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The Role of Smart Grids and Load Response Programs in Control of Power Network

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Abstract: In this paper, we have investigated the problem of electricity distribution grids as well as the impact of the smart grids and load response programs on distribution grids. Finally, a distribution grid controlled by smart grids has been simulated when the load is reduced or added.

Keywords: smart grids, load response program, diffuse sources.

1. Introduction

Electric energy is the most consumed energy, and %90 of it in the world is attained by fossil energy in thermal power plants. If we can increase the efficiency of the consumed energy, the use rate of fossil fuels and then greenhouse gases production will significantly reduce. Basic structure and fundamental distribution grid with a hierarchical structure leads to consumers' productivity power by crossing from distribution and transmission grids. Figure 1 shows the topology of traditional power grid that has a hierarchical structure that great plants are at the highest level of the structure and away from consumers who are at the lowest level (including coal, gas, nuclear, hydro and thermal plants). These grids are generally one-way highways that deliver total electricity to subscribers. There is not a two-way highway to flow and exchange information at the whole grids.

Key issues can be studied in the traditional electric grids as follows:

1. Inefficiency of electricity grid in managing peak demand
2. Inability of grids to establish the exchange of secure information
3. Supporting the limited grid capacity in using distribution generation resources
4. Inefficient grid with the expansion of PEVS
5. Susceptibility to blackout and power quality disturbance
6. Vulnerability of existing grids due to natural disasters
7. Being old and outdated grids

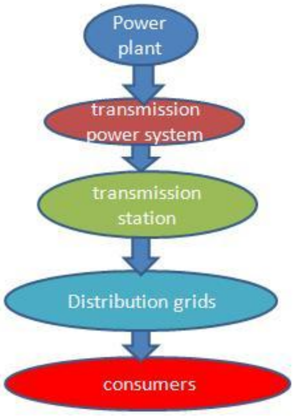

Fig.1. The topology of traditional power grid

Many of the shortcomings of the existing network which are briefly described above using the smart grids are removable. The smart grids can be assigned to developing and updating of existing grids including advanced monitoring, control of electricity production, transmission and distribution.

The increasing use of digital information and control technology make more reliability, security, efficiency of electricity grid, integration of distributed generation, response to demand, and efficiency energy. In summary, the importance of smart grids can be summarized as follows:

-Peak in shaving that is the main adoption result of smart grid with advanced technology in customer's house and distribution post

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-The reduced consumption of fossil fuels obtained peak energy losses associated with losing distribution lines.

-Reduction in subscribers, who have blackout, is an important result to predict or prevent potentially power outages and effective response in case of power failure for trouble shooting.

-Reducing the investment required for transmission and distribution projects to improve load balancing and reducing the peak load for advanced demand management.

-Cost reduction is the result of switching from remote subscribers.

2. Taking advantage of smart grid and load response programs to reform the energy consumption pattern

Load response programs can change the shape of load profile to achieve maximum efficiency during peak hours, mange load, reduce peak system, pass consumption to non-peak hours or even enter private generations to orbit. According to the division board of America's electricity market, load response is divided into two sub-categories:

1-Incentive based programs

2- Time- based programs

The successful implementation of load response programs is related to the consumer's choice to reduce power consumption at times when the bill is more expensive. Thus, the success of DR programs will depend on the economic, cultural, and social situation of the region and country. Here is a concept in economy called the Elasticity of Demand. It means a unit in the price of that product. Electricity has low traction compared to other products, and it just cannot expect prices to decrease consumption. Thus, it is a non-elastic product since the successful implementation of the program is highly dependent on the elasticity of electricity demand. Non-elastic of electricity demand is as a deterrent to successful implementation of DR programs. The non-elastic origin dates back to three issues:

1-Much of the load does not transfer to another time.

2-Consumers are not able or willing to change their way of life.

3-Companies are able to change their production processes.

Modeled solution electricity of demand is the use of new technology in the smart grid so that people are able to make changes without losing their welfare in their electricity consumption. To evaluate the load response and current grid compared with the smart grid will require a mathematical model that leads to two types:

1-Insider traction: It reduces the power consumption in time for increasing electricity price in the Jet time. It is always a negative quantity.

$$\mathrm{Eaa} = \frac{\Delta \mathrm{Da}}{\Delta \mathrm{Pa}} \leq 0 \qquad \text{relative (1)}$$

2- Mutual traction: It means reducing electricity consumption in the time for increasing electricity price in Jet time. It is always a positive quantity.

$$\mathrm{Eab} = \frac{\Delta \mathrm{Db}}{\Delta \mathrm{Pa}} \geq 00 \qquad \text{relative (2)}$$

In this relation:

ΔDa=consumption change in "a" time

ΔPa =price changes in "a" time

ΔDb =consumption changes in "b" time

Here each period represents one hour.

$$d(i) = \{d_0(i) + \sum_{j=1}^{24} E_0(i,j).\frac{d0(i)}{P0(j)}.[P(j) - P0(j)]\}.\{1 + \frac{E(i)[P(i) - P0(i)]}{P0(i)}\}$$

i=1,2,3…24 Relation(3)

d(j)=consumer consumption in ith time(MWh)

p(i)=Electricity prices in power moment market ($/MWh)

B(d(i)=consumer income in ith time($)

B.(i)=profit in the time of nominal consumption

p.(i)=nominal price of electricity when consumption has its own nominal value.

The amount of power consumption present to achieve maximum profit (minimum cost) in 24 hours period .this model van be examined to meet the impact of load response programs in a load curve. The intelligent technology in grid allows customers to change their peak consumption hours and also install DG unit in their hours in addition to the sell electricity to the grid and to compensate the cost of electricity to the grid and to compensate the cost of electricity consumption.

In this way, the impact of smart grid can be added to the DR model by increasing the elasticity of demand. The load curve of normal day in Iran has been selected to evaluate the response and without it in the smart grid.

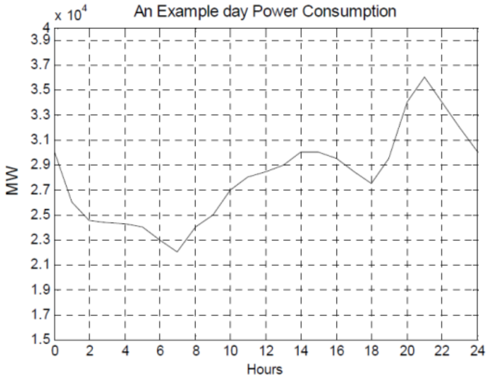

Fig.2. Load curve of Iran. (2006/8/28)[1]

Schedule consumption studied in this report has three prices for various times during the day. Cheap price range (low) is from 0 to 9, middle range (off-peak) from 9 to 19, and peak from 19 to 24. Electrical energy is in the form of 1.7$/Mwh for cheap range, 2.2$MWH for middle range, and 3$mwh for peak during above period. Percentage of participation in the program, %40 DR is considered. Table of various periods for the traction related to each other is considered as Table 1.

For advanced application and instant load response (real time pricing demand response program), we consider price chart during the day as follows:

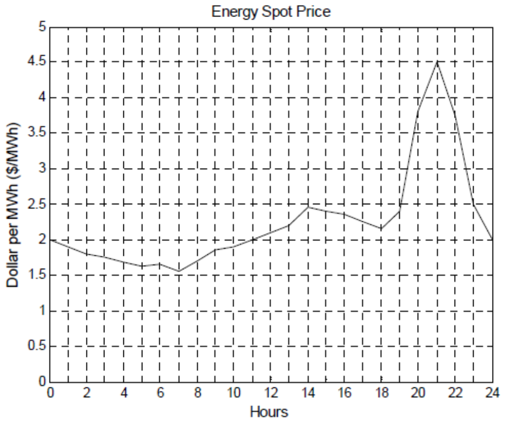

Fig.3. Electricity price curve during the day

In terms of real time to program each time separately with respect to specific traction, there will no longer be time scale, but here, for simplicity, we use the same regular intervals and examine traction from the same period (Table 2) [1].

With regard to program, the dramatic growth of traction, especially mutual traction, results in the extraordinary capabilities of load transmission to non -peak hours. In addition, the impact of DG units lays the increase. Finally, the impact of each program is applied on the load curve and examines the impact of the smart grid load cure on the wire [1].

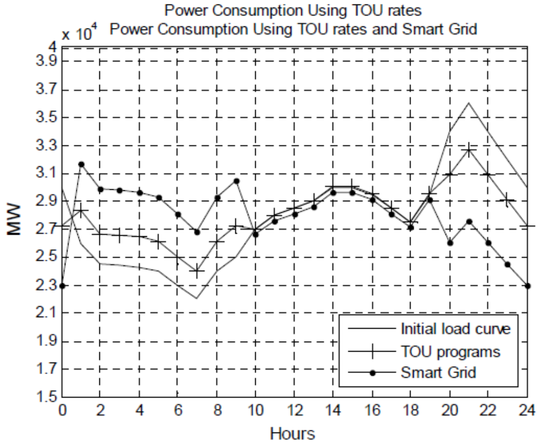

Fig. 4.Comparision between the initial load, load curve after ordinary TOU program, and load curve after ordinary TOU programs with smart grid [1]

Table1: Traction of various periods related to each other

	Peak	Off-Peak	Low

Peak	-0.1	0.016	0.012
Off-Peak	0.016	-0.1	0.01
Low	0.012	0.01	-0.1

Table2: Tractions of various periods

	Peak	Off-Peak	Low
Peak	-0.12	0.096	0.08
Off-Peak	0.096	-0.12	0.072
Low	0.08	0.072	-0.12

As you can see in the figure above, DR programs using smart grid technology has helped to improve the load grid curve and caused to reduce and smoothed the peak load curve. However, this study only considers the impact on consumer electricity prices and passes up the interaction of consumption on market price. The curve obtained will be approximate. In practice, the shape of the load cure will be flatter due to influencing the interaction of price on consumption and vice versa (due to real time market price and direct communication to consumers this will be possible) the loud curve will recess towards that power consumption, and its price during the day is an approximately constant value. The simulations have been performed in this study to show the impact. By considering both categories, impacts (price and consumption) will dynamically require a more sophisticated model.

3. Control simulation of a power System by smart grid

Below a 30-bus power system has been simulated by MATLAB. The impact of amount load changes in certain power buses, and the performance of smart grid in DGs control for compensation have been investigated.

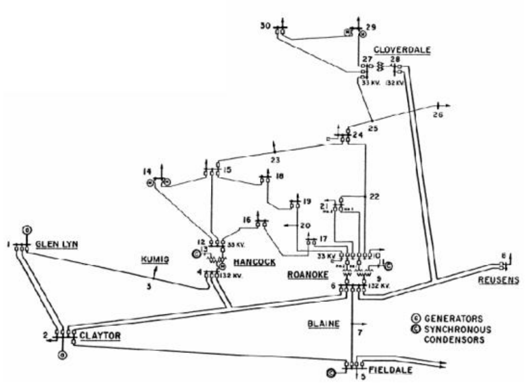

Fig. 5: Single linear map of standard 30-bus power system

The simulation results of the circuit in normal mode are as follows:

Table3. Output circuit in normal mode

Power(KVA)	Current(A)	Voltage(KV)	Number bus
5780.3	43.88	131.7	1
23735.7	180.4	131.5	2
2438.3	18.5	131.8	3
4191.2	31.8	131.8	4
31689.2	240.8	131.6	5
4627	35	132.2	6
9945.2	75.4	131.9	7
21865.8	165.4	132.2	8
3455.6	106	32.6	10
8489	261.2	32.5	11
7703.55	238.3	32.3	12
8288.22	258.2	32.1	13
3610	110.4	32.7	14
4464	136.1	32.8	15
18759	577.2	32.5	16
5077	156.7	32.4	17

1826.9	55.7	32.8	18
3437.4	104.8	32.8	19
1148.2	34.9	32.9	20
9609.8	296.6	32.4	21
9817.5	297.5	33	22
1976.7	61.2	32.3	23
4912.8	150.7	32.6	24
5711.5	175.2	32.6	25
1184.9	36.8	32.2	26
6848.6	208.8	32.8	27
14735.2	111.8	131.8	28
1363.5	41.7	32.7	29
4535.4	138.7	32.7	30

If the load is increased on the bus at any point of grid that has a voltage drop, the smart grid automatically connects to DG.

The following table shows the simulation results when the load buses of 30, 26, 20 and 8 are 1.5 times.

Table 4: Output circuit in the case of load buses of 30, 26, 20 and 8 is 1.5 times.

Power(KVA)	Current(A)	Voltage(KV)	Number bus
5525.5	42.7	128.8	1
22654.5	176.1	128.5	2
2314.8	18.01	128.6	3
3967.5	30.9	128.4	4
30088.5	234.6	128.2	5
4365.6	34	128.4	6
9417.2	73.4	128.3	7
25501.6	199.7	122.3	8
3254.8	103	31.6	10
8131.2	255.7	31.8	11
7320.6	232.4	31.5	12
7978.9	253.2	31.5	13
3415.3	107.4	31.8	14
4207.1	132.3	31.8	15
17759.2	562	31.6	16
4812.6	152.1	31.6	17
1723.5	54.2	31.8	18
3247.4	101.7	31.9	19
1084.8	33.9	32	20
9036.9	287.8	31.4	21
9232	288.4	32	22
1859.2	59.4	31.3	23
4904.5	155.7	31.5	24
5329.8	169.2	31.5	25
1370.2	44.2	28.2	26
6370.5	201.4	31.6	27
13748.4	108	127.3	28

1581.3	50.2	27.3	29
5237.5	166.8	27.3	30

The following table shows the simulation result after adding dg to bus that has the lowest voltage.

Table5: Results after adding of DG

Power(KVA)	Current(A)	Voltage(KV)	Number bus
5843.2	44.12	132.5	1
24012.4	181.41	132.3	2
2464.5	18.6	132.5	3
4226.7	31.8	132.5	4
32029.8	242.1	132.3	5
4674.5	35.2	132.8	6
10043.5	75.7	132.3	7
27406.8	207	132.4	8
3482.5	106.5	32.7	10
8590.2	262.7	32.7	11
7793.5	239.8	32.5	12
8388.3	259.7	32.3	13
3651.9	111	32.9	14
4500.7	136.8	32.9	15
18917.7	580.2	32.6	16
5150.2	157.5	32.7	17
1842.4	56	32.9	18
3474.9	105.3	33	19
1161.8	35.1	33.1	20
9685	298	32.5	21
9890.2	298.7	33.1	22
1992.6	61.5	32.4	23
4937.7	151.12	32.7	24
5735.5	175.4	32.7	25
1470.1	45.7	32.2	26
6840.8	209.2	32.7	27
13196.7	99.9	132.1	28
1703.6	52.1	32.8	29
5643	173.1	32.4	30

The table below shows the results of reducing load to 0.75 pu for those buses:

Table6: Orbit results after reducing load to 0.65 pu

Power(KVA)	Current(A)	Voltage(KV)	Number bus
6030	44.8	134.6	1
24847.1	184.042	134.6	2
2551.5	18.81	135	3

4404.2	32.6	135.1	4
33293.3	246.8	134.9	5
4892.4	36.01	135.9	6
10479.9	77.4	135.4	7
17512.1	128.2	138.3	8
3651.5	109	33.5	10
8851.1	266.6	33.2	11
8089.6	244.4	33.1	12
8600.1	263	32.7	13
3810.2	113.4	33.6	14
4714.6	139.9	33.7	15
19720.2	592.2	33.3	16
5377.4	161	33.4	17
1920.9	57	33.7	18
3640.2	107.7	33.8	19
1217	35.9	33.9	20
10169.8	305.4	33.3	21
10417.6	306.4	34	22
2094.9	63.1	33.2	23
5247	155.7	33.7	24
6103	181.1	33.7	25
955.2	28.6	34.6	26
1098.3	32.4	33.9	27
15731.1	115.5	136.2	28
1098.3	32.4	35.2	29
3657.8	107.9	35.1	30

The following table shows the simulation result after reducing production to compensate the impacts load reduction:

Table 7: results after reducing production

Power(KVA)	Current(A)	Voltage(KV)	Number bus
5816.8	44	132.2	1
23905.2	181.1	132	2
2460.7	18.5	132.3	3
4220.3	31.9	132.3	4
31928.5	241.7	132.1	5
4654.2	35.1	132.6	6
10022.6	75.7	132.4	7
17238.8	130.4	132.3	8
3479.2	106.4	32.7	10
8547.7	262.2	32.6	11
7758.5	239.46	32.4	12
8339.8	259.1	32.2	13
3648.6	110.9	32.9	14
4500.7	136.8	32.9	15
18833.7	579.5	32.5	16
5124.7	157.2	32.6	17

1842.4	56	32.9	18
3471.6	105.2	33	19
1161.8	35.1	33.1	20
9678.5	297.8	32.5	21
9886.9	298.7	33.1	22
1992.6	61.5	32.4	23
4969.2	151.5	32.8	24
5779.3	176.2	32.8	25
903.5	27.8	32.3	26
6892.5	209.5	32.9	27
17159.7	129.9	132.1	28
1033	31.4	32.8	29
3444.6	104.7	32.8	30

As shown in simulation, if the load increases in DG on the part of grid, it will have the greatest impact. In addition, the normalization of power and voltage due to the proximity of production place to consumer will have the lowest dissipation. However, the management of D6 resources or reduction in the event of losses smart grid will properly conduct. Thus, one of the most important conditions for using DG resources is to be intelligent production and transmission grid.

6. Conclusion

The smart grid technologies remove the failure of other grids to provide particle information and new management abilities. Indeed, the smart grid increases performance and efficiency of existing electric grid by integrating three key technologies including bidirectional communication infrastructure technology, informational technology, and electric power generation. It causes remote access, grid implantation control, dynamic monitoring of consumption, and also the potential use of automated scheduling. It helps to improve the load cure of the grid with implementing DR programs which will decease and smooth the load peak curve.

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