The Influence of Smart Grid on TOU Programs With Respect to Production Cost and Load Factor, A Case Study of Iran

Hassan Monsef[1], Pouyan Khajavi[2]

1 Associate Professor, Electrical Engineering Department, Tehran University, Tehran, Iran. Email: hmonsef@ut.ac.ir
[2] Electrical Engineering Department, Tehran University, Tehran, Iran.

Abstract

Reaching an electricity system which is both economically efficient and environmentally friendly is motivating countries to design and execute different types of TOU demand response programs. But there are certain deficiencies which prevent these programs to effectively modify the load shape. Smart grid as a means could help the electricity system to reach the highest demand side management goals which are inaccessible through today's methods. In this paper, problems facing today's demand response programs have been described and Iran's recently designed TOU program has been analyzed as an example. The influence of this program has been simulated on Iran's actual load curve. As a solution to the problems facing DR programs, Smart Grid has been introduced and the influence of Real Time Pricing (RTP) program in Smart Grid has been simulated on an actual load curve of Iran's grid, using multi period load model and adaptive periods. Reaching market equilibrium and the effect of Smart Grid on price curve has also been simulated. Finally, the current TOU program designed for Iran and the RTP program in smart grid have been compared with respect to load shape modification, load factor, price curve, and production cost. Eventually, savings made possible through smart grid per day have been evaluated.

Keywords: Demand response problems, Real time pricing, Smart grid, Time of use programs

1. Introduction

Demand Response (DR) as a part of DSM has been introduced by Department of Energy (DOE) as: "Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized". DR programs are being conducted to reach flatter load and price profiles [1].

Iran, as a developing country is facing problems with the electricity industry. Insufficient power production, old infrastructures in production, transmission and distribution levels are parts of problems to be solved in Iran's electricity grid. Typically during the summer, the load has its highest magnitude throughout the year which is due to extensive use of air conditioners in the country. Last year, Iran's grid management company (IGMC) decided to design a time of use demand response program to be executed throughout the country [2].

In this paper, the currently designed demand response program for Iran's grid has been described, also, problems with this demand response program has been introduced. As a solution to the problems facing Iran's grid, smart grid has been introduced and its several characteristics which helps demand response programs to become more effective has been described. Also, using a model for demand response programs, the influence of currently designed demand response programs and the demand response program in smart grid environment has been simulated on a load curve from Iran's grid. Both normal program and smart program have been compared with respect to load factor, electricity prices and production costs. Moreover, the amount of savings per day resulting from implementation of smart grid has been evaluated for Iran's grid.

All the simulations have been conducted using MATLAB.

2. **Demand Response Programs**

One of the most important differences between electrical energy market and markets of other commodities is the way in which customers participate in market which is believed to be the origin of many problems. In other commodities, customers have an active role in market. Having known the price, they participate in the market by purchasing their needed amount of the commodity. In electricity market however, customers don't have enough information and hardware to have an active role in the market. As a result, customers would continue to consume electrical energy even at times of high electricity price. As a result, this behaviour could lead to price crisis in electrical power market (price spikes, line congestion, etc) [3].

In this situation, electricity utilities invented Demand Response in an attempt to provide a connection between market and customers. An effective connection between the customers and the market could yield advantages to both the system and the market [4].

DOE has divided DR programs into two major categories and each category contains several programs, these programs are listed below [1].

1 – Incentive Based Programs:
- 1-1- Direct Load Control (DLC)
- 1-2- Interruptible/curtail able service (I/C)
- 1-3- Demand Bidding/Buy Back
- 1-4- Emergency Demand Response Program (EDRP)
- 1-5- Capacity Market Program (CMP)
- 1-6- Ancillary Service Markets (A/S)

2- Time-based programs:
- 2-1- Time-of-Use (TOU) program
- 2-2- Real Time Pricing (RTP) program
- 2-3- Critical Peak Pricing (CPP) Program

The focus of this paper is on Time Based Programs which rely on customer's choice to decrease or change their consumption in response to changes of electricity's price during a 24 hour period.

3. Problems Facing DR

DR programs available in today's electricity industry have certain problems which avoid them to reach their highest potential. The designed DR program for Iran's grid has been chosen to study problems facing DR programs.

A. Lack of Required coordination between designed program and actual load curve

In March 2009, Iran's power production and distribution company (Tavanir) announced that a time based DR program has been designed for Iran's grid which will be executed after renewing meters throughout the grid. The mentioned program contains 2 seasonal programs, one for spring and summer (warm season) and one for fall and winter (cold season) [2]. The periods and prices of this program have been listed in table I.

Table. 1
Time based DR program designed for Iran's Grid [2]

	Low	Off-Peak	Peak
Warm season	23 to 7	7 to 19	19 to 23
Cold Season	21 to 5	5 to 17	17 to 21
Price	0.25 Off-Peak Price	Off-Peak Price	2.5 Off-Peak Price

Sufficient coordination between the designed Time of Use (TOU) program and the actual load curve plays a critical role in the ultimate success of the program.

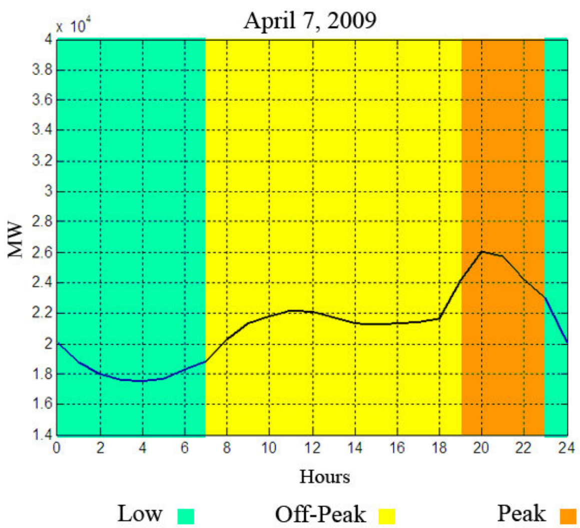

Fig. 1. Iran's Load on April 7, 2009 in comparison to designed DR program, acceptable coordination

By comparing the above mentioned program with Iran's actual load curve, the coordination between the program and the load curve could be examined. In fig. 1 an ordinary day from the beginning of spring has been chosen and the periods of the designed TOU program has also been showed in this figure. It could be observed that at this time of the year, Iran's load shows sufficient coordination with the designed DR program. Low, Off-peak and Peak periods show acceptable coordination with the actual load shape.

In Iran like so many other countries, the highest demand occurs during the summer due to extensive use of air conditioners. As the season changes from spring to summer, demand rises and shape of the load curve undergoes considerable changes. Fig. 2 shows Iran's load curve on July 19, 2009; the highest demand for electricity has also occurred in this day.

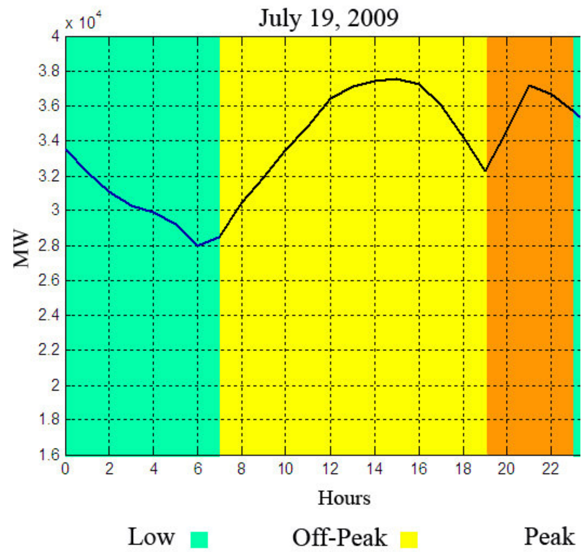

Fig. 2. Iran's Load on July 19, 2009 in comparison to designed DR program, lack of coordination

As it could be observed in fig. 2, load curve has a considerably different shape compared to fig.1 and demand has experienced considerable growth. It is apparent that the designed DR program does not coordinate with the load curve anymore. From 11 to 16'o clock is obviously a part of peak period in this day which is being considered as Off-Peak in the designed TOU program. On the other hand, the mentioned DR program considers midnight to be a part of Low period which is another clear mistake. Typically this lack of coordination becomes more evident as days become warmer, and it is most sever during July and August.

If a well coordinated TOU program is to be designed for this particular day, it should be similar to the program demonstrated in fig. 3.

Practically it is not possible to define such precise periods for Time of Use (TOU) programs. Moreover, even if was practical form the technological point of view, it wouldn't be accepted by the customers.

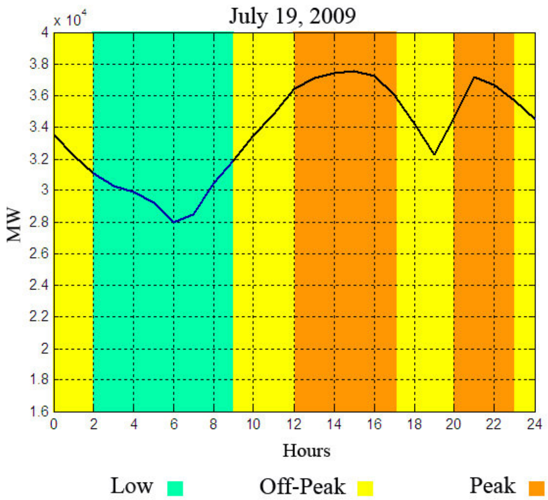

Fig. 3. Iran's Load on July 19, 2009 in comparison to a well coordinated DR program

This lack of coordination will prevent the TOU program to effectively reform the load shape. As a result, the designed TOU program not only doesn't make the load curve smoother, but it worsens the situation and could lead to higher rates of price volatility and risks in the energy market. This problem has its roots in the inherent deficiency of the current time of use DR programs. It is not possible to change the periods more than 2 or 3 times per year because it would make the programs too variant for the customers to get used to and hence would make it difficult for them to respond. By changing the periods 2 or 3 times per year, an acceptable coordination could hardly be reached.

B. Loss of customer's social welfare

Time based DR programs rely on customer's choice to respond to electricity's price changes during a day. In other words, these programs would be successful if customers shift their loads to time intervals with low energy price and decrease their consumption during high energy prices. An important issue which has been ignored by the electrical utilities and regulators is the loss of customer's social welfare.

If the price of energy increases in a certain time interval, customers would have 2 ways of confronting it. First they could shift some parts of their loads to other time intervals, and second they could decrease some part of their consumption if it is possible.

Considering the facts that shifting loads requires customers to change their lifestyle and do some of their activities during inconvenient hours of day such as late nights, and consumption decrease means not doing some desirable activities, it must be noted that both decreasing the consumption and shifting loads to other time intervals, cause customers to sacrifice a part of their social welfare. This would cause DR programs to have an ugly face in the society which could highly reduce their public acceptability and as a result the long term success of these programs; because people are not willing to lose their welfare easily.

C. Inelastic demand

In TOU programs, electrical utilities are looking forward to see customers change their energy usage pattern with respect to electricity price during a day, in other words decreasing and shifting loads with respect to price steps. This issue highly relates the success of DR programs to the concept of elasticity of demand.

Elasticity is defined as changes in demand with respect to changes in price: [5]

$$E = \frac{\partial q}{\partial \rho} = \frac{dq}{d\rho} . \frac{\rho_0}{d_0} \quad (1)$$

Where:

E =Elasticity of the demand
q = The demand value (MWh)
ρ = Electricity energy price (\$/MWh)
ρ_0= Initial electricity energy price (\$/MWh)
q_0= Initial demand value (MWh)

But electricity has a relatively low elasticity of demand compared to other commodities. Low elasticity means smaller consumption reductions and smaller load shifts which would prevent time of use DR programs to reach their predetermined goals.

The source of inelasticity in electrical energy's demand may vary depending on region. Considering the fact that a more elastic demand requires customers who are shifting or reducing their consumption in periods of higher energy price, the roots of inelasticity could generally be listed as [6]:

1- A large portion of electricity demand cannot be shifted to other time intervals and another large portion cannot be decreased.
2- People are not able or willing to change their lifestyle.

3- It is not possible for Industries to change their manufacturing routine.

Increase in demand's elasticity, would improve the result of Time-Based-programs, which would lead to better control of market price and load profile.

In order to have effective and influential demand response programs, it is necessary to find solutions to the above mentioned flaws.

4. Smart Grid

As it has been discussed in other papers, smart grid is an important concept in today's electrical energy literature. Smart grid refers to a modern and intelligent power system in which the needed information is available to both producers and consumers and all parts of the system have sufficient information to regulate their activities [7]. U.S. Department of energy defines Smart grid as today's grid joined by advanced metering and control devices such as:

1- Information Technology
2- Sensors
3- High speed, Real-time two way communications
4- Energy Storages
5- Distributed Generation
6- In-home Energy controllers
7- Automated home energy use

Having these smart infrastructures, smart grid has many advantageous characteristics including but not limited to following.

All customers regardless of their size, will be aware of instantaneous market price through high speed connections (depending on the market, price could be settled every hour, half an hour or every quarter of an hour). By having an in-home controller connected to all the appliances, every customer would be able to control his energy consumption automatically with respect to market price. For example the controller could be set to increase room temperature at times of high spot price, or to turn on washing machines at times of low spot price (2 or 3 am).

In this environment, electric and hybrid vehicles would be able to act as distributed storages, storing the energy at times of low electricity price and discharging the stored energy at times of high price.

Smart grid enables the use of distributed generation in all voltage levels. Domestic generators such as wind turbines or photovoltaic cells would help customers to reduce their energy bills and even sell extra to demand electricity to the grid. In other words, smart grid provides customers with enough information and hardware to be able to actively participate in the electricity market.

Some of Smart Grid's characteristics can be summarized as:

1- Real time pricing would be practical.
2- Smart Grid accommodates all distributed generation and storage technologies.
3- Customer participation would be at its highest level.
4- Smart Grid optimizes assets and operates efficiently.
5- System would be more economic.
6- It anticipates and responds to system disturbance (self healing).
7- The system would be more environmentally friendly.
8- It enables new products and market services.
[8], [9], [10]

In the following sections, the influence of smart grid on TOU demand response programs will be demonstrated. First, a model is needed to simulate the influence of the execution of time of use DR programs on the load curve.

5. Modeling Demand Response

In this section a model is demonstrated for determining the result of executing time of use DR programs on the load curve.

According to equ.1, two kinds of elasticity can be defined; Self elasticity (E_{aa}): changes in demand in a time interval with respect to changes in price of the same time interval (which is negative). [5]

$$E_{aa} = \frac{\Delta D_a}{\Delta \rho_a} \leq 0 \quad (2)$$

Cross elasticity (E_{ab}): changes in demand in a time interval with respect to changes in price of a different time interval (which is positive).

$$E_{aa} = \frac{\Delta D_a}{\Delta \rho_b} \geq 0 \qquad (3)$$

Where:

ΔD_a: Demand changes in period "a"

$\Delta \rho_a$: Price changes in period "a"

ΔD_b: Demand changes in period "b"

Here each time interval is supposed to be one hour.

Suppose that:

$d(i)$ = Customer demand in i-th hour (MWh).

$\rho(i)$ = Spot electricity price in i-th hour ($/MWh).

$B(d(i))$ = Customer's income in i-th hour ($).

It is supposed that customer's demand has the initial value of $d_0(i)$ which changes to $d(i)$ after executing DR programs, so:

$$\Delta d(i) = d_0(i) - d(i) \quad \text{(MWh)} \qquad (4)$$

Customer's benefit, S ($), for i-th hour would be:

$$S(d(i)) = B(d(i)) - d(i).\rho(i) \quad (\$) \qquad (5)$$

To maximize customer's income, $\frac{\partial S}{\partial d(i)}$ must equal to zero, so:

$$\frac{\partial S}{\partial d(i)} = \frac{\partial B(d(i))}{\partial d(i)} - \rho(i) = 0 \qquad (6)$$

$$\frac{\partial B(d(i))}{\partial d(i)} = \rho(i) \qquad (7)$$

Considering quadratic benefit function:

$$B(d(i)) = B_0(i) + \rho_0(i)[d(i) - d_0(i)].$$

$$\{1 + \frac{d(i) - d_0(i)}{2E_i.d_0(i)}\} \qquad (8)$$

Where:

$B_0(i)$= Benefit during nominal demand ($d_0(i)$)

$P_0(i)$= Nominal electricity price when demand is nominal.

$$\rho(i) = \rho_0(i)\{1 + \frac{d(i) - d_0(i)}{E(i).d_0(i)}\} \qquad (9)$$

Considering (8) and (9):

$$\rho(i) - \rho_0(i) = \rho_0(i)\{\frac{d(i) - d_0(i)}{E(i).d_0(i)}\} \qquad (10)$$

So, customer's demand would become:

$$d(i) = d_0(i).\{1 + \frac{E(i)[\rho(i) - \rho_0(i)]}{\rho_0(i)}\} \qquad (11)$$

The cross elasticity between i-th and j-th interval is defined as:

$$E_0(i,j) = \frac{\rho_0(j)}{d_0(i)}.\frac{\partial d(i)}{\partial \rho(j)} \qquad (12)$$

$$\begin{cases} E_0(i,j) \leq 0 & if \quad i = j \\ E_0(i,j) \geq 0 & if \quad i \neq j \end{cases}$$

If $\frac{\partial d(i)}{\partial \rho(j)}$ is supposed to be constant, the demand response to price variations could be written as:

$$d(i) = d_0(i) + \sum_{j=1}^{24} E_0(i,j).\frac{d_0(i)}{\rho_0(j)}.[\rho(j) - \rho_0(j)]$$

i=1,2,3,…,24 (13)

Combining (11) and (13) the final model would be achieved:

$$d(i) = d_0(i) + \sum_{j=1}^{24} E_0(i,j).\frac{d_0(i)}{\rho_0(j)}.[\rho(j) - \rho_0(j)]$$

$$.\left\{1 + \frac{E(i)[\rho(j) - \rho_0(j)]}{\rho_0(j)}\right\} \quad i=1,2,3,\ldots,24 \qquad (14)$$

Equation (14) shows the customer's consumption to reach the maximum benefit in a 24 hours interval. [11]

In the following sections, two different scenarios including the current TOU program designed for Iran's grid and the TOU program in smart grid's environment, have been defined and their influence on the load curve have been determined using DR model; also adding the effect of smart grid to DR model has been demonstrated.

6. Current TOU Scenario

Iran's Grid peak day in year 2009 which has been shown in fig. 4, has been chosen to analyze and compare the influence of both current TOU program and the Real Time Pricing (RTP) program enabled through smart grid technologies.

In this section, Iran's current time of use DR program which has been introduced in section III, has been chosen. Table II shows the summery of this program. This study only contains the warm season so only the program pertaining to spring and summer has been brought in table II.

Table.2
Iran's TOU Program for warm season

	Low	Off-Peak	Peak
Warm season	23 to 7	7 to 19	19 to 23
Price	0.25 Off-Peak Price	Off-Peak Price	2.5 Off-Peak Price

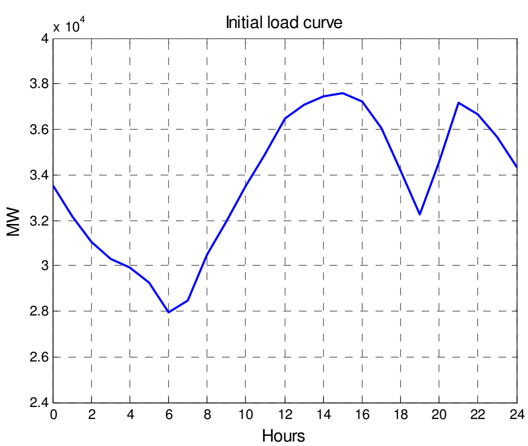

Fig. 4. Iran's grid Load Curve (July 19, 2009) [2]

It has also been considered that 30% of customers would respond to TOU programs and elasticities have the values shown in table III.

Table.3
Self and cross elasticities for normal TOU program

	Peak	Off-Peak	Low
Peak	-0.05	0.015	0.009
Off-Peak	0.015	-0.05	0.007
Low	0.009	0.007	-0.05

In [11], greater values have been chosen to study the effect of TOU programs on load curve. In the mentioned paper, simulating the effect of TOU program on load curve, has shown considerable changes in load during Low and peak periods. As [11] suggests, load reductions as large as 55% could be achieved during peak period. This large reduction in electricity consumption is very far from the reality of electricity grid. Thus, as table III shows, relatively small values (about the half of values chosen in [11]) have been chosen for elasticities for normal TOU programs.

7. Smart Grid's Influence; Adaptive Periods

In this section, the influence of using smart grid on time-based-rate DR programs has been evaluated.

In RTP program, every time period (each period is an hour in this paper) would have its own electricity price. By having the supply curve for Iran's electrical energy market, the price curve during the day could be derived from demand curve [2]. Iran's electricity supply curve is shown in fig. 5. The extraordinary shape of Iran's supply curve which is visible in fig. 5 is due to two main reasons; first, electricity is cheaper in Iran's market compared to other energy markets as a result of subsidies paid by government to power producers on their fuel. The second reason is the limit for maximum price of electricity in the power market which is 110'000 Rial/MWh (about 11 $/MWh). The limit allows Gencos to bid at higher prices knowing soon the price limit would be reached. This behaviour especially occurs during peak days of summer. As a result electricity would have its maximum price for 3 to 4 hour during the day. In other words, the price limit has made the market to be less competitive. On the other hand, because of lack of highly efficient power plants in Iran, the supply curve grows at a higher rate and has a relatively high gradient even in low demands.

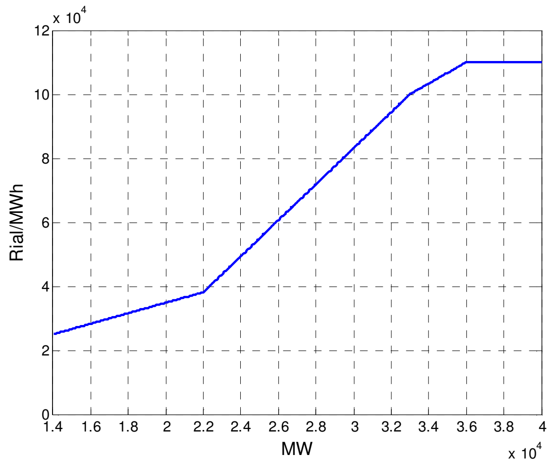

Fig. 5. Iran's electricity market price curve, July 19, 2009

Through the estimated supply curve of Iran, energy price curve during this day would be as shown in fig.6.

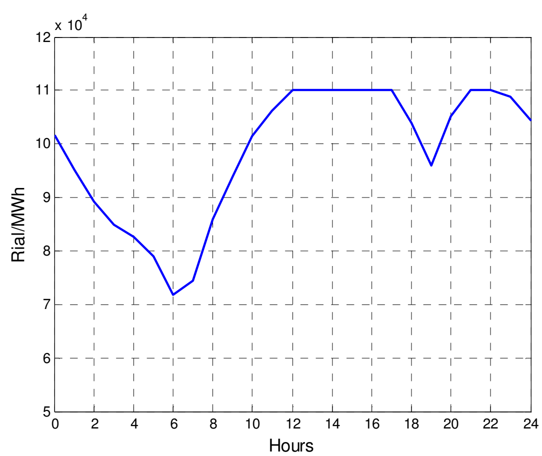

Fig. 5. Iran's electricity market price curve, July 19, 2009

Enabled through smart infrastructures, real time pricing could be practically executed. The price curve considered for real time pricing is the real price curve shown in fig. 6.

In RTP program, every two different time periods, would have their own cross elasticity and also every time period would have a different self elasticity. For simplicity, hours of a day have again been divided to 3 categories, Peak, Off-Peak and Low periods. But for modelling RTP program, these time intervals could not be assumed fixed during a day but they change depending on the load and energy price at that hour.

The technique used here is based on defining Peak, Off-Peak and Low periods depending on how high the electricity demand and relatively its price are. Obviously, hours with higher demand are Peak periods and the ones with lower electricity demands must be considered as Low periods.

Table .4
Adaptive periods used for simulating RTP program in smart grid environment

Peak period	Demand is between 70% and 100% of its range.
Off-Peak period	Demand is between 30% and 70% of its range.
Low period	Demand is between 0% and 30% of its range.

So, the periods are adaptive depending on the magnitude of demand. In this paper these periods have been considered to be as shown in table IV.

Smart Grid's characteristics defined in section IV will help customers to respond to changes in electricity price and vary their energy consumption during the day more effectively. In this new environment, even the smallest customers would have the ability to participate in power market and to adjust their consumption with respect to electricity price in order to reach the highest welfare. Enabled through Smart Grid's infrastructures, each customer would be able to install his own electric plant and appear as a producer who sells power to the grid at times of extra production [8].

This means, customers are able to buy less energy from the grid at times of high price, by shifting loads, using their own DG plant or even through discharging batteries of their hybrid electric vehicle charged during the night before.

Therefore Smart Grid's characteristics can be added to DR model by increasing the self and cross elasticities of demand. It has also been assumed that in Smart Grid environment, customer's participation increases for 20% and reaches a portion of 50%.

Elasticities between different time intervals have been increased comparing to the normal TOU program.

Table .5
Self and cross elasticities for RTP program in smart grid

	Peak	Off-Peak	Low
Peak	-0.06	0.04	0.024
Off-Peak	0.04	-0.06	0.018
Low	0.024	0.018	-0.06

The great increase in cross elasticities is due to smart grid's ability to effectively shift loads, also the influence of DG plants and distributed storages, lies inside this increase.

In an actual market, changes in load, lead to changes in market price; Therefore for analyzing the effect of smart grid on load and price curve during one day, it must be noted that in RTP program unlike normal TOU programs in which only price affects demand, demand would affect price curve too. That's because consumers have the ability to change their load in response to price, and this happens through interactions between demand and supply side in real time. So in order to derive the load curve in smart grid environment in the presence of RTP program, load shape should be derived in an iterative procedure.

Fig. 7 shows the initial load curve, the load curve after the execution of TOU program and the load curve using RTP program enabled by Smart Grid.

The load curve pertaining to smart grid shown in fig. 7 has been evaluated through 3 iterations. If iterations were continued further, the curve representing smart grid's load curve would become a straight line which is only theoretical and very far from reality.

As it is visible in fig. 7, the normal time of use DR program designed for Iran's grid, not only hasn't helped the load curve to become smoother, but has also made it more irregular. Fig. 7 clearly shows the devastating effect of inconvenient time of use DR program on load curve.

For having a better comparison between load curves shown in fig. 7, the load factors pertaining to each curve have been evaluated. Table VI demonstrates the mentioned load factors.

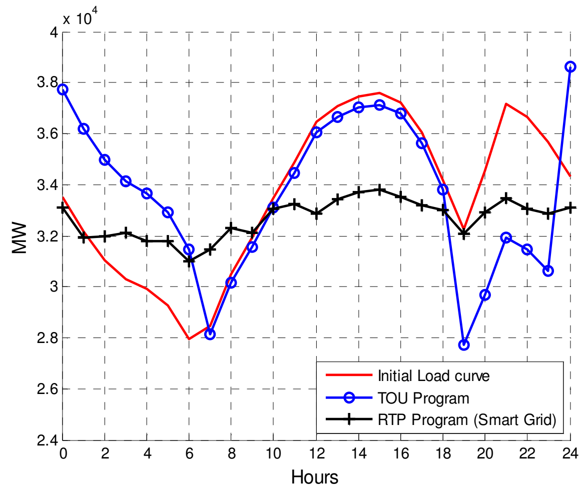

Fig.7. Comparison between initial load curve (July 19, 2009), load curve after TOU and load curve using RTP in Smart Grid

Table .6
Load factor for different load curves

Load factor for July 19, 2009	0.8945
Load factor for July 19, 2009 modified by normal TOU programs	0.8716
Load factor for July 19, 2009 modified by RTP program in smart grid	0.9664

The Load factor related to the load curve after executing normal TOU program designed by Tavanir for Iran's grid, clearly explains the deficiency of this program in reforming the load curve. Therefore this program won't yield the desired result but it also deteriorates the situation. Problems discussed in section III, prevent this TOU program to reach its predetermined goals.

As it could be seen in fig. 7, the ultimate load curve in smart grid environment is much smoother with a high load factor which shows the efficient operation of smart grid.

The smoother load curve in smart grid environment, leads to a smoother price curve. Moreover, energy has a cheaper price during the day and also price volatileness and price spikes are effectively eliminated. In contrast with initial price curve, electricity price doesn't reach its limit (110'000 Rial/MWh) any more. Price curve using smart grid can be seen in Fig. 8.

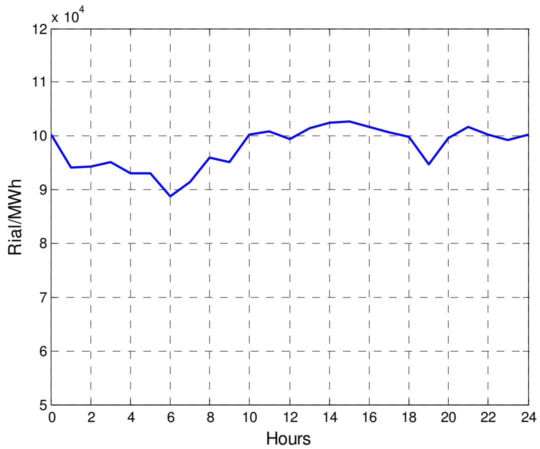

Fig. 8. Energy price using RTP program in Smart Grid

In order to determine the saving achieved through implementing the smart grid, production costs, have been compared for load curves of fig. 7. Production cost, is defined as the amount of money paid to the Gencos for supplying electricity to the grid. It could be calculated through integral of the product of load and price curves.

$$cost = \int_{0}^{24} D(t).\rho(t)\,dt \tag{15}$$

Table VII shows the production costs for normal load curve, load curve after executing designed time of use program for Iran and the load curve in smart grid environment with real time pricing.

Table VII
Production costs and savings brought by smart grid for July 19, 2009

Production cost for July 19, 2009	83’712’000’000 Rials
Production cost for July 19, 2009 modified by normal TOU programs	84’099’000’000 Rials
Production cost for July 19, 2009 modified by RTP program in smart grid	79’982’000’000 Rials
Saving resulting from smart grid	3’729’700’000 Rials

Considering the fact that the Iran’s electricity price does not represent the real cost of electricity due to subsidies paid by government, the actual amount of savings resulting from smart grid would be much higher than the amount presented in Table VII. An estimation for the actual savings brought by smart grid could be made from the announcement of Iran’s ministry of electrical power in which the actual price for electricity announced to be 8 times higher than the current price [12]. Considering this fact, the savings would reach the huge amount of 29’837’600’000 Rials (27’126’000 ($)) per day.

8. Conclusion

In this paper, time based demand response programs have been reviewed and the problems which are avoiding these programs to reach their highest efficiency have been identified. Iran’s recently designed TOU program has been analyzed and the drawbacks of this program have been proved. As a solution, Smart Grid has been introduced and the DR model has been upgraded to reflect the TOU programs in Smart Grid’s environment using adaptive periods.

The peak day in Iran’s grid was chosen to simulate the influence of both current TOU program and the modern RTP program in smart grid. Finally, the results of these programs have been compared with respect to load curve, price curve, load factor and production costs and the savings made possible using smart grid has been evaluated. It has been shown in this paper that using smart grid, higher demand side participation, increased elasticity of demand, more effective TOU programs and therefore a smoother and lower demand curve plus cheaper energy price could be achieved. Moreover, savings made possible through implementation of smart grid per day have been evaluated.

References

[1] U. S. Department of Energy, "Energy policy Act of 2005", section 1252, February 2006.

[2] Iran Grid Management Company, 2009, www.igmc.ir.

[3] D.S. Kirschen, "Demand-side view of electricity markets" IEEE Transaction on power systems, Vol. 18, No.2, pp.520-527, May 2003.

[4] US Department of Energy, "Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them", Report to the United States Congress, February 2006.

[5] D. S. Kirschen, G. Strbac, P. Cumperayot, D. Mendes, "Factoring the elasticity of demand in electricity prices", IEEE Transaction on power systems, Vol.15, No.2, pp.612-617, May 2000.

[6] P. Khajavi, H. Monsef, "Load profile reformation through demand response programs using smart grid", Modern Electric Power Systems (MEPS), pp.1-4, 2010.

[7] Rahimi F., Ipakchi A. , "Overview of Demand Response under the Smart Grid and Market paradigms", Innovative Smart Grid Technologies (ISGT), pp.1-7, 19-21 Jan. 2010.
[8] U.S. Department of Energy, “Smart Grid: An Introduction” 2008.
[9] USA’s National Energy Technology Laboratory (NETL), “A Vision For The Modern Grid”, March 2007.
[10] Powermag, Vol.152, No.5, pp.42-46, May 2008.
[11] H. Aalami, G. R. Yousefi, M. Parsa Moghadam, “Demand Response Model Considering EDRP and TOU Programs”, Transmission and Distribution Conference and Exposition, pp.1-8, 2008.
[12] Mehr News, Jun 2010, **www.mehrnews.com**.