Interconnection in the GCC Grid: The Economics of Change

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Abstract

The Gulf Cooperation Council (GCC) is nearing the completion of a high voltage transmission system designed to integrate the power systems of Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman. The objective of this paper is to review the underlying economics of electric supply within the GCC before interconnection, to evaluate the plans for further developments in generation by fuel type planned largely independent of the grid and finally to model and thereby provide an initial analysis of the market economics likely to exist once the countries are interconnected.

1. Introduction

The Gulf Cooperation Council (GCC) is nearing the completion of a high voltage transmission system designed to integrate the power systems of Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates and Oman. Stretching from Kuwait at the head of the Gulf to the northern most of the United Arab Emirates at the mouth of the Gulf and north to Oman with a DC link to the principal eastern population centers of Saudi Arabia, the GCC Grid will provide both economic benefits and significant economic challenges to the member countries. To this end the GCC countries have created the GCC Interconnection Authority (GCCIA) physically located in the Kingdom of Saudi Arabia.

The objective of this paper is to review the underlying economics of electric supply within the GCC before interconnection, to evaluate the plans for further developments in generation by fuel type planned largely independent of the grid and finally to model and thereby provide an initial analysis of the market economics likely to exist once the countries are interconnected.

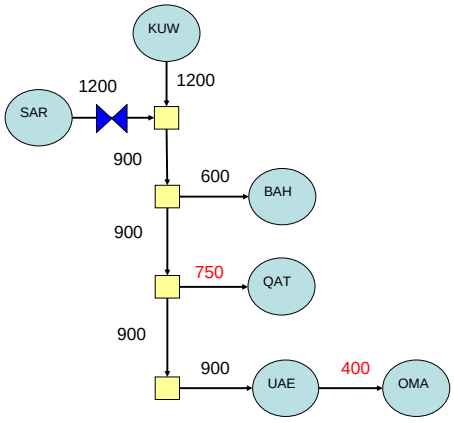
2. Background

The GCC grid will interconnect the six nations (see figure 1) with primarily a 400kV system. The physical transmission system will be predominantly on the land mass of Saudi Arabia connected to the high voltage system of the UAE and finally onto a link between the UAE and Oman. Bahrain and Qatar will be connected through spur lines from the backbone system while Saudi Arabia will be interconnected with a back to back High Voltage Direct Current (HVDC) spur. Oman is interconnected to the UAE at 220 KV. Saudi Arabia is the only of the Gulf countries with a 60Hz system while the other 5 have 50Hz.

Figure 1: The GCC Grid

Figure 2 provides as simplified 1 line diagram indicating the level of flows possible (when completed) of the individual elements of the GCC Grid.

Figure 2: One line diagram



The first phase of the system is scheduled for completion in late 2008 interconnecting Kuwait, Bahrain and Qatar. Interconnection to Saudi Arabia is the second step to follow shortly with the full system completed to the UAE and Oman by 2010. The stated goals of the investment are to:

- Reduce generating capacity in each system as a result of sharing generating reserves
- Share spinning reserves to cover emergency conditions
- Provide emergency support to any system during blackout conditions
- Lower operating costs by utilizing lowest cost by using the most economic generation unit in the interconnected system
- Provide opportunity to engage in regional and international energy trading

The six GCC countries currently have extremely rhigh growth rates in both energy consumed and in growth in capacity. At the high end, UAE shows a growth in installed capacity of nearly 15% per annum from 1997 to 2005 with a growth in consumption at 9.7%. Both Qatar and Oman show similar rapid patterns of growth in consumption. Only the Eastern Region of Saudi Arabia shows a slower growth rate but, as is clear, from a somewhat higher base.

Table 1: GCC Electrical Statistics

Country	Transfer capability from	Amount (MW)	to and from Grid	Amount (MW)	Installed Capacity 2005 GW	% Growth in Capacity 1997 - 2005	Consumption 2005 (Billion kWh)	% Growth in Consumption 1997-2005
Kuwait	Kuwait	1200	South	1200	9.4	3.7	36.3	6.3
Bahrain	Grid	600	Grid	300	2.3	8.3	9.2	7.4
Qatar	Grid	750	Grid	750	2.9	7.1	12.5	9.5
Saudi Arabia (Eastern Region)	Grid Grid	1800	Grid	1200	12.0	4.6	57.0	4.3
UAE	North UAE	900	Grid	900	16.6	14.8	52.6	9.7
Oman	North	400	UAE	400	3.3		13.3	9.6

With a total estimated capacity in the 6 GCC countries greater than 45,000 MW of capacity, the countries are poised to nearly double their installed capacity in the next 10 years.

Table 2 indicates the rough percentages of both fuel and of technology mix. As can be seen, the six countries have a significant difference in both their fuel and technology mix with Bahrain and Qatar being nearly entirely natural gas and simple cycle gas turbine. (80 and 70%) while Kuwait and Saudi Arabia have significant proportions of the fuel from heavy oil (also from crude) and burned utilizing steam turbines. All six have some level of lighter (distillate) in their fuel mix but Saudi Arabia reports nearly 40% overall in the country.

This spread in fuel and technology mix through the six countries has a significant impact on the marginal cost of generation in the six.

Table 2

GCC Country	$ Natural Gas	%FO2	%FO6	%Steam Turbine	%Gas Turbine	%Combined Cycle	Generation >10MW in Sample
Kuwait	35%	8%	57%	88%	12%		10,250
Saudi Arabia (East and Central)	39%	39%	22%	43%	49%	80%	13,650
Bahrain	87%	9%	4%	3%	80%	17%	3,750
Qatar	87%	3%	10%	10%	70%	20%	4,150
UAE	75%	19%	6%	15%	47%	38%	16,400
Oman	77%	23%		20%	98%		3,350

3. Structure and Impact of the GCC Grid

The advent of the GCC grid will provide a means of sharing of capacity for both normal operating reserves and emergency conditions and of developing a market structure to allow for economic interchange between the six countries. Even with the interchange the expectation is that there will bean estimated additional capacity of 20,000 MW by 2010.

Table 1 summarizes the transfer capability between countries, their installed capacity, and current demand levels as well as the calculated growth rate in both capacity and consumption from 1997 to 2005

As shown in table 2, all of the generating units of the six countries are fossil fueled. The majority of the generating units are either distillate or natural gas fired. These units can be divided, roughly into three categories. Those that are simple cycle, that is only the gas turbine; those that are combined cycle (gas and steam) and are greater than 10 years old and those that are combined cycle and less than 10 years old.

The significance of the division in age of unit is that even though many of these units are natural gas fired (or distillate fired) the efficiency with which they generate is dramatically different. As an example, older simple cycle gas turbines would have a heat rate as high as 15,000 BTUs per kWh. A highly efficient combined cycle (such as those being commissioned in Abu Dhabi) would have a heat rate more near 7,000 BTUs per kWh.

This difference in cost per MWh determines the loading order of generators when dispatched to supply load. The lesser costly generators are dispatched before the more costly. This dispatch based on short run marginal cost is the basis by which all utilities operate their systems subject, only, to the physical constraints associated with transmission, reliability or system stability.

The objective of interconnection such as is being provided by the GCC grid is to increase the

diversity both in the generating stock and in the timing of energy demand by the load. Stated simply, larger systems require proportionately lower percentages of reserve margin and are able to take advantage of any diversity in load that may be brought about by differences in the industrial or residential energy use patterns.

While the GCC shows only minor diversity in temperature related load there are differences in the current generating mix – more specifically in the efficiency of the units in the mix – that will allow for increases in overall economic efficiency that will be brought about through the creation of an electricity trading market that undoubtedly will develop with the completion of the Grid. Announcements by multiple of the GCC countries that they will be investing in Nuclear units will dramatically change the economics of the energy in the region not merely because there will now be lesser expensive electricity available, but because the units are large relative to the size of the individual utility systems and because they will come on line over time. This latter fact will lead to different flow patterns on the grid – and thereby different values to the energy flowing – as units are brought on line over time.

The economics of power flow in networks is now well understood (See Schweppe, Caramanis, Tabors & Bohn, *Spot Pricing of Electricity* Kluwer Academic 1988). The engineering economic arithmetic of transmission as developed by the MIT team in the 1980s and extended by the work of Professor William Hogan at Harvard is the underpinning of the electric markets throughout the United States, Australia, New Zealand, and Singapore. While the GCC Grid is far simpler than the complex interconnected grids of the US or even the far smaller grid of Singapore, the physical economic conditions of the transmission system are, along with relative fuels prices, the determining factor in the marginal value of delivered (or sold) at any point in the grid.

4. Economic and Regulatory Pressure

The physical interconnection of the six countries will create a complex set of economic or market pressures on each of the GCC countries as it becomes possible to both purchase and sell energy to any of the other five. As soon as it is possible for a national or semi-autonomous utility to sell electricity in a market, the trading decision becomes one of either regulatory control or opportunity cost. The utility will chose to sell (or buy) off-system as soon as the marginal value of the transaction exceeds the value of either producing only for local consumption or the cost of production exceeds the cost of purchase and transmission from another of the GCC countries.

The existence of the grid and its stated purpose – increased economic efficiency of operation, drives decisions on trading, consumption and pricing of electricity in the same manner as the forces of international oil markets have driven choices about the investment, development, use and pricing (internal and external) of fossil fuels within the GCC. The opportunity cost of burning natural gas to generate electricity and water is being traded off against the capital cost of nuclear generation whose marginal operating costs are extremely low, unit lifetimes extremely long, carbon environment costs zero, leaving the natural gas and other fossil products for higher and better economic use.

The pressure brought to bear on the national utilities takes one additional step with interconnection. When there is economic pressure for increasingly efficient operation of the wholesale structure as will occur with interconnection and trading between GCC members, the pressure for efficient pricing of electricity at the retail level increase as well. Today the majority of the utilities within the GCC have retail electric rates that are heavily subsidized either explicitly by the government – specifically with respect to members of the Royal families and locals – or implicitly through transfer prices for generating fuels that are well below international rates or both. This process of subsidization is coming under extreme pressures in all of the GCC countries as natural gas (with the exception of Qatar) becomes increasingly less available and increasingly valuable on the international market. Choosing to provide “cheap” electricity has encouraged highly inefficient commercial and residential construction – the heart of the real estate boom in the GCC – which in turn has caused demand growth to be, in reality, subsidized in part through the electric rates.

As trading begins in earnest, utilities and their supervising regulatory bodies or ministries will look increasingly critically at local tariffs whose rates encourage consumption of resources that have a far higher value on the international market than is realizable in local sales of electricity.

Tariff reform need not, and in all likelihood will not, mean that subsidy will be removed from Royal families or from locals, but rather that these subsidies will be evaluated and measured against the opportunity costs of international purchases and sales in the GCC market.

To see examples of the economic pressures that are exerted when one has even mediocre interconnection and establishes a market for electricity one need only look at the experience of the EC where these pressures have been significant, have led to major restructuring of the ownership and operation of the

utilities in the region and have, by all accounts, reduced the EC wide average cost of delivery of electricity to consumers.

5. A Simplified Model

The section that follows provides a simplified numeric model of the existing cost structure of the GCC countries assuming that there is no interconnection and no trading of energy. With only minor exceptions between UAE and Oman this is the case today.

Full data sets of generators for each of the six countries are not publicly available and data that are available do not contain heat rate, forced outage or values for VOM. As a result the analysis reported has focused on the detail of the national location, type, fuel, size and age of the units. From these data the heat rate has been estimated as is indicated in Table 3. While the absolute values may be questioned, the relationship between the age, fuel and technology are logically ordered.

To complete the analysis required a cost for each of the fuels used by the generating units. Because the GCC countries (or most) have significant fuel supplies the analysis was carried out against September 2008 international prices. Table 4 provides the values used in the analysis.

Figures 3 through 9 present the results of the analysis as Cost Duration Curves for the six individual countries assuming no interconnection and no trade. This clearing point at peak (given reserve margins) is shown in each figure by the red vertical line with the value at the intersection shown in the yellow box.

There are a series of conclusions that can be reached looking only at the six operating independently. As noted from Table 2, there is significant diversity in the technology and fuel. This difference is quickly seen in the marginal cost per MWH at peak. Starting at the northern end, Kuwait has a marginal value of $188 at peak, the eastern and central zones of Saudi Arabia of $218, Bahrain $100, Qatar $88, the UAE $104 and Oman $225

Table 3: Estimated Heat Rates

		Estimated Heat Rate	
Decade of construction	Generating Technology	Fuel=NG	Fuel = FO
2000	GT	8500	8000
1990	GT	10000	9000
1980	GT	11500	11000
1970	GT	13000	12500
2000	ST	9500	===
1990	ST	10500	10000
1980	ST	13000	12000
1970	ST	14000	13000
2000	GTCC	7500	7000
1990	GTCC	8500	8000
1980	GTCC	9500	9000
1970	GTCC	===	===

Table 4: September 2009 Fuel Costs

Fuel	Cost	Unit	$/MBTU
Natural Gas	$8	/MBTU	$8
FO2	$2.95	/gallon	$21.85
FO6	$2.09	/gallon	$14.50

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The dramatic difference is driven primarily by the quantity of natural gas available for generation and the size (in excess of demand) and age of the generating stock. Qatar has a wealth of natural gas and through the Dolphin Pipeline project from Qatar to the UAE, the UAE has been able to augment its natural supplies that are considerable.

The conclusion that is quickly reached is that there is significant opportunity for trade once the interconnection is completed and operational.

The green lines on figures 3 to 9 indicate the value point for trades between in the individual countries under the assumption that the trades are purely bilateral and given the transfer capability. The first, and most attractive transaction is for energy from Qatar to Saudi Arabia. The marginal cost in Saudi is $218/MWh while that in Qatar is $88/MWh. The only limitation to this transaction is the constraint on transmission of 750MW. As can be seen, Qatar is willing to sell the 750MW at any value greater than $100/MWh and Saudi Arabia to purchase at any value below $218/MWh.

Saudi Arabia has the ability to import an additional 450MW through its interconnection but is unable to find a seller whose marginal costs for (at the end of) the transaction will be lower than the marginal

cost of generation in Saudi Arabia given that the UAE has already sold energy to Oman and the line from Qatar is now constrained.

The second most attractive is the transaction from the UAE to Oman in an amount that fills the transmission capability – 400MW. The result for Oman is a purchase at anywhere below its marginal cost of $225/MWh. The UAE will sell at anywhere at or above its marginal cost to generate the energy, $152/MWh.

The final transaction is between the UAE and Kuwait over nearly the full length of the transmission system. In this instance Kuwait would prefer to buy a full 900MW from the UAE but is only able to purchase 800MW at a marginal cost that is below that of Kuwait. This is not because the cost in Kuwait drops but because the incremental 100MW (from 800 to 900) in the UAE shifts their marginal cost to a level higher than that of Kuwait.

6. Conclusions

While highly simplified, the example focuses attention on two critical points that will arise with the completion of the GCC Grid.

1. There will be significant opportunity for trading between the countries to minimize the cost of their electric supplies. The flow will not, however, be unconstrained as indicated. Even with this example, two of the links are constrained. The link out of Qatar is constrained because the cost of generation is driven by efficient natural gas technologies and the link into Oman is constrained in this example, because the in-country supplies are constrained and the marginal costs are relatively high.

2. Figure 9 shows the cost duration curve for the GCC assuming that the countries are centrally dispatched – an issue under discussion at present. As can be seen the marginal cost for the entire system under common dispatch is roughly $150/MWh. Were this to be the common clearing price for the system as a whole (ignoring transmission constraint costs for the moment) the result would be positive for Saudi Arabia and Oman , highly negative for Qatar and the UAE and marginal for both Kuwait and Bahrain – again in the example shown. The result for the GCC as a whole would be a complex transfer of funds within the system. The net beneficiaries of those funds transfers are not entirely clear from this example. While prices would go up in Qatar and the UAE, so would revenues and depending on how these revenues were paid out – to "shareholders" or consumers the impact might be negative or positive. For Saudi Arabia and Oman the results appear to be highly positive as they would be able to purchase at less than their marginal costs but would also be sending money out of the country.

That conclusion that is clear is that, if the system is jointly dispatched, the joint cost for all supplies in the GCC will be reduced. Across the six countries the average cost per kWh will be lower but with winners and losers.

The conclusion is that this paper and the simple example provide may have raised as many or more questions than it has answered with regard to the economic effects of the GCC interconnection. What does appear to be the case, however, is that the interconnection will provide significant opportunity for trade between the countries. The question left completely unanswered is at what transaction price will these trades take place?

Figure 3: Cost Duration Curve Kuwait

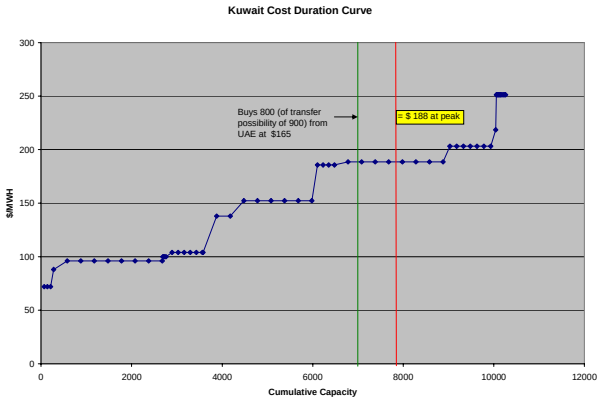

Figure 4: Cost Duration Curve Saudi Arabia

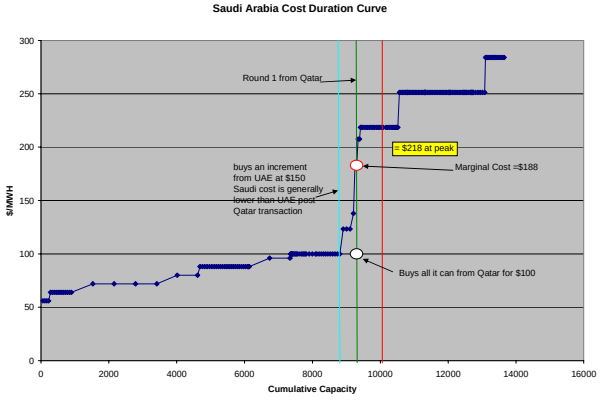

Figure 5: Cost Duration Curve Bahrain

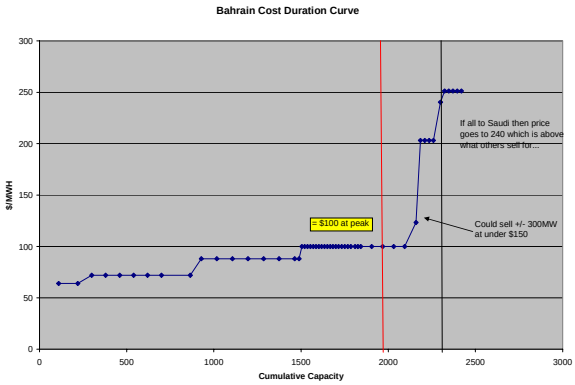

Figure 6: Cost Duration Curve Qatar

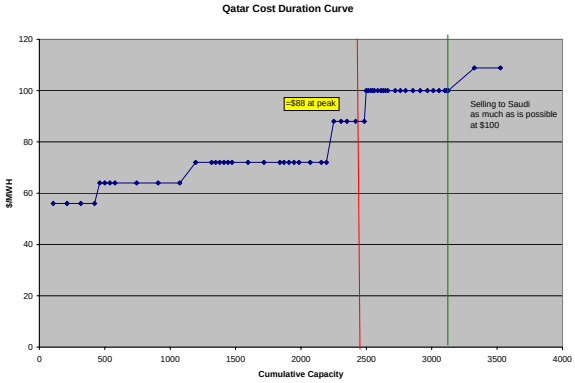

Figure 7: Cost Duration Curve UAE

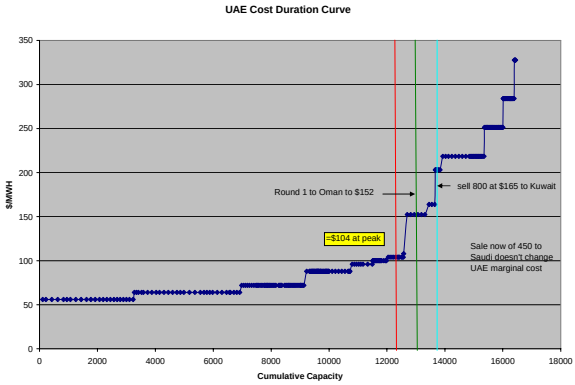

Figure 8: Cost Duration Curve Oman

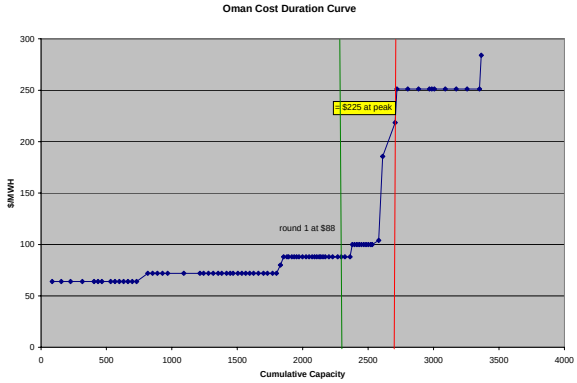

Figure 9: GCC Cost Duration Curve