GECOL

Demand Side Management in Libya – A Case Study of the General Electric Company of Libya

Transmission System Operation and Control Department

Khalil El-Arroudi, Mohamed Moktar, Belkasem El-Obadi, Salah Sanoga and Saleh Osman

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Abstract

Demand-Side Management (DSM) is a set of cooperative activities between the utility and its customers either directly or through the assistance of third-parties such as energy services companies to implement options for increasing the efficiency of energy utilization, with resulting benefits to the customer, utility, and society. Several electrical utilities around the globe benefited through DSM initiatives and there are several case studies of utility-sponsored DSM.

Many benefits can be acquired by application of the DSM technology. Recently, the General Electric Company of Libya (**GECOL**) has recognized the importance, benefits and the key role of the DSM in the electricity sector. Among the benefits that are of great interest to GECOL are: improving the reliability and quality of power supply, increasing spinning reserve, lowering the cost of delivered energy, enhancing load factor, optimizing economic dispatching, reducing investments in generation sectors, increasing the energy efficiency, contributing to the economic development, and minimizing adverse environmental impacts.

This paper presents a case study of DSM applications in **GECOL** and the experience attained on this subject. The case study covers three different applications, namely: a) reshaping the system load-curve by shifting substantial industrial loads; and therefore, improving system reliability through decrease in demand, b) reducing the system technical losses by adopting a comprehensive methodology for optimizing the network operational topology, and c) increasing the energy efficiency by installing cogeneration units using combined-cycle technology. Furthermore, the paper introduces some of the foreseen DSM projects in GECOL such as street lighting load-shifting, remote controlled load-shedding, power factor correction in distribution systems, and customer education programs.

Introduction

The total generated energy in GECOL is approximately 29 TWh in 2008, compared to 15 TWh in 2000. This represent an average annual growth of 7% - 13% as shown in figure (1). The annual peak load is 5015MW in 2009 compared to 2630 MW in 2000 which represents an average annual growth from (8-10) %. Figure (2) shows the annual peak load trends (1985-2009).

The electrical energy production by type of generation in 2008 was 50% for steam units, 30% for the gas units and 20% for the combined cycle, as shown in figures (3) and (4). The per capita consumption was 4, 16 kWh in 2007 compared to 2, 65 KWh in 2000 as show in Table (1). The sector distribution of electrical energy consumption in 2008 was about 12 % for the commercial sector and 27% for the residential sector 20% for the industrial and 13% for the agriculture, Figure (5) shows these classifications.

Calculations of losses in power systems have been attempted since long. Earlier efforts concentrated on energy loss estimation on a yearly basis and power loss estimations for maximum load situations. The estimated losses were important data when calculating the energy losses and planning grids. After the global deregulation of electricity markets, the situation has completely changed. Knowledge of the magnitude of losses with high accuracy is crucial for fair competition in deregulated markets. Today the energy market is divided into several segments; grid owners, energy suppliers and independent system operator. All of them, as well as the consumers expect the grid owners to report and handle losses with highest accuracy. To be able to calculate losses with high accuracy, high quality data on power input and output is required.

The daily data is prepared about fuel consumption and energy production from different generating units, specially combined cycle units, which represents about 20% of total energy produced in Libyan network, that to increase the energy efficiency and improving global environment by reducing CO_2 emissions.

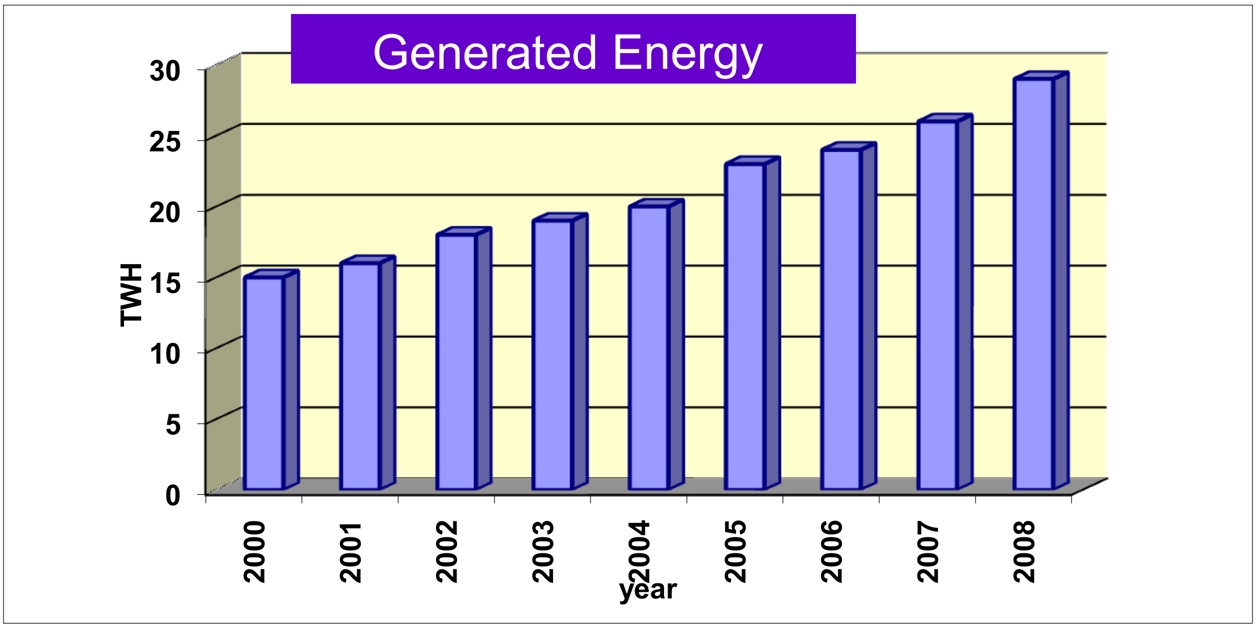

Fig (1) Generated Energy 2000 - 2008

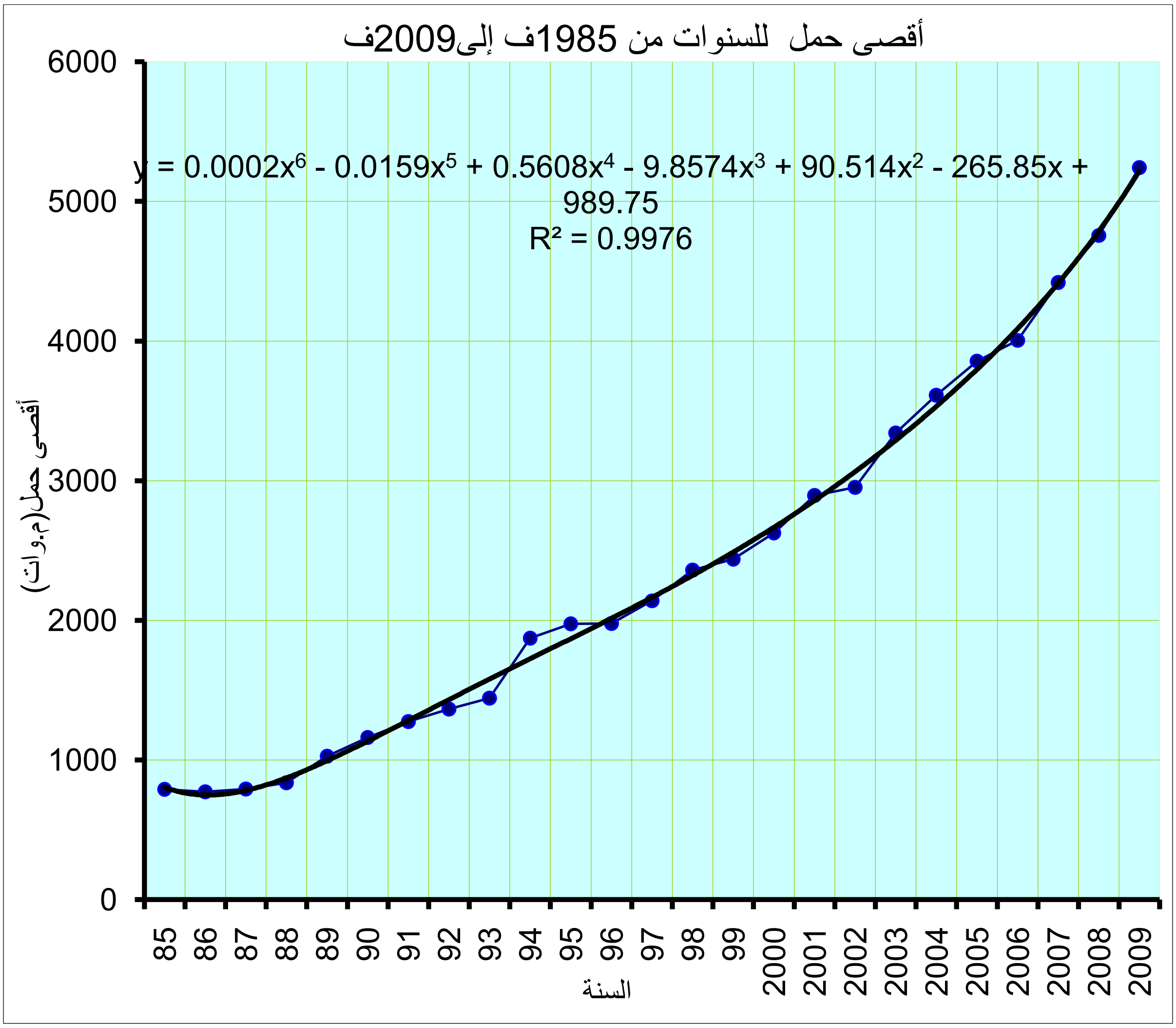

Fig (2) Peak load Trends between years 1985 – 2009. The fitting equation is given as shown

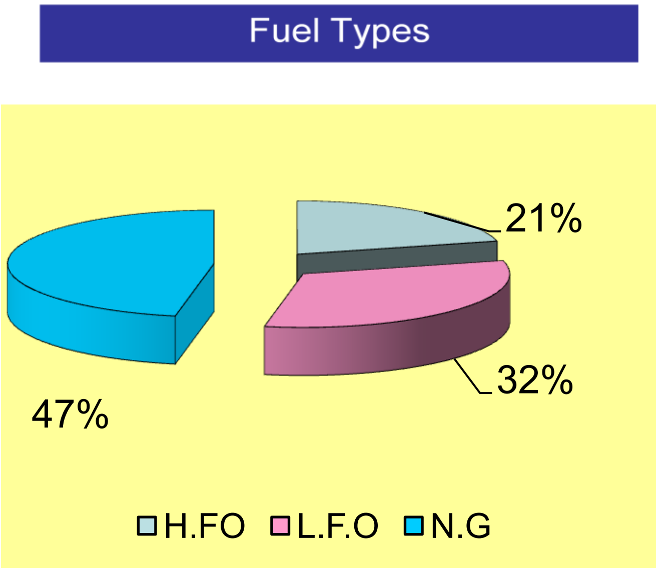

Fig. (3) . Fuel Types

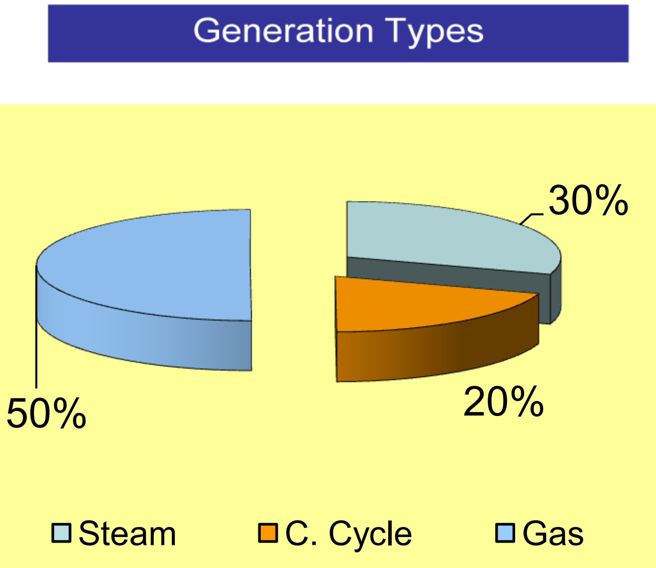

Fig. (4) Generation Types

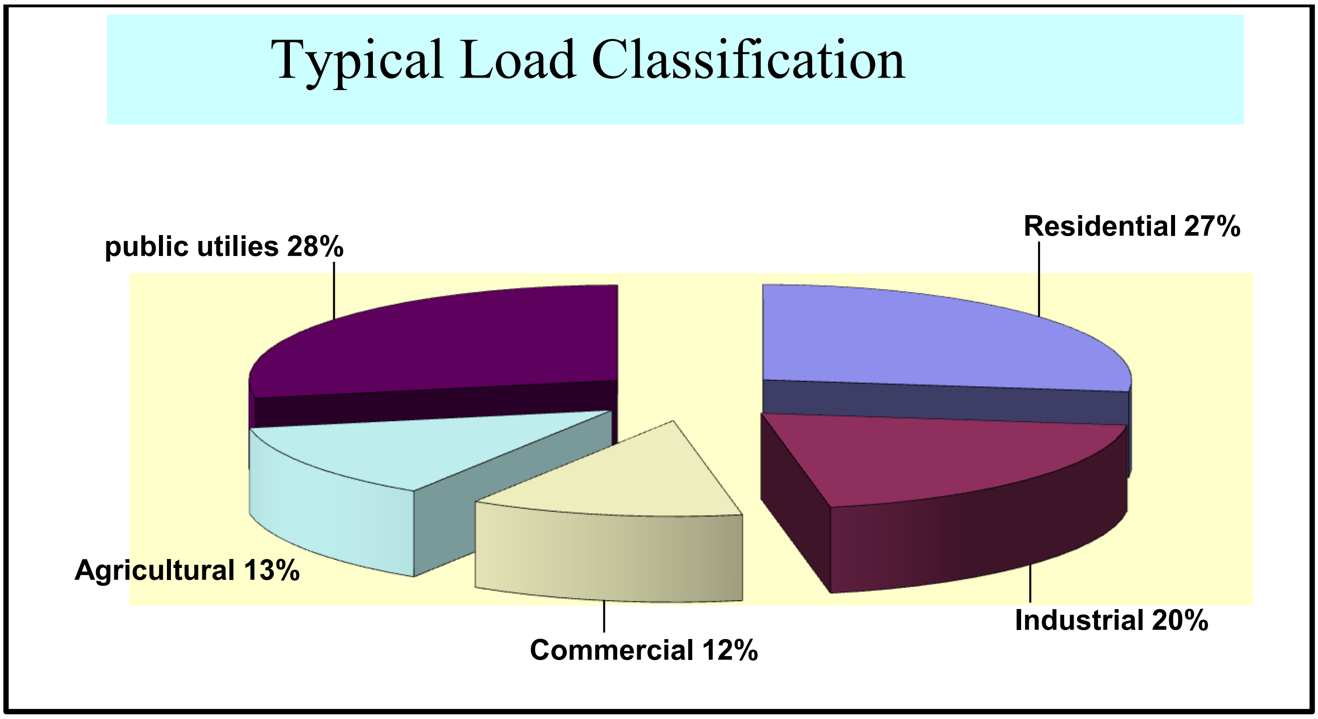

Fig.(5) Typical Load classification

Table 1: Per Capita Consumption

Year	Per-Capita Consumption (KWh)
2000	**2650**
2001	**2664**
2002	**2809**
2003	**2953**
2004	**3039**
2005	**3256**
2006	**3939**
2007	**4158**

This paper presents a case study of DSM applications in **GECOL** and the experience attained on this subject. The case study covers three different applications, namely: a) reshaping the system load-curve by shifting substantial industrial loads; and therefore, improving system reliability through decrease in demand, b) reducing the system technical losses by adopting a comprehensive methodology for optimizing the network operational topology, and c) increasing the energy efficiency by installing cogeneration units using combined-cycle technology. Furthermore, the paper introduces some of the foreseen DSM projects in GECOL such as street lighting load-shifting, remote controlled load-shedding, power factor correction in distribution systems, and customer education programs. The following section covers the abovementioned applications.

Section A: Reshaping Daily Load Curve

A-1 Daily load curve Characteristics for Libya network

A typical daily load curve of the Libyan network is shown in Figure (6). The 2009 winter peak was 5015MW as given in Figure (7). The full day is divided into two periods; first period extends from midnight to midday and second period after midday to midnight. Tthe analysis of these two periods is as follows:

- Peak load (P1) and minimum load (M1) in first period.
- Peak load (P2) and minimum load (M2) in the second period.
- (P1) is effected by industrial and commercial load.
- (P2) is often effected by time of sunset, where street lighting loads and residential loads start dramatically along with the rest loads.

It is clear from the load curves that the differences between the peak load (P2) and the minimum load (M1) is expressed in load factor (LF) which usually average somewhere between (60-63)% and almost constant in the day-to-day load curves. However in the holidays of Eid al-Fitr, Eid Al-Adha and the Ramadan the value of LF is different. On the other hand Figures (8, 9, 10, 11, and 12) show the general shape of the daily load curve of 2008 (summer, winter, spring, Ramadan, and Eid al-fater,), respectively.

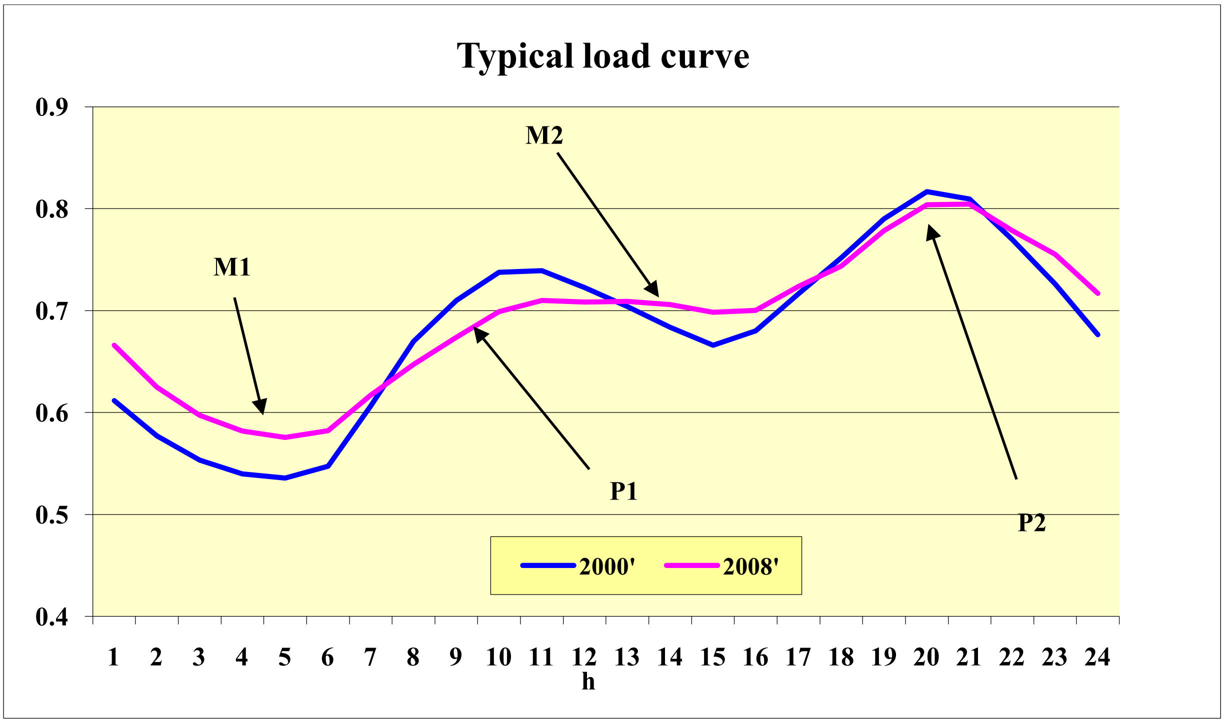

Fig (6) Typical normalized Daily Load curves for years 2000 & 2008. The normalization factor is the peak load within the respective year.

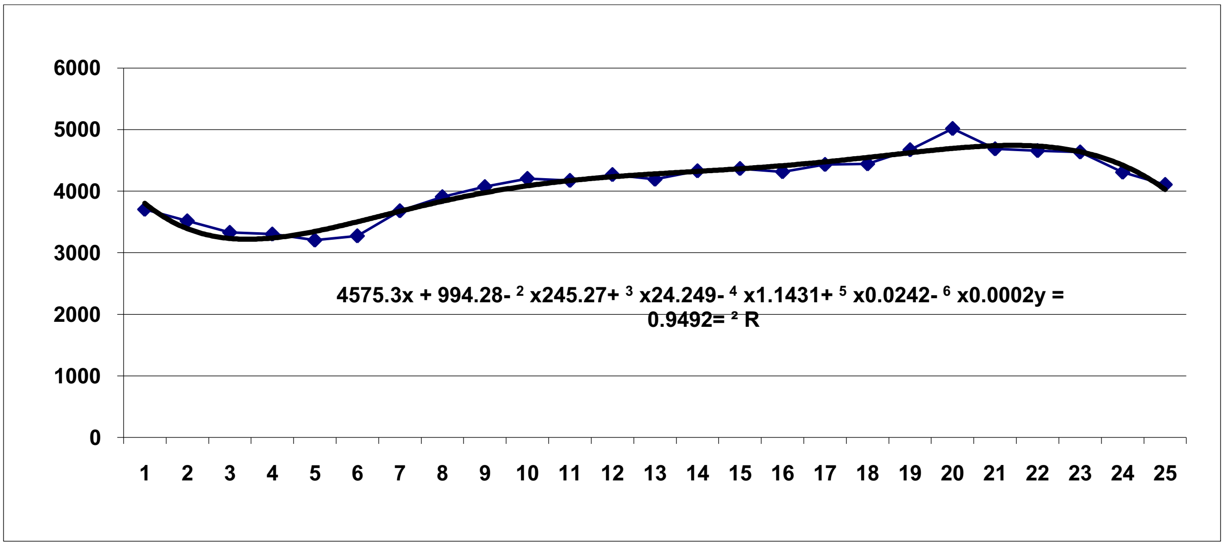

Fig (7) Regression to equation of the daily load curve of winter peak 2009

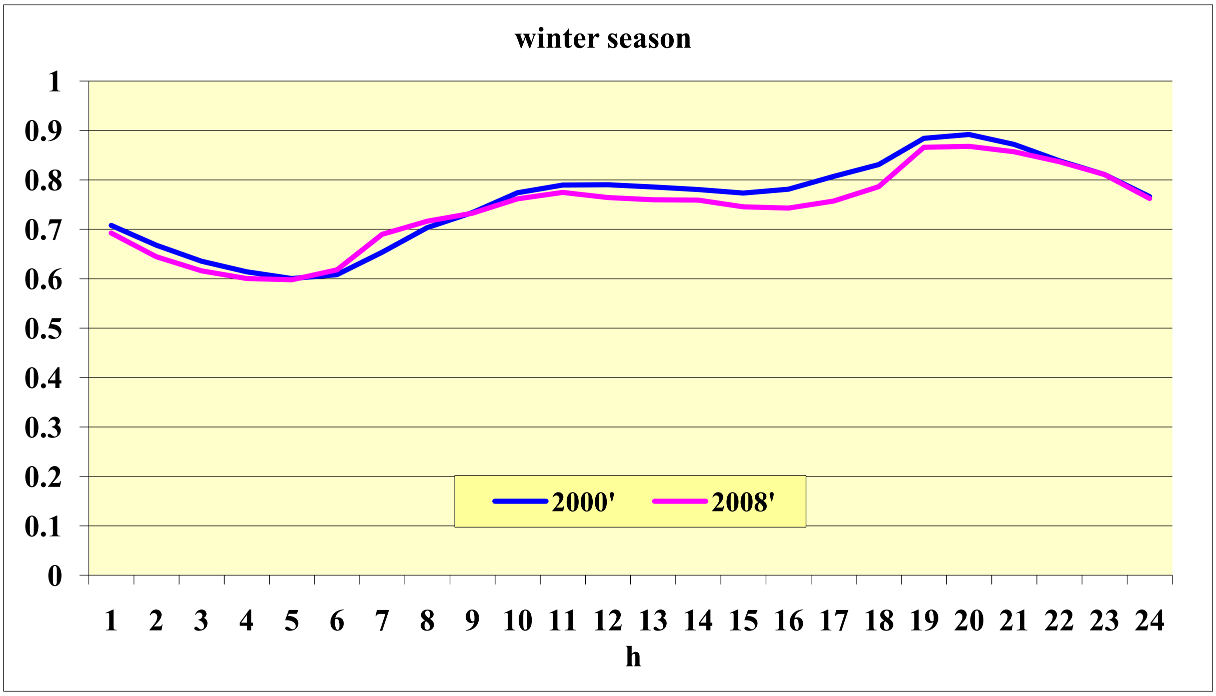

Fig (8) Normalized load curves for the winter Peak of years 2000 & 2008

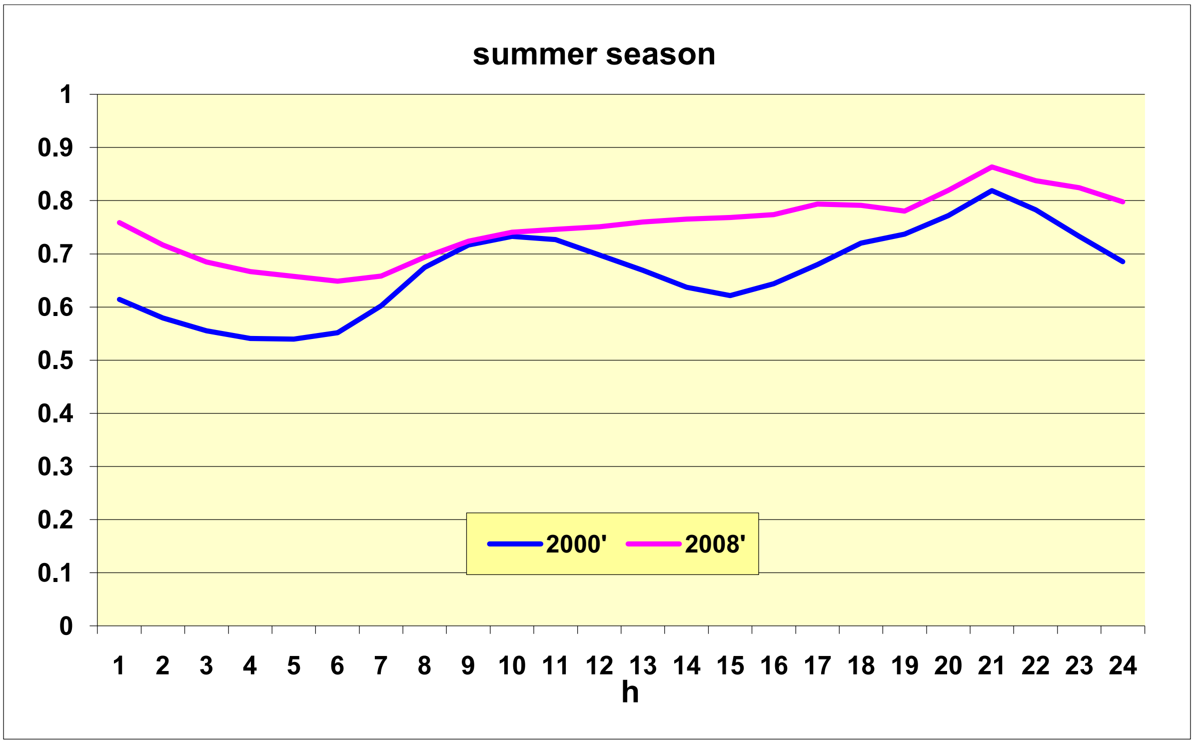

Fig (9) Normalized load curves for the summer Peak of years 2000 & 2008

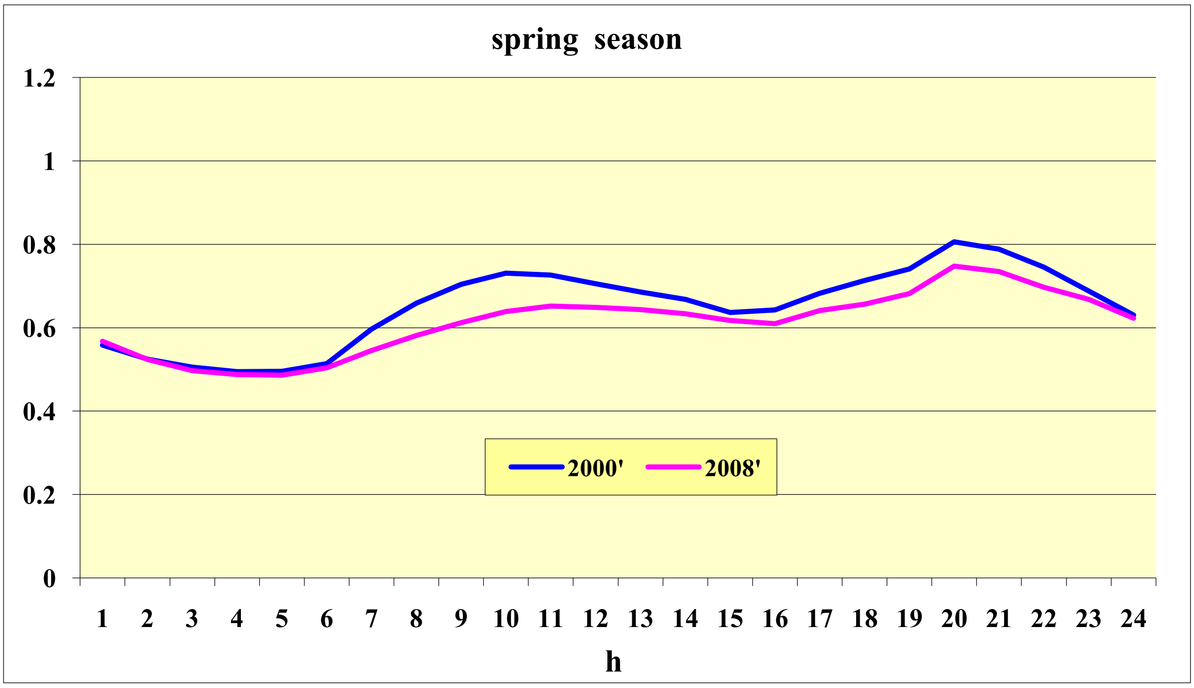

Fig (10) Normalized load curves for the spring Peak of years 2000 & 2008

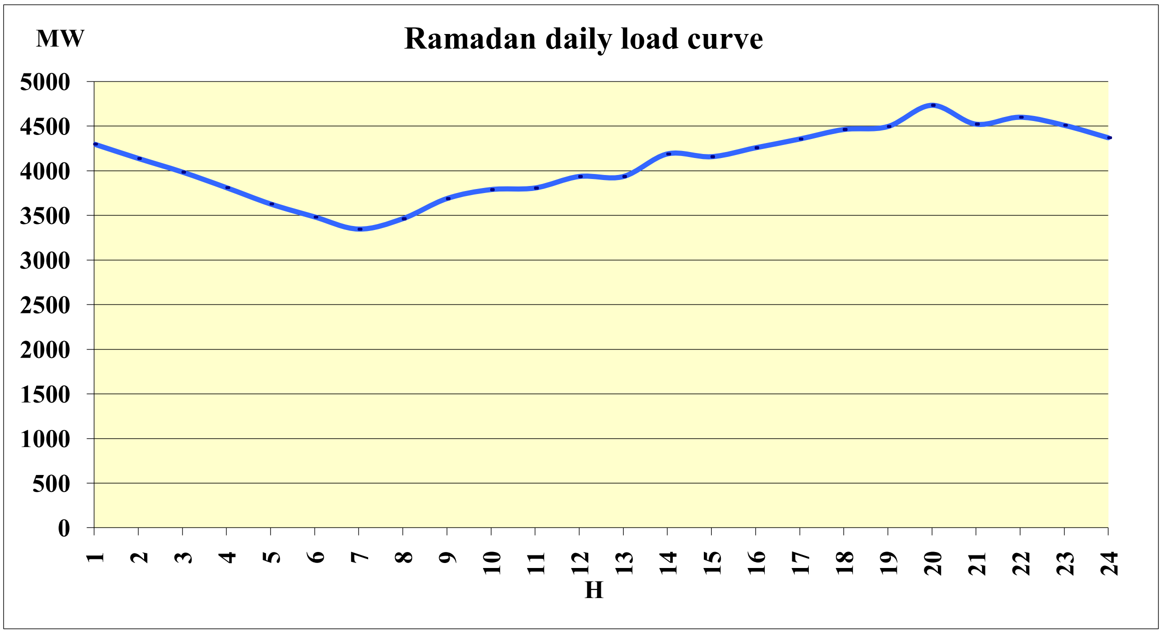

Fig (11) Ramadan 2008 peak day Load Curve

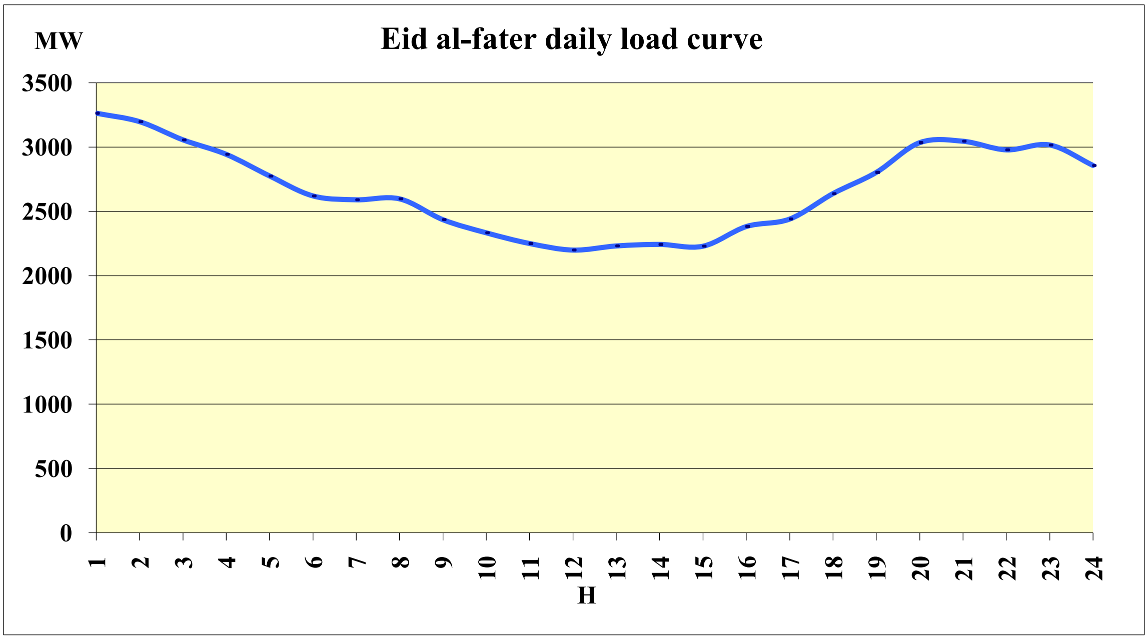

Fig (12) Eid al-fater for year 2008 daily load curve

A-2 Load curve improvement method

This method depends on the analysis of load sectors, namely; the agricultural, industrial, residential and public services. The load rate is 13% agricultural, 27% residential, 28% public utilities and 20% industrial. This method will focus on removing a part of the load from the evening (maximum) Load and re-distributing it at the minimum load in order to get convergence between the minimum and maximum either by direct action (remote control to open and lock the circuit breakers feeding the loads), or indirect action by encouragement method such as dual tariff.

Since the load of (iron and steel factory) plays a key role of increasing the evening load with (6 - 7%)of the overall load, so by focus on the removal of a large part of its load and compensating it in other periods . Figure (13) shows a typical load curve of iron factory.

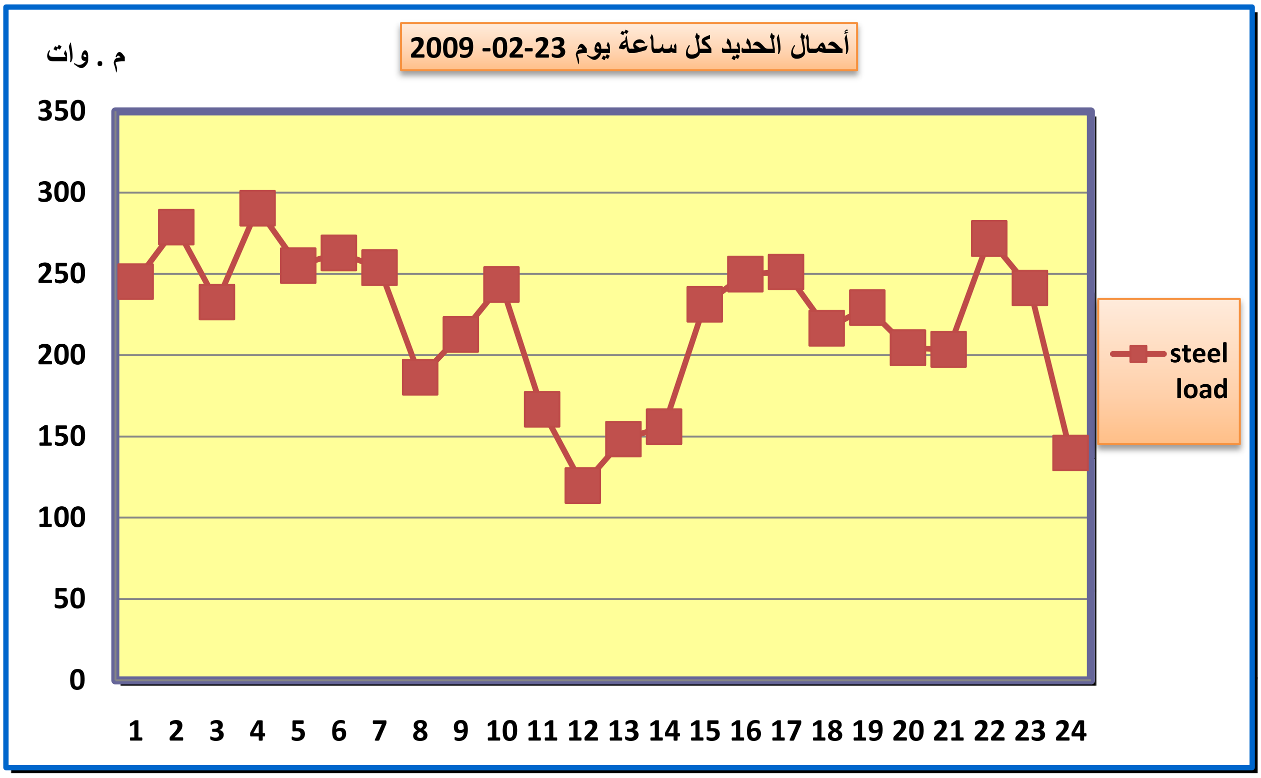

Fig (13) Typical load curve of iron factory

Table (2-A) shows the percentage value of each load sector and the exact value to be added to minimum load region or extracted from peak load region.

The average load is determined between minimum value 3203 MW and peak value 5015 MW, the average load is therefore 4109 MW.

The minimum load period starts from 1 O'clock to 7 O'clock where the difference between each hourly load and average value could be distributed between the load sectors as follows; 40% agriculture, 40% residential, and 20% street lighting and general services .

In the same way , the same amount of power could be rejected from peak load period , which starting from 19 O'clock to 24 O'clock, but with some difference in load distribution between sectors as follows; 20% residential, 30% agriculture, 30% industrial, 10% commercial, and 10% street lighting and general services.

Table (2-B) shows the hourly minimum loads, the percentage of each sector and the added value with its percentage, where the new percentage share value of all sectors. On the other hand, Table (2–C) shows load distribution at peak load period of the percentage value of each sector, the value to be rejected and the new sector percentage. It should be noted that the ΔP distributed on sectors is the difference between the minimum and maximum load as illustrated in the Tables (2-B) & (2-C). From these tables and figures, we note that the load factor is increased from 82% to 94%

Alternative methodology is to distribute the generation reserve instead of average demand methodology. Tables 3–A, B, and C show the results of methodology.

Table (2-A): 2009 Winter peak reshaping using Average Load methodology.

HOURS	GECOL LOAD IN MW (Pl)	ΔP=|PL-Pa|	Redistribution of ΔP: residential	agriculture	commercial	industrial	public utilities	Periods	sum
1	3703	406		162	162		81	minimum load period	4109
2	3515	594		238	238		119		4109
3	3328	781		312	312		156		4109
4	3301	808	0	323	323	0	162		4109
5	3203	906		362	362		181		4109
6	3272	837		335	335		167		4109
7	3679	430		172	172		86		4109
8	3907	none distributed period	None distributed period					none distributed period	3907
9	4071								4071
10	4204								4204
11	4172								4172
12	4267								4267
13	4191								4191
14	4328								4328
15	4365								4365
16	4313								4313
17	4431								4431
18	4441								4441
19	4670	561	157	62	107	67	168	peak load period	4109
19:30	5015	906	245	118	181	109	254		4109
20	4685	576	156	75	115	69	161		4109
21	4640	531	143	69	106	64	149		4109
22	4620	511	138	66	102	61	143		4109
23	4306	197	53	26	39	24	55		4109
24	4106	-3	-1	0	-1	0	-1		4109
aver	4109								4169
max	5015								4441
L.F	82%								94%
Pa	4109								

ΔP distributed on sectors is the difference between the minimum and maximum load as seen in the attendant Tables (2-B) & (2-C)

Table 2-B: Minimum Load period of Table 2-A

*Load sector	Load sector %	1 o'clock load	** Load gain 406(M.W)		New 1 o'clock load	
		3703	Target %	Target value	New load value(M.W)	New load %
residential	27%	1000	0	0	1000	24%
agriculture	13%	481	40%	162	644	16%
industrial	20%	741	40%	162	903	22%
commercial	12%	444	0	0	444	11%
public utilities	28%	1037	20%	81	1118	27%
	100%	3703	100%	406	4109	100%

PL 3703
Pa 4109

Table 2-C: Peak Load period of Table 2-A

*Load sector	Load sector %	19 o'clock load	** Load gain 561(M.W)		New 19 o'clock load	
		4670	Target %	Target value	New load value(M.W)	New load %
residential	27%	1260.9	20%	112	1149	28%
agriculture	13%	607.1	30%	168	439	11%
industrial	20%	934	30%	168	766	19%
commercial	12%	560.4	10%	56	504	12%
public utilities	28%	1307.6	10%	56	1252	30%
	100%	4670	100%	561	4109	100%

PL 4670
Pa 4109
* Load sector % = Load sector / hourly load(PL)
** this percent is taken by experience and the general method of daily load curve reshape

Table(3-A): 2009 Winter peak reshaping using generation reserve.

HOURS	GECOL LOAD IN MW (Pl)	ΔP=|PL-Pa|	Redistribution of ΔP: residential	agriculture	commercial	industrial	public utilities	Period	sum
1	3703	982	0	393	393	0	196	minimum load period	4685
2	3515	1170		468	468		234		4685
3	3328	1357		543	543		271		4685
4	3301	1384		554	554		277		4685
5	3203	1482		593	593		296		4685
6	3272	1413		565	565		283		4685
7	3679	1006		402	402		201		4685
8	3907	none distributed period	Non distributed period					none distributed period	3907
9	4071								4071
10	4204								4204
11	4172								4172
12	4267								4267
13	4191								4191
14	4328								4328
15	4365								4365
16	4313								4313
17	4431								4431
18	4441								4441
19	4670								4670
19:30	5015	330	89	43	66	40	92	peak load period	4685
20	4685	0	0	0	0	0	0		4685
21	4640	-45	-12	-6	-9	-5	-13		4685
22	4620	-65	-18	-8	-13	-8	-18		4685
23	4306	-379	-102	-49	-76	-45	-106		4685
24	4106	-579	-156	-75	-116	-69	-162		4685
aver	4109								4491
max	5015								4685
L.F	82%								96%
Pa	4109								

ΔP distributed on sectors is the difference between the minimum and maximum load as seen in the attendant Tables (3-B) & (3-C)

Table 3-B: Minimum Load period of Table 3-A

Load sector	*Load sector %	1 o'clock load	** Load gain 406(M.W)		New 1 o'clock load	
		3703	Target %	Target value	New load value(M.W)	New load %
residential	27%	1000	0	0	1000	21%
agriculture	13%	481	40%	393	874	19%
industrial	20%	741	40%	393	1133	24%
commercial	12%	444	0	0	444	9%
public utilities	28%	1037	20%	196	1233	26%
	100%	3703	100%	982	4685	100%

PL 4670
Pm 4685

Table 3-C: Peak Load period of Table 3-A

Load sector	*Load sector %	19:30 o'clock load	** Load gain 561(M.W)		New 19:30 o'clock load	
		4670	Target %	Target value	New load value(M.W)	New load %
residential	27%	1260.9	20%	66	1195	26%
agriculture	13%	607.1	30%	99	508	11%
industrial	20%	934	30%	99	835	18%
commercial	12%	560.4	10%	33	527	11%
public utilities	28%	1307.6	10%	33	1275	27%
	100%	4670	100%	330	4340	93%

PL 4670
Pm 4685
* Load sector % = Load sector / hourly load(PL)
** this percent is taken by experience and the general method of daily load curve reshape

Section B: Technical Losses Reduction

B-1 Characteristics of Losses

To make it easier to investigate losses it is helpful to divide different types of losses into different categories. It is common to use two categories, technical losses and non-technical losses. Technical losses are losses that occur in electrical equipment, especially cables, overhead lines and power transformers. The other category, the non-technical losses, consists of losses not related to the physical power system but rather to loss sources like electricity thefts and errors in billing and meter reading. To find errors in networks and also to be able to reduce losses it is important for grid owners to know how much of the losses that are technical and how much that are non-technical.

B-2 Technical Losses

There are different ways to classify technical losses. One possible classification is to use the categories load losses and no-load losses. This classification method is particularly useful when studying the dependence of losses on power flow. Current flowing through cables and other pieces of electrical equipment causes load losses. No-load losses are losses that are independent of the actual load situation. Sources of no-load losses are the iron cores of transformers and corona discharges. There are also resistive losses in the primary winding of transformers contributing to the no-load losses. These resistive losses are so small that they can be neglected. Another source of no-load losses is energy meters. These losses are mainly iron losses in the voltage coils.

Another way to categories technical losses is to divide the losses into resistive losses, leakage losses and corona losses depending on the origin of the losses. The resistive losses, or copper losses, are losses due to the finite conductivity of the conductors in cables, lines, transformers and other pieces of equipment. Conductors can be modeled as impedances. Higher impedance corresponds to lower conductivity, which in a conductor results in higher losses. The leakage losses are losses due to the finite resistance of the insulation materials. For example no cable insulation is ideal; they always have a certain conductivity resulting in a small current flow through the insulator. Also dust and pollution on string insulators supporting overhead lines cause leakage currents and thereby leakage losses. At really high voltage levels corona losses also occur. Corona losses are caused by partial discharges in the air surrounding overhead lines.

B - 3 Loss Determination Methods

Loss determination seems first quite simple; losses are the energy input to the grid minus the energy delivered to consumers. However, in practice it is not that easy. If high accuracy is wanted a lot of high quality data is necessary. Often sufficient data for a detailed analysis is not available. This problem can partly be overcome by the use of models and computer simulations. Sensitivity analysis can be used to study the influence of different parameters.

Like methods in many other branches of network loss determination methods can be divided into top down (system perspective) and bottom up (component perspective) approaches. Characteristic for top down methods are quick estimates that are not very exact. Bottom up methods are more detailed and thereby more exact solutions are obtained. These more detailed methods require more data and are also more time consuming than the top down methods. There are also different kinds of methods that could be classified as hybrids of top down and bottom up methods. These methods yield more accurate solutions than the top down methods and are less time consuming than the bottom up methods.

B – 4 Basic Losses Equation

$$E_{Loss} = 3 \times I^2 m \quad \times R \times L \times H \times T \times 10^{-3} \quad (kWh)$$

Where,

E_{Loss} : Line conductor's electric energy loss(kWh)

I m : Maximum line current(A)

R: Conductor resistance per phase(/km)

L: Line length(km)

H: Loss factor

T: Calculation period(8760h/yr)

B -5 Technical Losses Reduction

From an environmental and sustainable development perspective, the short and long-term detection and reduction of technical losses at first seems important. Additional energy needs to be produced and transferred to cover technical losses. During peak load non-renewable energy resources like gas and oil are often used and the energy prices at these occasions are high. Energy consumption increases continuously and if losses are successfully reduced, the length of life of the present networks is extended, since the loss reduction facilitates a certain consumption increase. By reducing losses, money can be saved and the impact on environment can be reduced.

Reduction of losses during peak load in power systems reduces both the cost of energy production and energy transportation. Improved knowledge on energy losses is a major objective for all operators involved. However it is often expensive and difficult to reduce technical losses. Replacement of old equipment is one way to reduce technical losses. Electrical power components are very expensive and built to last for a long time, often 30 years or more. They are too expensive to be replaced, if not necessary for other reasons e.g. damage. However when installing new transformers, cables and other pieces of equipment; losses should be taken into consideration.

Due to the long lifetime of power system components, a more expensive piece of equipment can be less costly when losses are taken into consideration than the unit that at first seemed to be the cheapest.

B-5 .1 General measures to reduce technical losses

1- **Flat voltage profile reduces the losses**. If the network is not simply radial but more grid structured circulating currents will appear if the voltage profile is not kept at a common level throughout the network. The circulating currents cause losses. To avoid this, the voltage is allowed to vary only a few percent from nominal value.
2- **Reactive power compensation**, i.e. keeping power factor close to unity, is a common way to minimize losses. By keeping the power factor close to unity, reactive power flow is reduced and thereby current flow and active power losses are reduced. At large inductive loads, for example large induction motors, capacitors are installed close to the load. In the case of long underground capacitive cables, shunt reactors can be needed to reduce the reactive power flow. By keeping the power factor close to one, not only currents through the lines are reduced but also the voltage drop over the line is reduced, resulting in a more flat voltage profile.

3- **Increasing the normal voltage level of the network** reduces the losses; because at higher voltage a lower current is needed to transfer the same amount of power,

4- **Phase balancing** is another way to reduce losses. Phase balancing means that all three phases carry the same amount of power. This is an issue especially for heavily loaded lines

B- 5.2 GECOL methodology for Losses Reduction

The practical procedures that are taken by GECOL towards losses reduction could be summarized as follows

- Reduce high voltage line lengths by energizing more 30 KV substations
- Increase conductor size (thickness)
- Improve phase unbalance
- Optimization of operating capacity
- Load factor effects $L.F = \frac{Average\ Load}{Peak\ Load} X100$
- Loss factor effects $Loss\ F = \frac{(average\ current\ )^2}{(Maximum\ current\ )^2}\ X\ 100$

- Optimization of transformer locations

- Power factor correction : GECOL installed some capacitor Banks in southern area as listed in Appendix

B-6 Summary of Energy Losses in Libyan GECOL grid

In the whole GECOL grid at all voltage levels 220\132\66\60\30\11\0.4 kV, the total figures of energy losses for year 2008 could be summarized in Table (4) as follows:

Table (4) Technical losses summary

Voltage level KV	Measured value %	Calculated value %	Notes
220\132	3.8	2.0167	Without Transformers
66\60\30	5.9	3.3564	With 220\30 transformers
11\0.4	7.5	5	7.5% as a sample 5% Kepco measured samples
Total	17.2	10.3734	

- Non- technical losses = 23.1 %

The difference between 17.2% as measured value, and 10.3734% as calculated value may related to the following factors:

- Meters settings errors in measured values
- Estimated value for 11/0.4 kV in measured values
- The value of peak load, where losses are calculated, 220/66/30 kV levels
- The samples accuracy and degree of right selection, for 11/0.4 kv , that taken from KEPCO are not so exact.

Section C: Combined Cycle Technology

Detailed daily data is prepared about fuel consumption and energy production from different generating units, specially combined cycle units, which represents about 41% of total energy produced in Libyan network.

15% of combined cycle units are steam based turbines, while 26% of them are gas based turbines , the total generated energy from combined cycle units is about 32 GWH/day , 12 GWH generated from steam based turbines , while 20 GWH generated from gas based turbines.

Case 1: With combined cycle technology

This generation production needs daily about 7000 m^3 of light fuel, with rate of 0.218 m^3 / MWH, which cost about 602,000 LYD.

On the other hand, it needs 5 million m^3 of gas, with rate of 156 m^3 / MWH which cost 100,000 LYD.

Case 2: Without combined cycle technology

Without using combined cycle units, the above figures will increases up, 10,500 m^3 of light fuel, which cost 900,000 and 7.5 million m^3 of gas which cost 150,000 LYD.

Cost Saving Using Light Fuel cost saving 300,000 LYD

Using Gas Fuel Cost saving 50,000 LYD

Efficiency: From Fig 13 we get 15% energy from C.C. steam every day. Without consuming fuel this can contribute to the Environment

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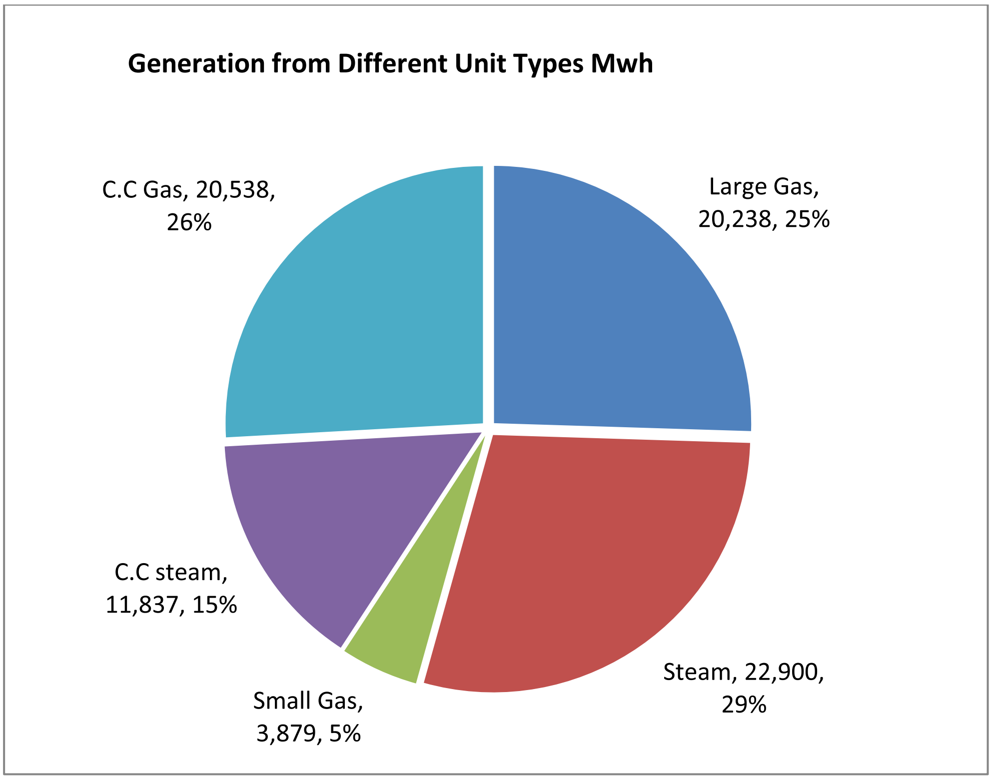

Fig (13) Generation from Different fuel types

CO2 Emission

The Environmental impact of different types of fuel is calculated based on reference [4]. Table (5) shows the value of CO2 emission for case 1. Table (6) shows the value of CO2 emission of case 2. Comparing the results of both cases, it is obvious that the use of combined cycle units would reduce the CO2 emission.

Table (5) CO2 Emission during 2008 without using combined cycle technology

Fuel type	MWH	Fuel m^3	Conversion factor	Kg CO2 /year
Gas	10541915	3323188774	0.185	1950180275
Light fuel	8851515	3363604	2.518	8469554872
Heavy fuel	5670738	1802846	2.674	4820810204

Table (6) CO_2 Emission during 2008 with combined cycle technology

Fuel type	MWH	Fuel m^3	Conversion factor	Kg CO_2 /year
Gas	10541915	1825000000	0.185	1078557500
Light fuel	8851515	2555000	2.518	7056654500
Combined Cycle	3601973	---	2.674	1947046505

Conclusions

This paper presented a case study of DSM applications in **GECOL** and the experience attained on this subject. The case study covers three different applications, namely: a) reshaping the system load-curve by shifting substantial industrial loads; and therefore, improving system reliability through decrease in demand, b) reducing the system technical losses by adopting a comprehensive methodology for optimizing the network operational topology, and c) increasing the energy efficiency by installing cogeneration units using combined-cycle technology.

The Demand side management plays vital role in daily operation of power grids; it has substantial impact in both economy and environment. Therefore, the DSM applications have to be taken as a prior issue for daily operating policy for GECOL in order to get real benefits for system operation.

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