ENERGY COST OPTIMIZATION THROUGH THE IMPLEMENTATION OF COGENERATION AND GRID INTERCONNECTION

Mohammad A. Dashash
Saudi Aramco – Saudi Arabia
Mohammad.dashash@aramco.com

Emad Ragaban
Saudi Aramco – Saudi Arabia
emad.ragaban@aramco.com

ABSTRACT

With increasing awareness of energy conservation and environmental protection, the Arab World is moving to further improve energy conversion efficiency. The equivalent of over 2.7 MM bbl is being daily burnt to fuel the thermal power plants that represent 92% of the total Arab power generation. This adds up to close to one billion barrels annually. At a conservative 40$ per barrel, this represents a daily cost of over $108 Million.

This paper will introduce two strategies with the ultimate objective to cut-off up to half of the current fuel consumption.

Firstly, Cogeneration Technology is able to improve thermal efficiency from the current average of less than 25% to up to 80%. Just 1% improvement in power plant thermal efficiency represents 4 million $/day in fuel cost savings. In addition, a well-designed and operated cogeneration plant will:

- Reduce unfriendly emissions by burning less fuel as a result of higher thermal efficiency
- Increase the decentralization of electrical generation

I. INTRODUCTION

With the recent substantial increases of the fuel prices, finding strategies to lower the domestic oil consumption is becoming a first priority, not only for the net importers, but also for the oil exporter countries. This reality is also applicable for the Arab World where increasing awareness of energy conservation and environmental protection are being noticed, and pushing to further improve energy conversion efficiency.

In fact, on one side the region major oil producers have seen a greater interest to save energy and export the high valued surplus of hydrocarbon products. On the other side, importer countries are taking all means to reduce their dependence on liquid and gas fuels to generate electricity.

This paper is a contribution proposing two approaches to reach these goals and optimize the power generation within the Arab world.

It is proven now, that cogeneration technology is able to bring the thermal efficiency from the current average of less than 25% to more than 80%. Saudi Arabia experience of implementing cogeneration will be highlighted, both within its industrial hydrocarbon facilities and in the desalination plants.

The second approach consists of integrating the individual grids into a single and reliable power pool. The substantial time zone difference from Eastern to Western Arab World makes it easy to exchange power during peak and low demand periods. This will also help reducing the reserve capacity and save on corresponding capital investment, fuel, and O & M expenses.

II. COGENERATION: CONCEPT & MODES

Cogeneration is the sequential production of two or more forms of energy (i.e., electricity and heat, or electricity and water) from a common fuel source (i.e., natural gas or liquid fuel). Figure 1 illustrates a typical example of fuel savings expected from Cogeneration as compared to the separate generation of power and steam. To the left side of Figure 1, we have a traditional separate generation of steam and power with a typical assumption of 40% efficiency to generate electricity and 90% efficiency for a boiler supplying high pressure steam. On the right we have a cogeneration system that needs a fuel quantity referred to as 100% to generate a certain amount of power and heat. To get the same outputs from both systems, the separate generation system will need 29% more fuel than for cogeneration.

Modern Cogeneration systems can achieve thermal efficiencies of up to 82%, making them far superior to traditional simple cycle power generation, which achieve a maximum of 40% in thermal efficiency. As the cost of fuel rises, the economic benefits of Cogeneration increase. In parallel, the new environmental requirements will be easier to meet as a result of utilizing less fuel.

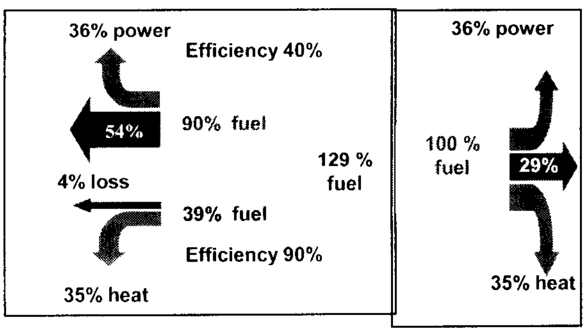
Cogeneration is used under different modes and technologies, depending on the target application. The main applications found today in the Arab World are the following:

First, the combined cycle power plants using gas and steam turbines and leading to 45-50% thermal efficiency;

Second, the desalination plants using either gas or steam turbines to supply electricity and heat to the Multi-Stage-Flash (MSF) desalination process and leading to 70-82% efficiency;

Finally, the oil and gas plants where gas turbines are matched with Heat Recovery Steam Generators (HRSG) leading to 70-80% thermal efficiency.

It is proven that petroleum industry is one of the most suitable industrial fields where cogeneration has a high potential of success. In fact, gas plants, refineries, and oil processing plants are all of them major power consumers, at the same time they need substantial quantities of high pressure steam.



(a) Separate Generation (b) Cogeneration

Fig 1: Typical example of fuel saving from Cogen

III. POWER GENERATION IN THE ARAB WORLD

In this paragraph, we will present an overview of power generation in the Arab World with some key statistics on the current load demand and forecast growth, as well as the impact on fuel consumption.

The total installed capacity is forecasted to increase form the current 121 GW to over 200 GW by year 2015 (Table 1). As shown in the power generation categories breakdown (Figure 2), 92% of this energy is obtained through thermal power plants burning fossil fuels [1]. For some countries, as for the Gulf region, this portion actually reaches 100%. Except for the few countries with some Hydro resources making less than 10% of the total capacity, all the others use technologies that burn fossil fuels to run their power plants. These plants have simple cycle thermal efficiencies as low as 13%, and even the new most efficient ones barely exceed 40%.

Table 1: Generation forecast and corresponding fuel cost in the Arab World

Year	Instal. Cap. (GW)	Peak Load (GW)	Res. Cap. (%)	Fuel (MMbbl per Day)	Fuel Cost (Million$ per day)
2004	121	98	23	2.7	81
2015	203	170	20	4.5	136

As per Table 1, the ratio between the installed capacity and the peak load reflects the reserve capacity used for planned and unplanned outages. Even with 20%, forecasted for 2015, this ratio is still relatively high, meaning that this portion of the resources is not used in an optimal way.
Assuming a conservative figure of $40 for one barrel of crude oil, $108 MM is the fuel cost currently supported to run these power plants. By 2015, these figures are expected to double. Considering not only the major economic impact, but also the emission effect on the environment, energy conservation has become a high priority issue in the Arab world.

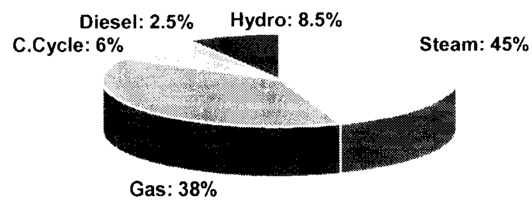


Fig 2: Repartition of power generation types in the Arab World

One way to contribute resolving this problem is through cogeneration new technology. By burning less fuel, cogeneration will not only help meeting the goals regarding energy conservation, but also substantially reduce the unfriendly emissions in the atmosphere. As for the high reserve capacity, the grid interconnection is the way to improve the situation.

ISSUE	*SOLUTION*
Low Efficiency	Cogeneration
High Reserve Capacity	Grid Interconnection

IV. CASE STUDY: SAUDI ARABIA COGENERATION IMPLEMENTATION

Saudi Arabia is a natural example where the need to implement cogeneration has imposed itself within the oil and gas industry, desalination plants and in combined cycle power plants.

The Kingdom of Saudi Arabia's total generation capacity is approximately 31 GW. Out of that, 7 GW representing 23%, is supplied through cogeneration. As shown on Figure 3, the Kingdom's peak demand is forecasted to grow from the current 28 GW, to reach 60 GW by year 2020, based on annual average increase of 5%.

	Capacity (MW)	Notes
Desalination Pants	3,425	6 SWCC Plants (12%)
Combined Cycle	3,000	Riyadh + Rabigh PPs
Saudi Aramco	155	Abqaiq Plant + RTR
Others Industries	910	Yanbu – Marafiq Desal.

Currently, power generation in Saudi Arabia uses 57% of gas fuel and 43% of liquid fuels that include Diesel, Crude Oil and Fuel Oil. The average thermal efficiency is higher than that of the Arab World but still around 34%. This is mainly due to that fact that many of the power plants are relatively recent and use new equipment with high performance technology.

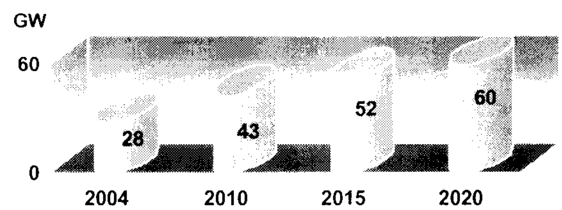


Fig 3 Power demand forecast in Saudi Arabia

Recent studies involving Saudi Arabia's overall capacity, including Saudi Electricity Company (SEC) power plants, desalination plants and other power generators, revealed that if the average thermal efficiency was 45% rather that the current 29%, the savings on fuel would be $1.38 Billion per year (Table 2). This amount jumps to $3 Billion by 2020. This is based on the conservative assumption of an average fuel cost of $1.34 per MM Btu. The Unit cost of fuel is the weighted average of the current fuel mix including natural gas, diesel, and Heavy Fuel Oil (HFO). To the Kingdom of Saudi Arabia, Diesel cost is considered to be relatively expensive with $2.75 per MMBtu. The study revealed that 45% overall power generation efficiency Kingdom-wide is achievable if all new plants are built for cogeneration, with either steam export to industrial parks or to water desalination facilities.

Table 2: Thermal efficiency impact on fuel cost

	2004		2020	
Thermal efficiency (%)	29	45	29	45
Power Generated (GW)	28	28	60	60
Unit Fuel Cost (composite; MBtu)	1.34	1.34	1.34	1.34
Annual Fuel Cost ($MM / Yr)	3,870	2,490	8,290	5,340
Fuel Savings ($MM / Yr)		1,380		2,950

Existing Facilities

The Saudi Arabia Kingdom's existing cogeneration facilities can be segregated as per Table 3 into the desalination plants supplying over 3400 MW. The Saudi Electricity Company with 2 power plants totals 3 GW and the remaining 1 GW is generated by other large industries, including Saudi Aramco Company. Saudi Aramco has an ambitious on-going plan to implement cogeneration within its hydrocarbon facilities that will be adding over 1,700 MW.

Table 3: Existing Facilities Cogeneration in K.S.A.

Future Plans

This section addresses future cogeneration plans where many projects are under construction or have been approved for short term implementation.

For Saudi Aramco, the current peak load is approximately 2.8 GW, and is expected to exceed 3.5 GW by 2010. Then, a steady 3% annual increase is anticipated, to reach about 5 GW by 2020. With this continuing load growth, cogeneration is expected to be part of all future plants and facilities. In fact, Saudi Aramco has conducted a comprehensive study on selected gas plants and refineries to reduce the energy cost that the company bares to run these facilities. The results proved that cogeneration can lead to annual savings of 54% to 60%. By end of 2006, on-going projects will deliver over 1,700 MW (Table 4).

Table 4: Cogeneration future plans in K.S.A.

	Capacity (MW)	Completion
Saudi Aramco	1,750	2004 / 2006
Desalination Pants	5,000	2010
Sadaf	250	2005
Marafiq-Jubail	2,400	2007

Regarding the desalination plants, Saudi Arabia will consolidate its world leading position by building 5,000 MW over the next five (5) years. Other large companies are getting involved into Cogen, like the SADAF (one of the companies under SABIC, Saudi Basic Industries Corporation), 250 MW project and Marafiq 2,400 MW planned for the Jubail industrial area.

V. ELECTRICAL NETWORKS INTERCONNECTION

The Arab world countries have a time zone difference of four (4) hours between the extreme west and east. This represents a major incentive to interconnect the power networks as the peak demands are not simultaneous in different countries. The power system interconnection has the following major benefits:

1. Avoid over building power generation facilities and thus reduce capital investment as well as reduce the overall fuel demand
2. Share of reserves among the systems
3. Improve system reliability
4. Reduce Operating and Maintenance costs
5. Improve efficiency
6. Reduce pollution and meet national and international standards
7. Help implement new emerging technologies

Table 5: Current and forecast reserve capacity

Year	1990	2004	2015 Forecast
Installed Capacity (GW)	74	121	203
Reserve Capacity (%)	33	23	20

The current reserve capacity of the Arab countries is close to 23% of the total installed capacity of 121GW (Table 5). Lowering this value from the expected 20% to the more acceptable value of 12% through grid interconnection, will not only save a capital cost of 11 billion dollars by not building an additional capacity of 12 GW, but will also have major impact on reducing fuel burning pollution.

An optimal grid interconnection can help reach this goal and eliminate the equivalent emission released from about 9 million cars.

Table 6: Distribution of power generation capacity in the Arab World

	Capacity (GW)	Capacity (%)
GCC Countries	59	49
Middle East	42	34
North Africa	20	17

Table 6 below shows the distribution of the Arab World generation capacity among three distinct groups: GCC, North Africa and the other Middle East countries. The GCC region has the highest generation capacity, which satisfies the area's oil and gas large industrial base. Together, Saudi Arabia and Egypt represent near 41% of the total capacity. Only for these two (2) countries, the avoidance of building 10% of their total installed capacity projected for year 2015 will save around $5 billion US in Capital Costs.

The grid interconnection is being achieved following the geographical distribution. Starting with the GCC interconnection including the six Gulf Countries. Then, the EIJLST interconnection including Egypt, Iraq, Jordan, Lebanon, Syria and Turkey. Finally, the North African Arab countries are already interconnected together, but there is still room to increase the power capacity that can be exchanged.

On the other hand, many preliminary studies are already seriously considering the eventual interconnection of the European Electrical grid through the Mediterranean Ring called MEDRING. It is very important to finalize and coordinate the overall Arab system within a reliable single power pool, and adopt the highest international standards, before integrating the European grid through Spain, Italy and Turkey.

VI. CONCLUSION

As a summary, we first introduced the Cogeneration concept leading to improved energy utilization by burning less fuel and reducing unfriendly emissions.

Then, we gave an overview of power generation statistics in the Arab World, underlining the fact that more that 92% of its generation is obtained by burning the equivalent of close to one billion barrels of crude oil annually with poor thermal efficiencies.

As an example to improve this situation, we presented a case study involving Saudi Arabia and its leading role into cogeneration implementation. We covered its existing facilities that already make 24% of its total generation, and shed some light on the future plans.

Finally, we introduced the power system interconnection between Arab countries as a must and basic contribution to reach the objectives regarding energy conservation and the tighter environmental regulation from national and international standards. A coordinated action can lower the reserve Capacity to 12%, and save 11 billion dollars on

Capital Cost, in addition to the fuel, Operating and Maintenance, and other expenses.

References

[1] M. Badawi, "Towards an Arab Power Market: Options and Challenges". May 2002. Report prepared by the Direction of Technical Division, Arab Fund for Economic and Social Development Kuwait.