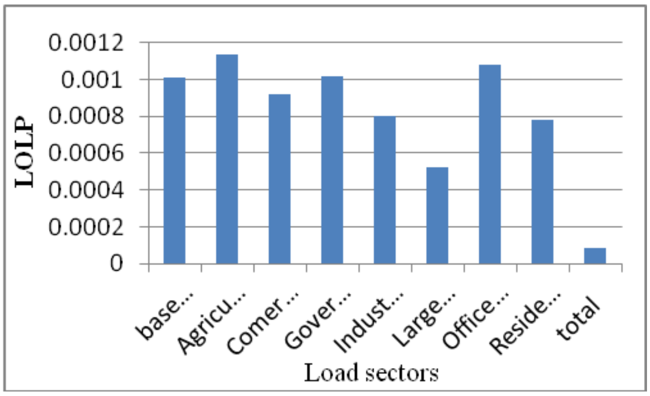

Fig. 11. Diagram of risk probability variations due to the incorporation of various loads in to demand response with fast charging

In this mode, with 10% penetration of the vehicles in to the network, the probability of risk is increased, which is compensated for by the commercial demand response at the level of 95%. Now, if the commercial load can be incorporated in to the demand response at the level of 90%, the percentage of the electric vehicles' penetration can be increased from 10% to 20%, while the risk probability of the system does not exceed its normal value With more active incorporation of the commercial load in to the 85% demand response, the percentage of the electric vehicles' penetration can be increased by 30% while maintaining the system's reliability.

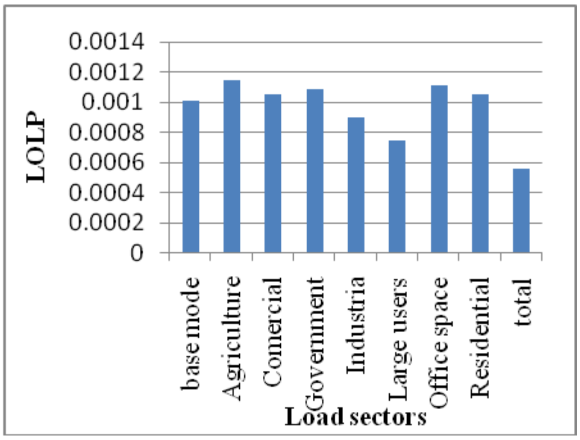

Fig. 12. LOLP variations due to the incorporation of various loads shifting in load shifting with slow charging

Table 6. System criteria with load shifting and 20% penetration of electric vehicles in to charging time plan 3 with slow Charging

Load	Load Shifting	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)	Load	Load Shifting	Healthy Probability P(H)	Healthy Probability P(H)	Healthy Probability P(H)
Agriculture	95%	0.967618	0.031239	0.001143	**Large users**	95%	0.972253	0.026856	0.000891
	90%	0.967618	0.031239	0.001143		90%	0.975312	0.023945	0.000743
	85%	0.967618	0.031239	0.001143		85%	0.977833	0.021524	0.000643

	80%	0.967693	0.031169	0.001138		80%	0.981561	0.017918	0.000521
Comercial	95%	0.968260	0.030637	0.001103	**Office space**	95%	0.967787	0.031083	0.001130
	90%	0.969081	0.029868	0.001051		90%	0.968021	0.030866	0.001113
	85%	0.970027	0.028970	0.001003		85%	0.968183	0.030716	0.001101
	80%	0.971390	0.027687	0.000923		80%	0.968461	0.030453	0.001086
Government	95%	0.967874	0.031003	0.001123	**Residential**	95%	0.967680	0.031179	0.001141
	90%	0.968309	0.030603	0.001088		90%	0.968884	0.030060	0.001056
	85%	0.968775	0.030170	0.001055		85%	0.970859	0.028228	0.000913
	80%	0.969231	0.029743	0.001026		80%	0.972996	0.026222	0.000782
Industrial	95%	0.969861	0.029124	0.001015	**total**	95%	0.974503	0.024722	0.000775
	90%	0.972049	0.027051	0.000900		90%	0.980386	0.019058	0.000556
	85%	0.973718	0.025459	0.000823		85%	0.988800	0.010879	0.000321
	80%	0.974142	0.025055	0.000803		80%	0.996320	0.003593	0.000087

5. Conclusion

In this paper, the effects of adding the electric vehicles as the new load on reliability of the electric systems as well as effect of the load shifting as a method for improving the reliability were investigated.

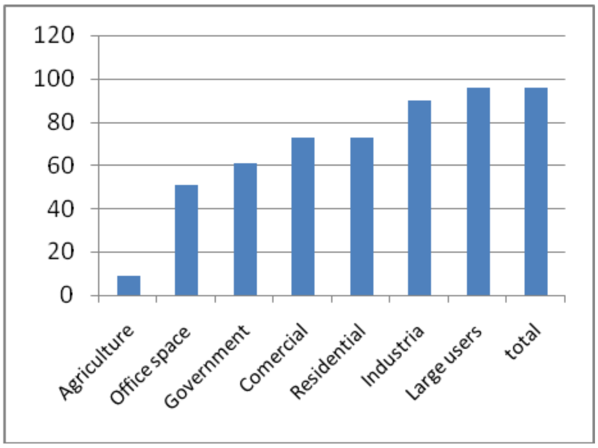

Fig. 13. Diagram of the number of modes of risk probability improvement by different loads in demand response

Based on these results, addition of the EV to the electric systems based on the EV charging time plan and type of charging , caused an increase in the risk probability so that the higher the number of the electric vehicles added to the system, the higher the risk probability would be. Charging the vehicles at peak and mid-peak hours negatively affected the reliability of the system. By applying the demand side management as load shifting, the reliability of the system was improved and the system's risk probability was decreased so that the more the load shift, the higher the effect of the load shifting on reliability would be. Based on the obtained results, seven different load sectors including residential, commercial, industrial, large user, agricultural, governmental, and official were investigated. As observed in the simulation results, enabling demand response from different load sectors has different impacts on system well-being and penetration of EV. This is mainly due to different shares from system load and different load sectors profiles. Further, with the incorporation of each system load in to the demand response, the number of the electric vehicles penetrating in to the system can be increased while maintaining the system's reliability.

References

[1] Andreas Poullikkas, "Sustainable options for electric vehicle technologies". Renewable and Sustainable Energy Reviews., vol. 41, pp. 1277–1287, January 2015.

[2] Banajiger, A.Aravinthan,V., "Radial feeder reliability evaluation in the presence of battery storage using modified Sequential Monte Carlosimulation," IEEE Conference Publication. pp. 1-1, Dec. 2014.

[3] B. Dupont , K. Dietrich , C. De Jonghe , A. Ramos, R. Belmans , "Impact of residential demand response on power system operation, " Applied Energy vol. 122, pp. 1–10, June 2014.

[4] Wencong Su: Mo-Yuen Chow , "Performance Evaluation of an EDA-Based Large-Scale Plug-In Hybrid Electric Vehicle Charging Algorithm," IEEE Trans. Smart Grid., vol. 3, no. 1, pp. 308–315 , June 2011.

[5] D. Wu, D.C.Aliprantis, and K. Gkritza, "Electric energy and power consumption by light-duty plug-in electric vehicles," IEEE Trans. Power Syst., vol. 26, no. 2, pp. 738–746, May 2011.

[6] Abdoulkarim Bouabana, and Constantinos Sourkounis, " Development of attesting device for Electric Vehicles Chargers, " Renewable Energy Research and Applications (ICRERA), 2015 International Conference

[7] Giuseppe Graber, and Giovanni Massa, and Vincenzo Galdi, "Performance comparison between scheduling strategies for PEVs charging in smart grids ",

Renewable Energy Research and Applications (ICRERA), 2015 International Conference

[8] Dominik Buecherl, and Christiane Bertram, and Igor Bolvashenkov, and Hans-Georg Herzog, “Derivation of Basic Energy Storage Parameters for Future Electric Vehicles ”, International Journal Of Renewable Energy Research, IJRER, Vol.1, No.2, pp.105-109 ,2011

[9] Zdeněk Čeřovský, and Pavel Mindl, “Impact of Energy Production Technology on Gas Emission by Electric Hybrid and Electric Vehicles**”,** International Journal Of Renewable Energy Research, IJRER, *Vol.1, No3, pp.118-125 ,2011*

[10] Eklas Hossain, Mashrur Zawad, KH Rakibul Islam , Md Qays Akash, “Design a Novel Controller for Stability Analysis of Microgrid by Managing Controllable Load using Load Shaving and Load Shifting Techniques; and Optimizing Cost Analysis for Energy Storage System **”,** INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH E.Hossain et al., Vol.6, No.3, 2016

[11] E. Sortomme, M. Hindi, S.D.J. MacPherson, S.S. Venkata, “Coordinated Charging of Plug-In Hybrid Electric Vehicles to Minimize Distribution System Losses”. IEEE trans. Smart Grid, vol. 2, no. 1, pp. 198–205, March 2011.

[12] K.Clement-Nyns, E. Haesen, J. Driesen, “The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid,” IEEE Trans. Power Syst, vol. 25, no. 1, pp. 371–380, February 2010.

[13] J.R. Pillai, B. Bak-Jensen, “ Vehicle-to-Grid for islanded power system operation in Bornholm, ” IEEE Power and Energy Society General Meeting. , no. 1944-9925, pp. 1–8, July 2010.

[14] Jenkins, S.D. , Rossmaier, J.R., Ferdowsi, M, “Utilization and Effect of Plug-In Hybrid Electric Vehicles in the United States Power Grid, ” IEEE Vehicle Power and Propulsion Conference (VPPC). pp. 1–5, Sept. 2008.

[15] Weihao Hu, Zhe Chen, Bak-Jensen, B., “Impact of optimal load response to realtimeelectrici typriceonpower system constraints in Denmark, ” IEEE Universities Power Engineering Conference (UPEC), pp. 1–6, Sept. 2010.

[16] R.N.Allan, R. Billinton, I.Sjarief, L. Goel,K.S. So, “A reliability test system for educational purposes basic distribution system data and results. ” IEEE Trans. Power Systems, vol. 6, no. 2, pp. 813–820, May 1991.

[17] Pramod Bangalore, “ Development of Test System for Distribution SystemReliability Analysis, Integration of Electric Vehicle in to the Distribution System”. Department of Energy and Environment Division of Electric Power Engineering Chalmers University of Technology Göteborg, Sweden 2011

[18] Najibifar, M., Mortazavi and Kianinejad, “Optimization of parking lot charging of the hybrid electric vehicles with the aim of increasing the reliability of the distribution system using Monte Carlo method**”**, International Conference on Electrical Engineering and Computer Sciences, 2015.

[19] Rahmatian, M.R., Nazari, E., and Rahmatian, M.A, “Demand side management to reduce fossil fuels as well as consumer costs by charging and discharging PHEVs in smart homes**”**, Electronic National Conference of Environment and Energy, Safashahr, Iran, 2014.

[20] Sedghi, A., Ghasemipour M., Ramezani M., and Aghaebrahimi M.R.,“Reliability assessment of the independent wind/photovoltaic/storage systems with presence of the electric vehicles**”**, the 28th International Power System Conference(PSC), Tehran, Iran, 2013.

[21] Sedghi, A., Aghakouhi, P., Ramezani, M., “Effect of demand side management on reliability of generation system in presence of wind power plant**”**, the 3rd Annual Conference of Clean Energy, Kerman, Iran,2011.

[22] Nabi, B., Amini, M.H., and ParsaMoghaddam, M., “Effect of electric vehicles on line congestion in distribution network**”**, the 17th National Conference of Power Distribution Networks, Tehran, Iran, 2010.