Best Way Of Savings in ME Utilities

How augmentation of Smart Power Generation in a Utility is a must to bring flexibility to a grid system

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1. Abstract / Executive Summary

In today's energy world, a lot of research and development has been invested in finding optimal ways and means to harness naturally available energy, whereas the equally important issue of optimization of the grid systems for various load patterns, (that is baseload, intermediate load and peaking load) remains to be studied in depth.

In this paper we will use three different examples to explain how baseload is indeed required but robust, flexible power plants are equally important and a necessary part of a resilient grid system. 'Smart Power Generation', a concept introduced by Wärtsilä, is the first major step in this direction.

Our three examples will be CAISO (Californian Independent System Operator), from California, USA; NEPCO (National Electric Power Company), based in Amman, Jordan; and ADWEA (Abu Dhabi Water and Electric Authority), headquartered in Abu Dhabi, UAE. Our analysis sets a strong foundation, reinforcing the idea that serious consideration is mandatory before any tender is floated for flexible power for the optimization of the grid system. Said analysis, with its underlined results, reveals that future power that needs to be added into the power system can be anything but Combined Cycle Gas Turbine (CCGT).

The utilities in ME are already overburdened with CCGT power plants. Adding further CCGTs would be putting the already inflexible grid system under pressure to take up flexible load. The decisive fact is that CCGTs are not designed to take up the role of a flexible power provider. As a basic rule, the technology that needs to be added in the grid system must qualify not only in terms of technical and environmental regulation but also economic grounds.

A digression of view may be accepted here, away from the traditional CCGT addition in the grid system, by letting the technology be 'open' (i.e. not expressing any technological preferences, provided all other requisites are met) for competing bids in new tender processes for flexible power plants. This will, after all, benefit the utilities allowing the choice of optimal technology, resulting in better economic terms.

2. Introduction

Smart Power Generation

Mankind has walked a long way in generating energy; from the first time energy was generated by rubbing two stones to start a fire. Today, we have the comfort and ease of utilizing the energy to our benefits by clicking the buttons for switching on or off our lighting, heating, air-conditioning, etc. In the 21st century we are aggressively harnessing energies occurring naturally from the sun and wind, among others. Whilst the inertia of power industry propels the quest for better resources, the requirements for sustainability and optimization become more important than ever owing to ever increasing population, industrialization, and commercialization that continue to challenge mother earth's environment.

For a sustainable and optimized power sector growth on the supply side, Wärtsilä presents a novel, robust and affordable solution named 'Smart Power Generation' in the form of power plants that can run as continuous base load, intermediate/load-following, peaking load, and is a viable solution to fast ramp up and ramp down, voltage control above all being extremely reliable. In short, 'Smart Power Generation' has all the items contained in the wish list of a power load dispatcher.

The term 'Smart Power Generation' is the envisioned enabler for the Smart Power Systems we will need in the 21st Century. Wärtsilä invests approximately 4% of its net sales in research and development, continuously striving for excellence by putting up the passion for optimizing lifecycle value for our customers with modern and sustainable power solutions.

Nearly all the grid systems in GCC have been adding base load capacity to their already heavily inclined base load power generation portfolios. A robust grid system requires flexibility of operations, fuel, and energy efficiency, three key points that Smart Power Generation excels at providing. These topics will now be addressed by analysing the challenges endured by three utilities CAISO, NEPCO, and ADWEA and their corresponding solutions.

3. Flexibility brings savings - California Utility Case

Introduction

The western US state of California is home to more than 38 million people and has a GDP larger than that of Russia or India. Given those numbers, plus the fact of it being an economy focused in high-value goods and services, it is evident that the power demand of the state is indeed huge. California is also on the leading edge worldwide regarding sustainability. The state has long ago committed to drive the development of an environmentally sound power system through self-imposed regulations that, for example, ban the usage of inefficient cooling systems for power plants. All of these measures put the state on track for the very ambitious goal of achieving a 33% share of renewable energy sources in the final electricity consumption, set in 2002, which would crown the so-called 'golden state' as the most developed area with such a high renewable penetration, and the second most populous only behind Brazil. It is anticipated that there will be significant ramp up/down, and flexibility required to meet net load profiles due to California's goal of achieving a 33% renewable energy provision by 2020, and retiring old plant.

CAISO is a non-profit entity in charge of managing the regional power grid, catering to approximately 80% of the total power demand in California. CAISO has 72 GW of installed capacity, of which 45 GW use natural gas as fuel. The California Public Utility Commission (CPUC) periodically forecasts load growth and resource adequacy through Long Term Planning and Procurement (LTPP) proceedings, which address capacity needs over the next 10 years to meet resource adequacy goals.

Load Profile

The load profile forecast in California for the near future is a true eye-opener. A strong push for enlargement of the renewable capacity, whose power is always fed first into the grid when available, leads us to the definition of *net load*, this is, the load that must be taken by thermal plants once the available renewable power is subtracted from the raw demand. The lowest daily value of this *net* load will set the upper boundary for base load capacity, which can be operated 24/7 regardless of the demand, since it will be equal to the maximum amount of inflexible power. The rest of the load must be supplied by flexible power, which can seamlessly start, stop, ramp up and down as required by the demand and the available fed-first renewable power. As we see in Figure **1**, the projected load profile in 2020 has 28 GW of *raw* base load, but after deducting the contribution of renewable, the number drops by 32% to a mere 19 GW of *net base load*. To add another dimension of complexity, new and much more demanding ramp events would occur that were not previously observed in the load pattern before the accelerated growth of renewable capacity, posing challenges that few technologies can accomplish.

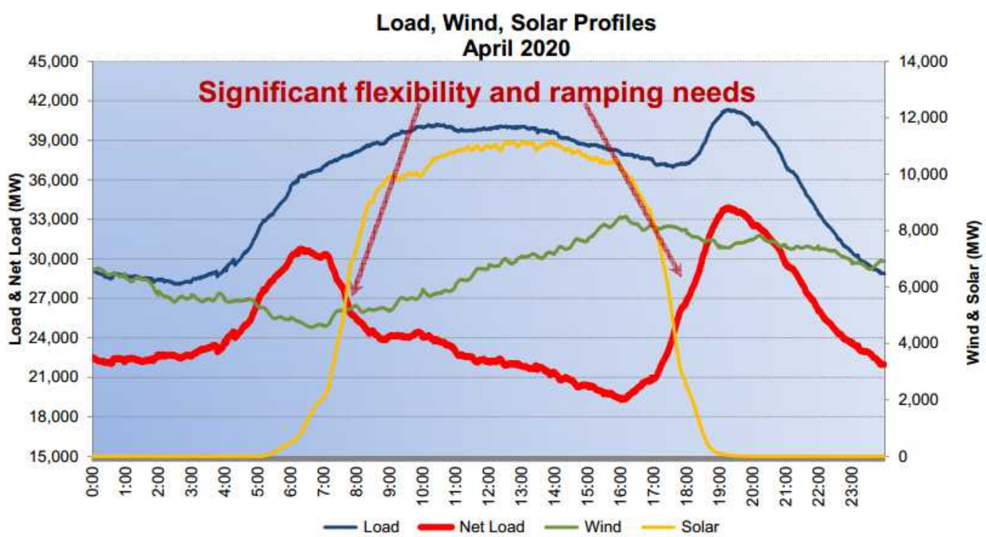


Figure 1: Flexibility is paramount to deal with future grid dynamics in California **(Skinner, 2012)**

CAISO recognized that a significant change in load is going to start from 2015 which will deepen more in year 2020 and beyond. To integrate a significant amount of renewable energy, CAISO will need to invest in flexibility to meet these net load ramp requirements as indicated in **Error! Reference source not found.Error! Reference source not found.**.

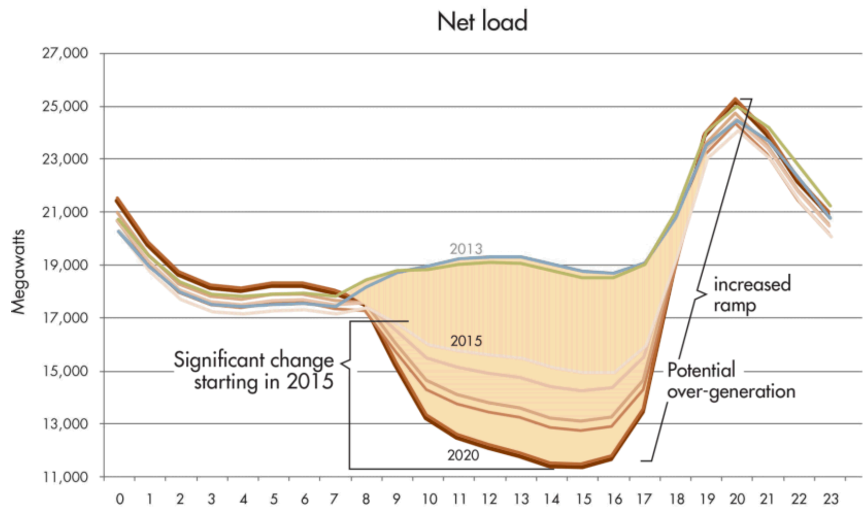


Figure 2: Development of the net load in California, 2013 – 2020 **(Rothleder, 2013)**

Case

LTTP identified 5.5 GW assets to be retrofitted or replaced in order to comply with California's recent 'Once Through Cooling' (OTC) restrictions, to avoid thermal pollution to marine ecosystems. For 5.5 GW of replacements, LTTP specified 3.2 GW of new CCGTs, and 2.3 GW of new open cycle gas turbines (OCGTs). The challenging question that came up was, "*Is the suggested replacement most economical flexible and sustainable solution?*"

Analysis

Wärtsilä evaluated CAISO's operations and costs for the year 2020 using a dispatch simulation tool. The comparison envisaged outcomes if the 5.5 GW of new CCGTs and GTs were replaced by Wärtsilä gas engines in simple cycle mode (Wärtsilä 34SG) and / or as Flexicycle™(using Wärtsilä 50SG engines). The analysis was performed by the independent consultant DNV KEMA, utilizing the publicly available PLEXOS™ model of the WECC (Western Electricity Coordinating Council) model. The DNV Kema White Paper with the complete analysis can be found at www.smartpowergeneration.com. However, for the purpose of this paper, here is the brief result of the analysis:

Conclusion

The total annual system savings using the Smart Power Generation alternative are between 900 MUSD (10.9%) and 300 MUSD (4.2%), depending on the backstop mechanism assumed. The Smart Power Generation alternate yield a 4% reduction in variable generation (fuel + VOM) costs, and start/stop costs are also cut almost in half. The Smart Power Generation alternative uses approximately 7.6 million m^3 less water annually. The CO_2 cost savings were 4.2% (=1.46 million tons/year). Besides, huge savings in regulation up/down, load following up/down, and spinning/non-spinning reserves.

Overall, the impact of 5.5 GW of gas engines capacity instead of gas turbines was that of fleet optimization. The flexible Wärtsilä engines ramps or/and cycle in a more cost effective manner, and allow the existing fleet of CCGTs to operate in a more uniform fashion, with fewer ramps, starts and stops, all of which result in operational savings.

4. GCC Power Grid System

General Trends

The power demand in GCC is experiencing a robust growth from 5% to 11%, regardless of the size of the grid. The economic growth in GCC has propelled the demand of electricity owing to the increase in commercial, industrial and especially domestic consumption. The summers pose another challenge in the shape of sharp midday load also referred to as 'air-condition' load. The installed capacity of GCC in 2009 was 94 GW and is projected to reach 145 GW by 2015[i]. Today the installed capacity of GCC is somewhere in the ballpark figure of 130,000 MW (excluding captive power). A very conservative growth of 5% would require for an augmentation of 6,500 MW capacity increase every year.

Nearly all the utilities in ME have overwhelming power plants as base load, mainly CCGTs and main fuel used is natural gas. The base load CCGT power plants are compelled to perform role of load following and peaking plants as well. The situation further worsens when one third of capacity is cycling during the day, regardless of season.

The induction of solar and nuclear power makes the grid system less robust and flexible. The challenge becomes '*how to add flexibility in the grid system without adding any additional cost?*'

According to the World Energy Council, the GCC will require 100 GW of additional power over the next 10 years to meet demand. Hence, it is all the more important to add additional power in the system which covers all the tiers of dispatch, that is, base load, load following and peaking power plants. Here we will discuss the successful case how Jordan utility NEPCO benefited by adding flexibility in the system and how other utilities in the region can benefit from Smart Power Generation.

5. Future-proofing a national grid - Jordan, a successful case study

Introduction

Jordan has a population of 6.41 million with 100% electrification. A total of 97% energy needs are met through fuel imports, but with a high dependence on the gas pipeline that supplies gas from neighbouring Egypt. This has become a major concern, since political instability has caused major disruptions in the supply and seriously jeopardised the stability of the Jordanian power system.

As an example, in 2009 natural gas-fired power plants supplied 89% of the total electric generation, while in 2011 a major disruption to Jordan's single source natural gas supply, the Arab Gas Pipeline, intensified energy security concerns. Natural gas imports to Jordan were reduced from 89 billion cubic feet (bcf) in 2010 to 29 (bcf) in 2011. To compensate for the natural gas shortages, Jordan's fuel oil imports increased by more than 25 percent. Diesel and heavy fuel oil (HFO) accounted for 64 percent of total electric generation in 2011 and 78 percent in 2012. This abrupt shift from natural gas to fuel oil and diesel also affected the efficient and economic dispatch of Jordan's generating units. As a result, the cost of energy relative to Jordan's gross domestic product (GDP) increased from 11.5 percent in 2009 to 21.3 percent in 2012.

NEPCO had at the end of 2012 a total installed capacity of 3,452 MW, while the yearly peak load reached 2,770 MW. Electric power demand varies in Jordan by as much as 30 percent daily, presenting operational and planning challenges for the transmission system operator, a role also exerted by NEPCO. Before 2013, the demand has been met primarily with steam turbine and CCGT capacity. Heavy reliance on plants that are designed to run at high load factors provides limited ability to adapt to daily fluctuations in demand. This is reflected in an overall average thermal efficiency of the generating fleet of 40.2 percent in 2012.

Study

Wärtsilä performed an in-house detailed study for NEPCO. It was found that in December the load variation was 900 MW, and a maximum ramp rate of 230 MW per hour. The summer (September) daily load variation was 520 MW with maximum ramp rate of 150 MW per hour. Most plants were to operate on part loads to follow load demand pattern (Figure **3**).

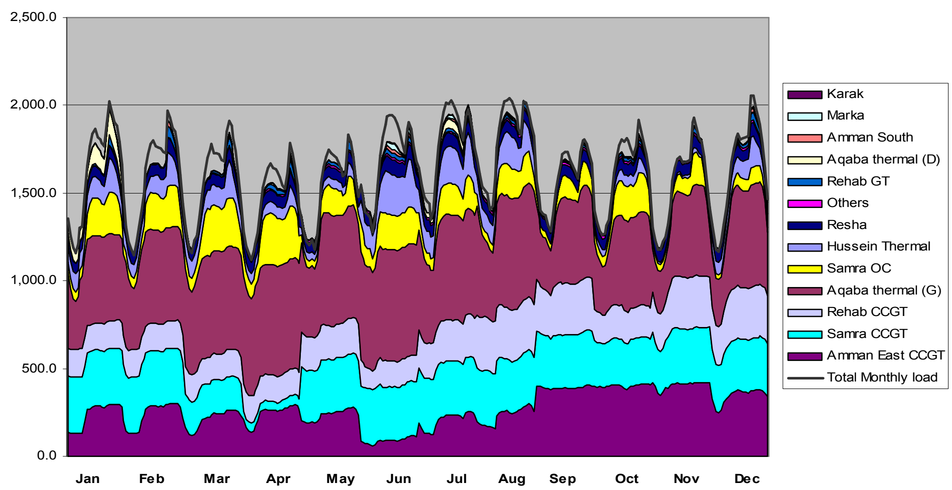


Figure 3: Average daily load curve in NEPCO **(Nygard, 2012)**

The study analysed the dispatch pattern by taking data of hourly dispatch of all power plants in NEPCO system for the last one year. When the graphs were plotted against the numbers, it was found that the daily load profile was very similar throughout the year; the base load demand is ~60% of daily peak demand, regardless of the seasonal variations (Figure **4**).

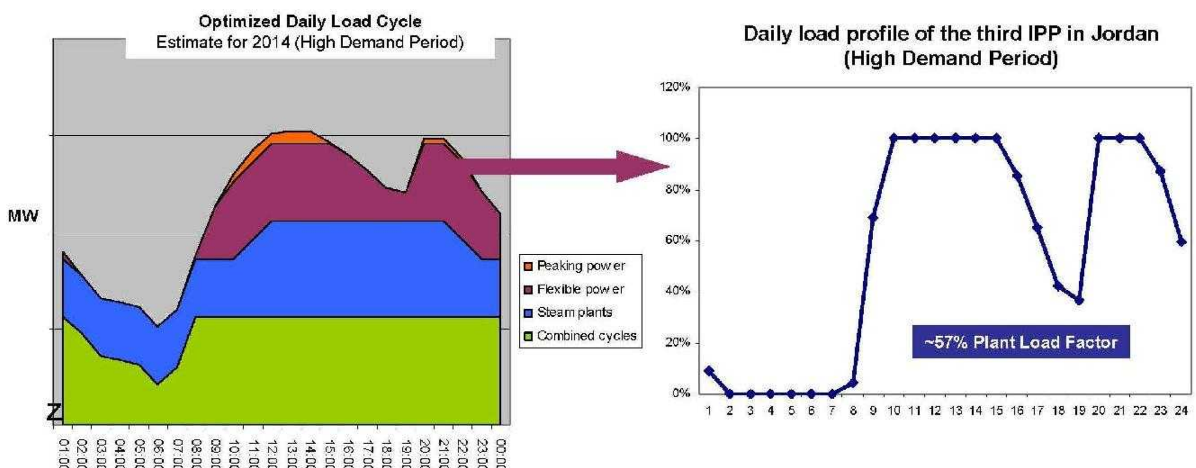


Figure 4: Daily load profile of proposed third IPP plant in Jordan. Please note how the Smart Power Generation capacity (purple) absorbs the peaks and allows the existing CCGT capacity to run at full load and full efficiency **(M. Al Azzam & Paldanius, 2014)**

The findings also revealed that the future augmentation must be flexible plants and not base load plants. That is way the flexible plants of up to 900 MW can be added in the system to follow the load curve, thus allowing base load plants to operate more efficiently at stable loads.

Analysis

Analyses were made on the basis of future augmentation in the system for continuous base load and flexible power plants.

The first analysis showed that if the Plant Load Factor (PLF) is 66%, the CCGT would perform better at continuous base load while Wärtsilä would provide the lowest cost on any liquid fuel (Figure **5**).

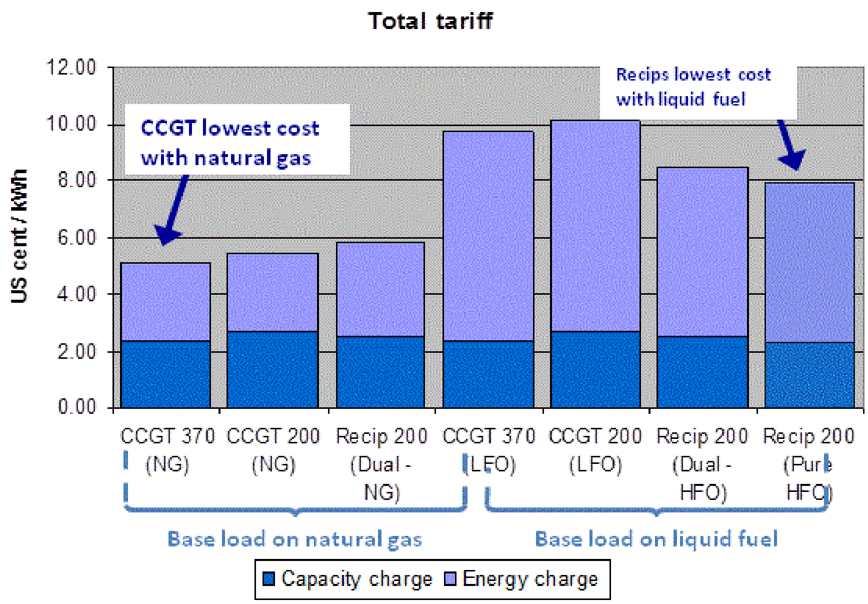


Figure 5: At 66% PLF and full load, CCGT offers better performance

The second analysis showed that if the PLF is 66%, Wärtsilä would outperform CCGT in flexible-load operations (Figure **6**). Reciprocating engines are far too competitive and inexpensive, whereas there is no place for steam turbines in flexible load operations.

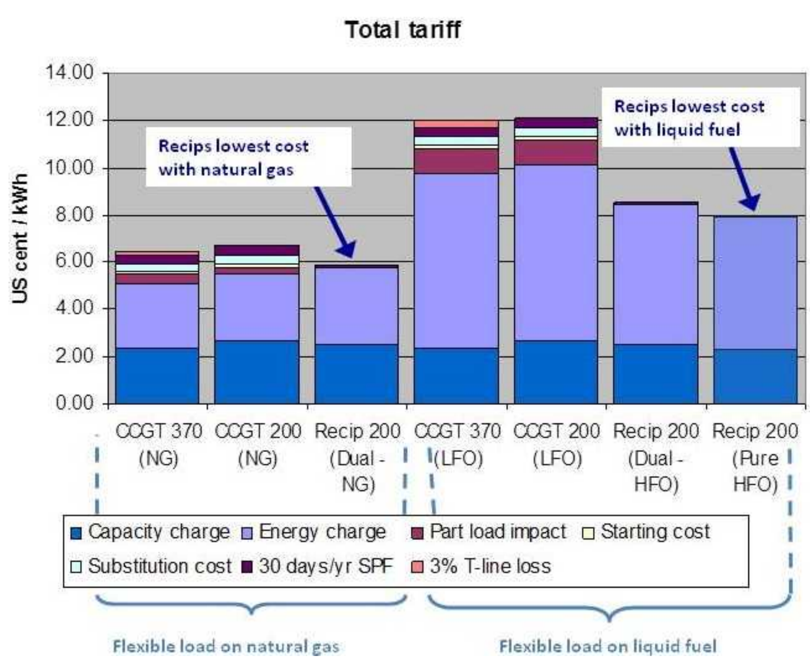


Figure 6: However, for flexible load operations, reciprocating engines offer clearly the best performance

Conclusion

It was estimated that during the low demand periods, flexible power plants will run at approximately 50% plant load factor but steam plants will be in the stand-by mode. In retrospective, all major demand load variations, so to say, abusive load will be taken up by reciprocating engines, and all stable (base load) will be taken up by CCGTs. This way the lowest tariff and optimal operating regime can be achieved as evident from the finding depicted in Figure **7**.

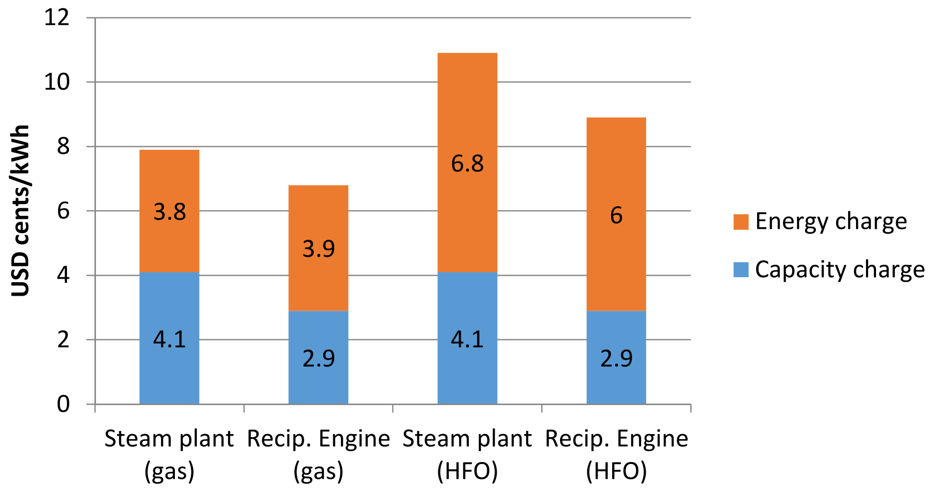


Figure 7: Tariff comparison for flexible loading

After Wärtsilä's study, the NEPCO appointed an independent consultant and got the same confirmation that the future load must be flexible power plants with dual fuel technology.

Today a 600 MW, expected to have a flexible load factor of 60% is under construction with 38 high efficiency tri-fuel reciprocating engines that will be using HFO during initial years and will be converted to natural gas later.

Another 250 MW peaking power plant, expected to have a flexible load of 40% has achieved commissioning and is up and running smoothly with 16 high efficiency tri-fuel reciprocating engines that will be using HFO during initial years and will be converted to natural gas later.

6. Paradigm shift for utilities in the Middle East - ADWEA case study

Introduction

The Emirate of Abu Dhabi is home to a population of more than 2.2 million, and is in an upward spiral of growth and development; the power demand increases accordingly. Like most of Middle East, the Emirate of Abu Dhabi has to deal with challenging environment, dominated by desert climate. This puts the power system under extreme duress, since not only is the need for power very high, but the need for (desalinated) water is also very high. The utilities of GCC countries especially those with exceptionally high growth rates like Abu Dhabi, a peculiar and resilient reference is formed vis-à-vis power system development.

The power generation fleet in the UAE is nearly 100% fired by natural gas, predominant technology being CCGT although there are some open cycle gas turbines in operation too.

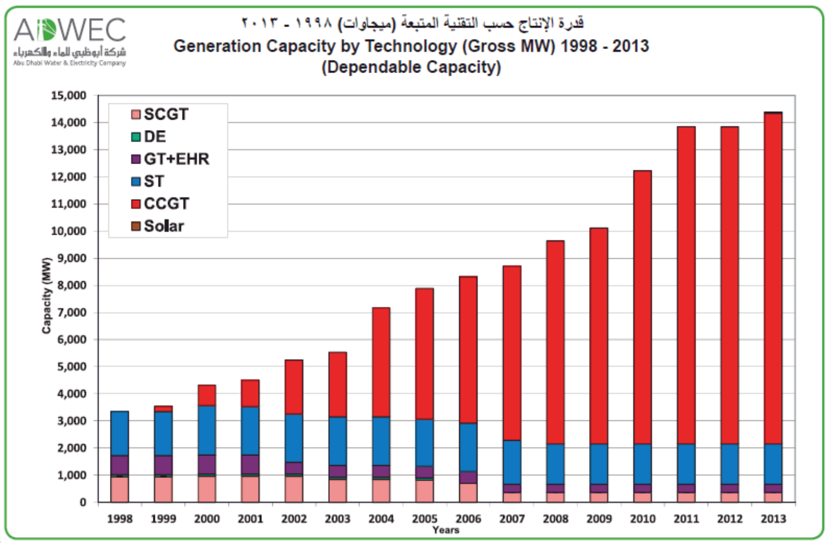
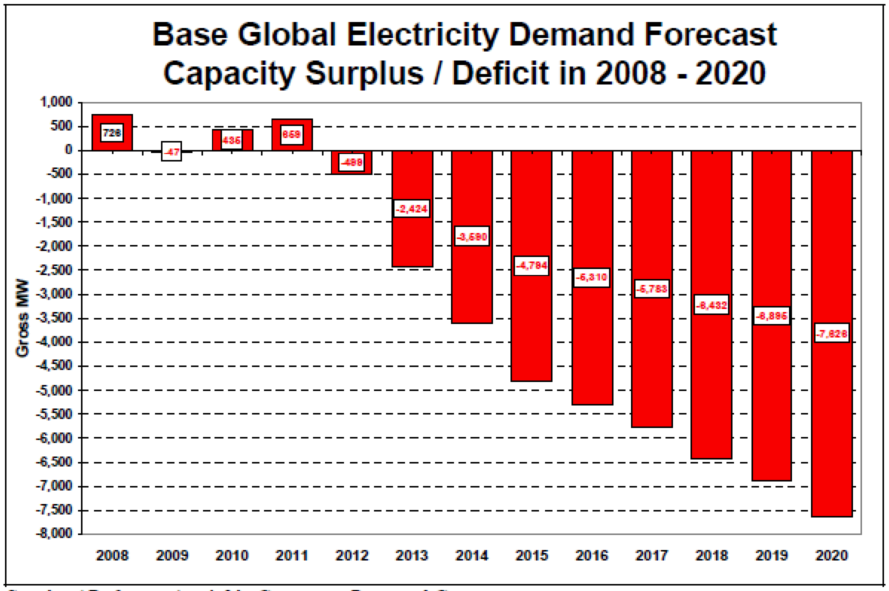


Figure 8: Generation mix in Abu Dhabi 1998-2013 **(Abu Dhabi Water & Electricity Company, 2013)**

The power demand in Abu Dhabi is growing at a staggering rate, probably the highest in all the utilities of Middle East. This demand is driven by an increasingly electricity-intense society (which relies heavily on air conditioning for commercial and residential buildings). This does not leave room for anything other than a sustainable and reliable increase in generation capacity, as a part of the long-term resource planning. Figure **9** depicts the forecasted demand of ADWEA at well over 7.6GW for the next five years.



Surplus / Deficit = Available Capacity - Required Capacity.

Figure 9: Forecasted capacity deficit 2008-2020 **(Abu Dhabi Water & Electricity Company, 2013)**

Regulatory framework

ADWEA decides future capacity planning and power system development. ADWEA has adopted the Independent Power Producer (IPP) model on public private partnership with a binding Power Purchase Agreement (PPA). The power and water are procured by ADWEA and later retailed by the wholly-owned subsidiary ADWEC, the "Single Buyer and Seller" of water and electricity in the Emirate of Abu Dhabi.

This model is beneficial as it reduces requirement for upfront investment and financing which, enables a rapid expansion of the generation capacity, on a fixed price. While the model is suitable, it also has drawbacks. The task of optimizing the power system is in the responsibility of ADWEA, and the optimization potential is limited by the requirements set in the tenders. For example, a certain choice of fuel or generation technology can heavily influence the direction in which the system is developed, and may block paths for potential improvement which had not been considered in the study leading to said tender.

Reserves

Amid accelerated growth of the power demand, it is extremely important to guarantee the stability of the power system and its ability to overcome any generator malfunctions, unplanned outages or forecasting errors. The Emirate of Abu Dhabi has long ago implemented strict policies that govern the allocation and activation of power system reserves, and nowadays features one of the most reliable grids in the entire region. The Generation Security Standard (GSS) uses a Loss Of Load Expectation (LOLE) of 1 day in 10 years (Abu Dhabi Water & Electricity Company, 2008). For these high standards to hold, further investments in capacity must be undertaken in the near future, with the aim of keeping a positive reserve margin and improving the quality of the reserves needed to deal with a greater complexity of the system that can likely be caused by inflexible base load, that is, CCGTs, renewable, and nuclear capacity additions.

Yearly power demand profile

The yearly power demand in Abu Dhabi has a very irregular profile, due to the tremendous impact of the power consumption from HVAC equipment on the hottest months of the year. Due to this, the power demand in the winter months can be as low as half of the yearly peak, which tends to occur in July or August. This imposes a great stress on the system, since the vast majority of the generation capacity in Abu Dhabi is well suited to work at full output, but rapidly loses efficiency when forced to part-load to provide flexibility.

Cross-analysing climate data (National Oceanic and Atmospheric Administration, 2014) and energy demand data (Abu Dhabi Water & Electricity Company, 2013) of Abu Dhabi, we can find that there is a very strong correlation between both sets, as we initially presumed. This will provide us with a very valuable set of test conditions for our analysis. The power consumption doubles from 1500GWh to 3200GWh with an increase in temperature from 20 C in winter months to 42 C in summer months.

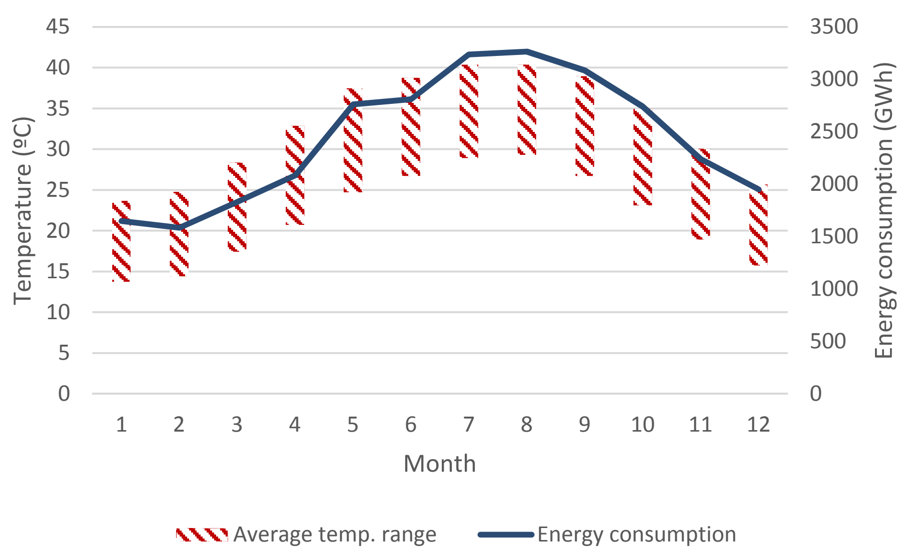


Figure 10: Temperature-demand correlation in Abu Dhabi

The impact of climate: derating and efficiency loss

Abu Dhabi, like most of the GCC area, has a sub-tropical, arid climate. This implies sustained high temperatures all year round, very scarce precipitations and, in the case of coastal regions, a near-constant humidity of around 60%. This has a tremendous impact on power generation, since this set of conditions represents a '*perfect storm'* for most power generation technologies. The Gulf climate tests the limits of the power generation equipment by exposing it to extreme ambient temperatures and very humid air, far away from its design condition. For this matter, the ability of the different technologies to withstand such harsh climate whilst minimizing its impact in their output and efficiency is very crucial.

To study the impact on efficiency against average monthly temperatures we took climate data (National Oceanic and Atmospheric Administration, 2014) and publicly available information about the behaviour of different generation technologies under hot ambient conditions (extracted from calculation software GTPRO and PerfPro). We plotted the estimated base load efficiency of four different generation technologies, as a function of the average monthly temperature in Abu Dhabi. The four technologies under scrutiny in this case study are:

- Open Cycle Gas Turbines (OCGT)
- Combined Cycle Gas Turbines (CCGT)
- Gas-fired Internal combustion engines (Combustion engines)
- Flexicycle™, a concept trademarked by Wärtsilä, consisting on a flexible combined cycle powered by gas-fired combustion engines.

The two main factors that were taken are a) the reduction of the efficiency (more fuel burnt per unit of output power), and b) the de-rating (reduced output power) that the four technologies will incur under the site conditions of Abu Dhabi, as seen in Figure **11**.

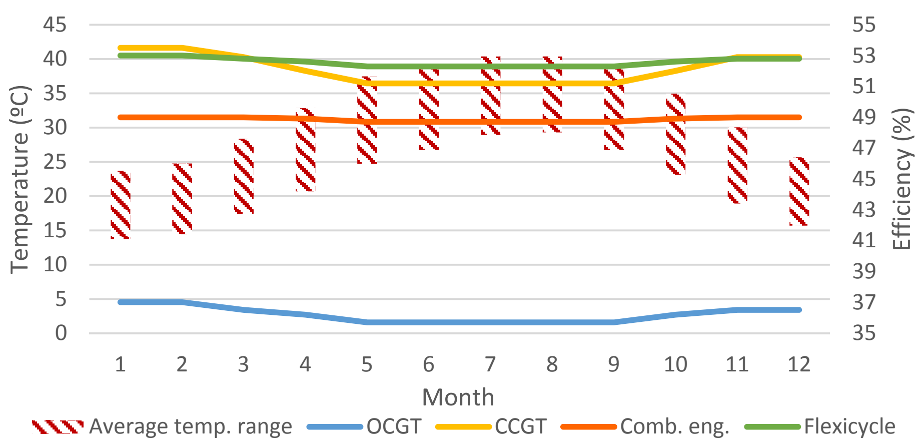


Figure 11: Monthly expected average efficiency in Abu Dhabi, depending on temperature range

The figure shows some alarming results. The nameplate nominal efficiency of CCGTs is normally the highest in all technologies analyzed but the high temperature cause considerable impact, lowering the effective efficiency much below than that of Flexicycle in the hotter months. The shape of curves reveals that gas turbine-based solutions are more sensitive, whilst gas combustion engine-based solutions remain relatively immune to high temperatures.

The effect of high temperature on efficiency and output is plotted in **Figure 12**. This exposed a potential problem of CCGT technology: when the consumption is highest, when the energy is most needed, the gas turbine-based solutions fail to maintain its efficiency inevitably wasting resources. However, this is not the case with combustion engine-based solutions, which can keep their efficiency regardless of the ambient temperature.

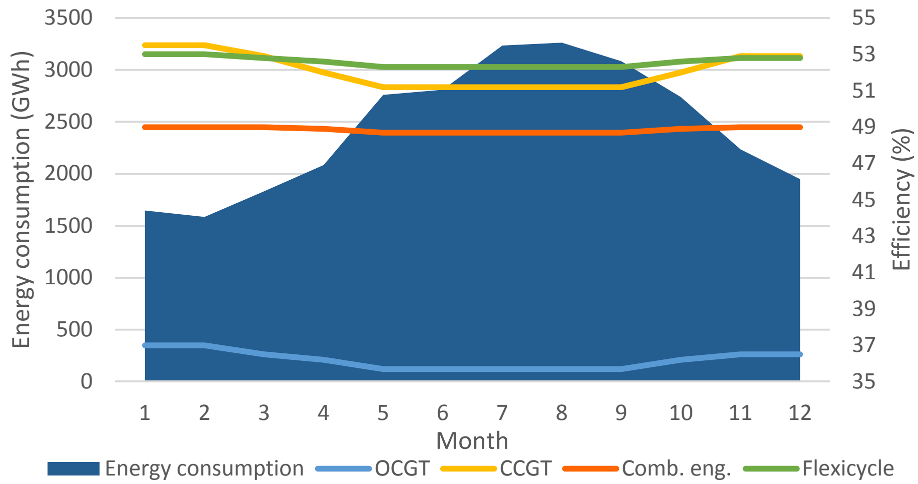


Figure 12: Monthly expected average efficiency in Abu Dhabi and monthly energy consumption

With regard to the output reduction, de-rating, all technologies are adversely affected by the high temperatures, and none of them is able to keep their design output. However, the loss of output is much more noticeable in gas turbine-based plants: during the hottest months of the year as evident from Figure 13.

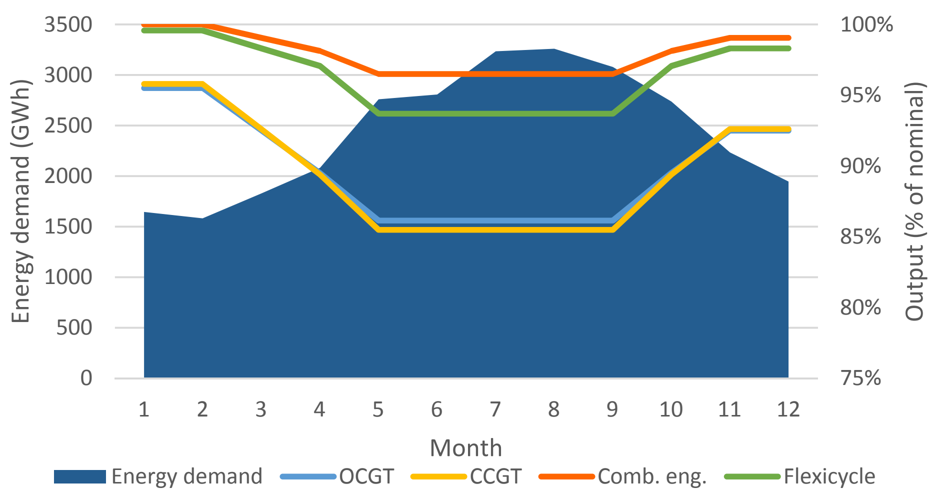


Figure 13: Monthly expected de-rating in Abu Dhabi and monthly power demand

Hot day performance

One of the most critical aspects to be taken into account when planning capacity expansions in Middle East is 'hot day performance'. In this scenario, we have to consider the impact of extremely hot days in the power system, for it is doubly challenging. One important consequence of this exceptionally high temperature is an increase of the power demand. The demand in hot weather increases due to increase in domestic consumption sector as air conditioning increases drastically., On the supply side, the power generation equipment, especially gas and steam turbines, suffers noticeable reduction in their output and efficiency, due to the higher ambient air temperature. When the mercury rises, much-needed generation capacity will inevitably underperform.

This reduction in performance is, as we have seen in the previous chapter, very different among technologies. For that matter, we will now conduct a brief study evaluating the hot day performance of different technology options for Abu Dhabi.

By making use of an extensive climate dataset (National Oceanic and Atmospheric Administration, 2014) and some engineering savoir-faire we can build a sample 'hot day' that would correspond to a unusually (but foreseeable) hot day in Abu Dhabi, probably in the months of June to August. The construction of such sample hot day has been done by applying the fraction-range method for climatic performance evaluation of thermally stressed equipment, as per the ASHRAE handbook of 2008 (American Society of Heating, Refrigeration and Air Conditioning Engineers, 2008). The outcome of this method is an hour-by-hour dry bulb temperature profile, consistent with the empirical data.

According to research performed by ADWEC, a simple linear regression model might suffice in many cases to provide a moderately accurate forecast of the hourly power demand in Abu Dhabi. An analysis of hourly data from June 2008 suggested that each degree Celsius change in the temperature can be expected to induce variations on the hourly load of around 100 MW (Abu Dhabi Water & Electricity Company, 2008). A more accurate depiction of such linear regression model is given by the equation

$$\widehat{D} = 1337.56 + 95.21\,T$$

Where $\widehat{D}$ represents the expectable hourly power demand, in MW; and T is the input variable for the temperature in that hour (in Celsius). Here it may be noted that the analysis by ADWEC dates back to 2008 and the current peak load is sizably larger in 2014 but this does not impose any loss of validity for our study. It is safe to assume that the behaviour of the regression model would be the same nowadays if the power consumption patterns stay the same, so the multiplier of the equation would not be affected, keeping the shape of the demand curve unchanged. Once we apply this regression equation to the previously generated hourly temperature profile, we obtain an accurate representation of how the power demand will evolve, hour by hour, in our sample hot day, seen in Figure **14**.

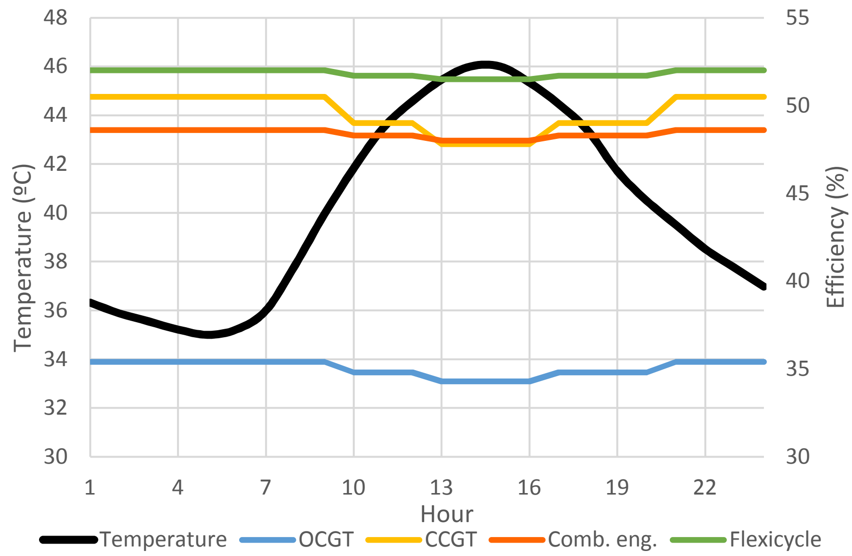


Figure 14: Hot day efficiency impact of the different generation technologies

The de-rating of various technologies is evident but highest is observed in gas-turbine based solutions, as depicted in Figure **15**.

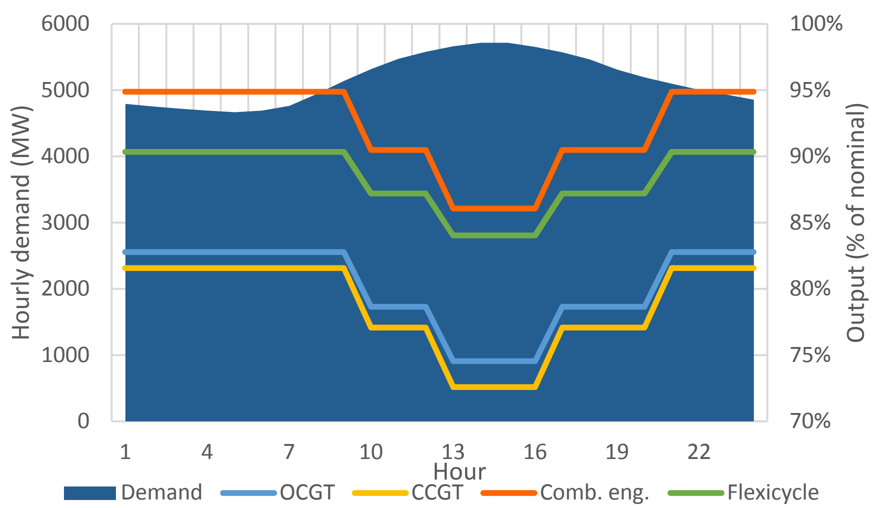


Figure 15: Hot day de-rating of the different generation technologies

The high temperatures are inversely proportional to the efficiency and output but far more so to gas-turbine based solutions.

The effect of temperature is just one aspect of the whole picture. When we account for the adverse effect of daily and seasonal load variations / cycling (almost 1/3rd of the utility output is in cycling) the scenario becomes much more alarming. In view of the above it is mandatory to take a holistic picture for flexible power plant in the system for any new tender in the future.

Off-season desalination

Like most of the Gulf region, Abu Dhabi is heavily reliant on desalination as a means of obtaining fresh water. Desalination plants are normally embedded in power generation plants and make use of the residual heat or steam to power the desalination process. This is a one way of dealing with the issue, but it brings challenges. For example, a quick read of ADWEC's Statement of Future Capacity Requirements 2008 – 2030 reveals the following:

"During the winter months when electricity demand is low, perhaps 30% - 35% of the annual peak, TRANSCO sometimes encounters problems with producing enough water to satisfy demand. This problem arises because electricity generation (from gas turbines) is too low to produce all of the hot exhaust gases needed by the Heat Recovery Steam Generators (HRSGs) as a heat input. The HRSGs convert the heat of the hot exhaust gases from the gas turbines into the steam needed by the water distillers. Thus low levels of electricity generation can result in reduced water production. Essentially this problem is a function of the current technologies used at existing IWPP stations." (Abu Dhabi Water & Electricity Company, 2008)

There is little to argue that this challenge is an unwanted side effect of the excessive reliance on CCGTs as the single source of power. The situation will further compound when nuclear power plants and solar power plants will come on line. If new IWPPs were to be fitted with combustion engine technology, either standalone or in Flexicycle configuration, this problem would be all but eliminated. Wärtsilä-designed power plants are equipped with a hang-on heat recovery system, which is fitted to the exhaust of the engines. This system has the rare benefit of being 'unnoticeable' for the power generation side of the plant: the amount of heat recovered does not affect the output or electrical efficiency of the plant.

By using this state-of-the-art heat recovery systems fitted to combustion engines, the production of desalinated water would be fully flexible and independent from that of large amounts of power. In the low season, a reduced number of generating units could be employed, providing the needed amount of power, enough steam for the multi-stage flash distillers; and most importantly, doing this at full nominal efficiency, with the flexibility to vary the output power at will with the flick of a switch. In addition to the previously visited benefits, the inclusion of a sizeable share of flexible power generation capacity in the form of Wärtsilä combustion engines, either in simple cycle or Flexicycle configuration, would remove the problem of off-season desalination for the Emirate of Abu Dhabi.

Conclusion

All in all, optimized adoption of reciprocating engine technology as a provider of flexible power, either in the form of simple cycle or Flexicycle plants for water desalination or just generating power could provide very significant benefits for the Emirate of Abu Dhabi. It is indeed not an optimize solution to start and stop a CCGT in a day or do partial loading on CCGT. It not only cost high operation and maintenance costs but also de-rates life time wear and tear of the machine.

Agreed that the conclusion needs more qualification to it by an integrated approach which takes the hourly dispatch pattern of all power plants in one year while keeping the forecasted demand in view, and also followings:

- Low load efficiency (at part load turbines compromise a lot on the efficiency)
- Daily cycling requirement (as $1/3^{rd}$ of the output is ramped up and down),
- Ambient conditions (high temperature and humid weather)
- Cooling requirements of turbines (combustion engine need air radiators for cooling)
- Gas compressor (additional load)

Keeping the demand forecasted and the above mentioned items in view, the only solution forward for the heavily inflexible ADWEA system is Wärtsilä's flexible power plant.

7. Smart Power System – Glove in Hand – Smart Power Generation

One good point is the optimization of the whole power system efficiency and flexibility by simply adding non-spinning reserve capacity in the form of gas-fired internal combustion engines. An overwhelmingly share of fast-reaction system reserves are provided by spinning units, namely CCGTs. These units run at part load just to keep some margin of power available, in case of demand increase or due to tripping of a generation unit. This erodes the very concept of Smart Power System. However, adding Smart Power Generation in the system is the answer to flexible power requirement for a robust grid.

Let us take a simple example, in a traditional way, reserve capacity is provided by a 400 MW CCGT plant whose electrical efficiency at full load is 55%. Such a synchronized plant can provide operating reserves only by running at part-load but it will compromise on its nominal efficiency (48%). Since efficient generating units are part-loaded to provide the operating reserves, power plants with higher marginal cost will need to be brought online to supply energy − in this case a 200 MW CCGT with an efficiency of 51%. The system with the traditional method of providing operating reserves will operate with an average electrical efficiency of 50%.

With fast-starting generating units on stand-by, there would be no need to run the efficient CCGT plant on part-load. It can be run at its optimal load (corresponding to an efficiency of 55%), as the operator will feel secure with the comfort of having fast start-up plants that can be deployed instantly for reserve capacity. Hence, the overall electrical efficiency can be raised by 5 percent units. The comparison between the 'traditional' way and this 'new way' is illustrated in Figure **16**.

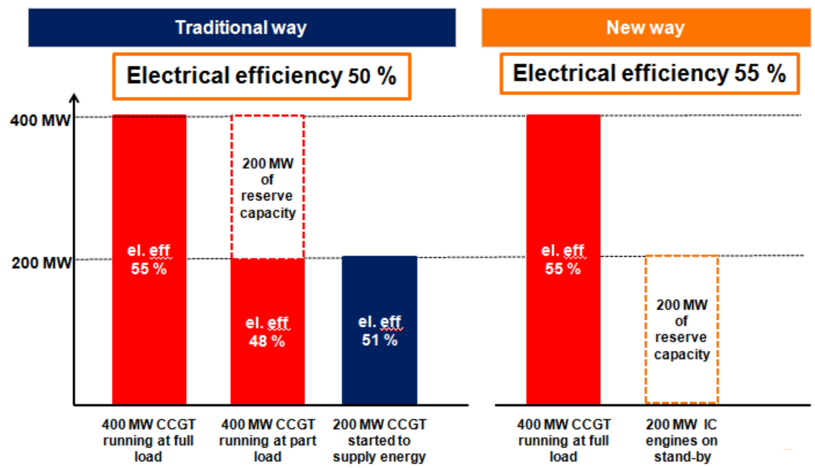


Figure 16: Power system optimisation with non-spinning reserves **(Hultholm, 2014)**

The question of increasing the quality of power system reserves is not a trivial one. The paper 'Non-spinning standby reserves enabling an efficient power system' (Hultholm, 2014), presents in deeper detail the case for reserve optimization in the Middle East by means of an expansion of non-spinning reserve capacity which is flexible. The subsequent substitution of current spinning reserve-providing generators, mostly CCGTs, by combustion engines with far superior dynamic capabilities and, can provide an enhanced security of supply without the need for the generator to be operating at part-load at a reduced efficiency, wasting fuel and producing unnecessary emissions.

Continuing the trend of several professionally-conducted technical analyses (KEMA, 2012), the frequency stability capabilities of combustion engines enable, in many cases, the replacement of all existing secondary reserves (in our case, provided by part-loaded CCGTs) with non-spinning, fast-ramping combustion engines with short start up times. Such a replacement would not impact negatively the power system behaviour. On the contrary, the ramping capability of the non-spinning combustion engines can considerably improve the frequency recovery in case of a generation trip (Hultholm, 2014).

As exposed by the previous three examples, although potential efficiency gains derived from the implementation of Wärtsilä technology are in the range of 2 to 3 percent for baseload plants, but the biggest potential lies in mid- and peak-load plants providing flexible generation as the cornerstone of an Smart Power System. This way, the potential gains can be as high as 30 percent due to clever reserve optimization. By concentrating IPP tenders in the baseload category, the GCC is forgoing much of the economic gain that IPPs could provide, as highlighted by Booz&Co. in their latest report about the topic (Sarraf;Gardner;Fayad;& Decker, 2010) Rethinking the concept of national power grids, moving towards the concept of Smart Power Systems, is a gateway to important savings while at the same time adapting grids to the 21st century. Especially in the case of utilities in the Middle East, the consideration of Smart Power Generation as a very competitive technology for upcoming tenders is, in the opinion of the authors, supported by the plethora of facts, existing analyses and success cases, the best path to savings.

All in all, a smart way forward for a Smart Grid System is the augmentation of Smart Power Generation.

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