Combined Cycle Power Plant Advantages in Long Term Maintenance Agreements

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0. Abstract

The electricity consumption and GDP is increasing rapidly in Asia. The economy growth happens primarily in Asia, electricity power need to be supported for industrial and residential use. Supporting electricity for the power is required with the lowest harm to environment and safety. Power plants need to be reliable to support big amount of electricity and produce less emission. Thermal power plants are majority of choice for power plants.

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP growth rate</th>
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</thead>
<tbody>
<tr>
<td>Macau</td>
<td>11.9 %</td>
</tr>
<tr>
<td>Mongolia</td>
<td>11.8 %</td>
</tr>
<tr>
<td>Laos</td>
<td>8.3 %</td>
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<tr>
<td>China</td>
<td>7.7 %</td>
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(N.B. Sourced by World Bank)

Asian countries are the fastest growing economies in the world
- China & India are impacting economies since early 1990's
- Electricity consumption & capacity is increasing fast with GDP

Natural gas is widely used in thermal power plants under high efficiency and less emission. Combined cycle power plants are consecutively increasing. Investors face many variables in combined cycle power plants and knowledge related to life-cycle power plants must be attained. High availability and reliability during life-cycle of the power plants are crucial factors. In order to receive high availability and reliability, operation and maintenance of power plants must be at its best service.

1. Introduction

Thermal power plants generate 66% (3,354GW) electricity globally and 71% in Asia (1,348GW) by 2010. The great development LNG has had recently in the world market is mainly due to the use of gas as fuel for power stations. A significant number of countries without a gas market see in LNG an opportunity to attend the growth of electricity demand. A successful integrated LNG and power project deals with many levels of complexity. It requires an efficient and rational technical design, a realistic LNG supply strategy, and a business model that synchronizes properly all the commercial terms of the different contracts.

Even though the technical components of the generation system based in LNG are well known and well established, not all projects manage to fulfil their objectives in time and within budget. Commercial aspects and market conditions have a significant influence in the success probabilities.

Investors face long-term challenges in the electricity markets. The contract of the service is one of the challenges many plant owners face. Understanding and determining the Life Cycle Cost (LCC) of the power plant will develop the realistic value of power plant in long term.

This paper presents the challenges that the investors face and the opportunities to overcome availability and reliability through Operation & Maintenance (O&M) agreement.
2. Electricity Market in Asia

The electricity market has been implemented in many countries and regions in the world. The electricity consumption is continuously increasing in the world especially rapidly increasing in Asia. China is top electricity consuming country (2,592 Mtoe, 21.7%) in the world followed by the United States of America (2,276 Mtoe, 19.1%) in 2012 whereas China was the 2nd country with highest electricity consumption (924 Mtoe, 10.1%) and the United States at 1st (2,354 Mtoe, 25.6%) in 2000. Within 12 years of gap, China has consumed almost tripled of electricity while the U.S. increased its consumption of only 3%.

The thermal power plants in Asia have the highest installed capacity with 1,353 GW followed by hydroelectric power plant of 337 GW. The difference of installed capacity power plants of the highest and 2nd highest are more than 1 TW. The majority of power generation source is thermal which are coal, gas and oil. Out of thermal power source, natural gas is the cleanest burning fossil fuel to produce less emission. Natural gas power plants demand is becoming bigger. Asia countries have generated 994 TWh in 2010 and 1,066 TWh in 2011. The IEA announced “The Asian natural gas market is the fastest-growing gas market worldwide, and is expected to become the second-largest by 2015, with 790 billion cubic metres (bcm) of natural gas demand” from Developing a Natural Gas Trading Hub in Asia.

2.1 GDP and increase of power plants

Asian countries are definitely in need of new power plants in order to meet the Gross Domestic Product (GDP) growth. The GDP growth rate shows the countries are economically developing in terms of production, income and expenditure. Developing countries require electricity support on the growing economies of building new power plants for commercial and industrial purposes. As from above figure, Asian countries’ GDP growth rate in 2013 is greater than others. Standard Chartered Bank announced “Asia developed economies and Asian countries are outperformance against weak global backdrop.”

Consumption of electricity is increasing fast in Non-OECD countries of the world while the OECD countries are more of neutral by slow economic growth and small number of expanding populations. Developing countries of Non-OECD countries are focused in Asia. China and India have been the fastest growing economies since early 1990’s. Electricity consumption in Asia is increasing rapidly supported by China and India of developing countries by strong economic growth and expanding populations. In 2040, Energy Information Administration (EIA) issued China is expected to consume 8,724 Mtoe in 2040 while China consumed 2,592 Mtoe in 2012 from International Energy Outlook 2013.

![Power Consumption and GDP in China](image)

All power source of the generation is expected to increase over the time. Thermal power plants take more than 70% of energy source in Asia. Out of thermal power sources, coal takes the biggest capacity
at the moment. The rapid increase of energy consumption is directly related with environment and safety which brings major threat to the environmental and climate problems over the world. With high local regulations and restrictions, natural gas power plants are the fastest growing source of generation due to the environmental benefits compared to other fossil fuels that can generate electricity. All power sourced power plants are expected to increase its capacity over the decades and natural gas is expected to be the fastest growing energy source other than renewable. In thermal power plants, combined cycle power plants are rapidly growing in the world market due to the low operating cost with less emission.

2.2 Power Plant Life Cycle Cost

The long term profitability of power plant of life cycle must be considered instead of power plant at new and clean condition value. Determining of Life Cycle Cost (LCC) is a crucial factor for the planning on the investments in new power plant. Nonetheless, the key criteria when choosing the optimal power generation technology are still the basic parameters of net present value (NPV) of project cash flow, the internal rate of return (IRR) in relation to the perceived risk of the investment, and pay-back time. Hence, understanding the concept of LCC, as well as the accuracy of the assumptions underlying the LCC calculations, remains crucial for power industry decision makers.

The availability, reliability and load curve would have the crucial influence on the LCC. The up-front acquisition cost is usually the most easily quantifiable and also the largest factor in the LCC; however, the list of parameters varies which are crucial factors:

- Capital cost related parameters
  - Up front investment cost (equipment, buildings etc.)
  - Implementation time (engineering, development, procurement, construction etc.)
  - Debt parameters (interest during construction, interst rates, debt service reserves etc.)
  - Other costs (fuel reserves, working capital, consulting etc.)
  - Contingencies

- Fuel cost related parameters
  - Fuel price and quality
  - Plant efficiency
  - “New and clean” vs. lifetime efficiency
  - Part load efficiencies
  - Start up time and efficiency impact
  - Load following capabilities and efficiency impact
  - Plant output
  - Derating over time (heat rate and power output)

<table>
<thead>
<tr>
<th>Year</th>
<th>Thermal</th>
<th>Hydroelectric</th>
<th>Nuclear</th>
<th>Renewable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>225 (68%)</td>
<td>75 (23%)</td>
<td>20 (6%)</td>
<td>12 (3%)</td>
<td>332 GW</td>
</tr>
<tr>
<td>1990</td>
<td>389 (69%)</td>
<td>111 (20%)</td>
<td>46 (8%)</td>
<td>19 (3%)</td>
<td>565 GW</td>
</tr>
<tr>
<td>2000</td>
<td>602 (71%)</td>
<td>172 (18%)</td>
<td>70 (7%)</td>
<td>35 (4%)</td>
<td>969 GW</td>
</tr>
<tr>
<td>2010</td>
<td>1,348 (71%)</td>
<td>337 (18%)</td>
<td>87 (5%)</td>
<td>120 (6%)</td>
<td>1,892 GW</td>
</tr>
</tbody>
</table>

Units: GW

- Capacity of Thermal Power Plants almost doubled every 10 years period
  - Majority of thermal power plants are coal-fired
  - Number of LNG-fueled thermal power plants are increasing since early 2000
- Renewable power is rapidly increasing since 2000
- Ambient conditions
- Operating parameters
  - Variable costs related to generation
  - Fixed fees irrespective of generation
  - Fuel flexibility
  - Availability and reliability

The availability of power plants needs to be evaluated over the life time, which can be directly and indirectly influenced by the Operation and Maintenance (O&M) concept.

3. Crucial Factors over the Power Plant Life Cycle

3.1 Challenging Markets / Competition of the power market

Power plant owner/operators face few challenges to meet the targets and schedules. Operating Expanditure (OEPX) is one of the variables of that decision would be affected. In the combined cycle power market, availability and reliability are the keys for the higher Return of Investment (ROI). In order to maximizing ROI of existing assets and increasing revenue, O&M does play an important factor. The inconsistency in performance is unrelated to the age or the manufacturer. It is critical to understand the common cause of the unavailability.

The common unavailability is based on the scheduled inspection without non-failure in turbine, generator or other small components. A power plant has scheduled inspection such as minor inspection, hot gas path inspection and major inspection.
The challenges of setting up the right strategy and motivating the organization to sustain continuous improvement in O&M should not be underestimated. Establishing a continuous improvement culture requires a very proactive attitude and cooperation with key stakeholders like OEM and O&M suppliers.

3.2 Customer Evaluation Model

The goal of all enterprises is to maximize their value by transforming monetary wealth into assets by making investments. These assets are expected to generate value and profit over their lifetime, which will spawn the monetary resources necessary for future investments. In order to quantify value generation, the metric of cash flow is used. The cash flow represents the sum of all in- and outgoing payments in one period and thus reflects the changes in the asset’s value. The evaluation is based on LCC to determine customer value generation over the life time of product or project.

One of the fundamental investment principles is the fact, that money loses value over time and that the value of future money is related to the risk of its investment. The comparison of the limited expected earnings of a low-risk savings account with those of a more risky investment in shares, where the expected earnings may be higher, but where you could also face the complete loss of the investment. The principle is considered in LCC evaluations by using present value to determine today’s value of a future or past monetary value.

\[
\text{Present Value}_{(\text{Period } n)} = \frac{\text{Cash Flow}}{(1 + \text{Interest})^n}
\]

The competitiveness and profitability and thus the ability of a power plant to generate value for its owner are influenced by a range of key factors, which can be divided into the areas of capital investment, technical characteristics/performance and operating cost. These factors and their development over time are represented by the positive (earnings) and negative (cost) cash flows evaluated in a LCC analysis. Some of these factors can be precisely determined, some of them are volatile and can only be vaguely mapped and especially the prediction of their future performance may be associated with a relatively high degree of uncertainty. This uncertainty also affects the validity and sensitivity of the evaluation metrics at changing economic boundary conditions.

Different power generation market structures and changing economic boundary conditions worldwide lead customers to employing different metrics and evaluation approaches for the valuation of a power plant project.

4. Reliability / Availability

Reliability is the ability of the Gas Turbine / power plant to consistently perform its intended required function on demand without degradation and/or failure.

The availability factor of a power plant is the amount of time that it is able to produce electricity over a certain period, divided by the amount of the time in that period. Occasions where only partial capacity is available may or may not be deducted. Where they are, the metric is titled Equivalent Availability Factor (EAF). The Availability Factor should not be confused with the Capacity Factor. The Capacity Factor for a period will always be less than the Equivalent Availability Factor for the same period. The difference depends on the utilization of the power plant.
The availability of a power plant varies greatly depending on the type of fuel, the design of the plant and how the plant is operated. Everything else being equal, plants that are run less frequently have higher availability factors because they require less maintenance. Most thermal power stations, such as coal, geothermal and nuclear power plants, have availability factors between 70% and 90%. Nowadays plants tend to have significantly higher availability factors, but preventive maintenance is as important as improvements in design and technology. Gas turbines have relatively high availability factors, ranging from 80% to 99%. Gas turbines are commonly used for peaking power plants, co-generation plants and the first stage of combined cycle plants.

The capital costs for the Combined Cycle Power Plant are converted to annualized payments. An investor-owned utility or independent power producer must recover the cost of its investment and a return on the investment, accounting for income taxes, depreciation rates, and the cost of money. These variables are encapsulated within an annualized capital cost for a project computed using a “capital charge rate”.

Combining the annualized capital cost with the annualized operating costs yields the total estimated annualized cost of a project. This annualized cost is divided by the projected yearly output of electricity to calculate a cost per MWh for the Combined Cycle Power Plant.

The reduction of the availability of a Combined Cycle Power Plant will have a direct and substantial impact to the ‘Internal Rate of Returns’ as well to the ‘Net Present Value’ even when keeping all other levers stable and equal. The financial losses for the owner may be possibly increased by paying penalties according to the ‘Power Purchase Agreement’ due to lower availability of the power plant.
5. Maintainability – a prerequisite for enhanced power plant availability

The SGT-8000H series was from the very beginning intended to not only achieve more than 60% combined cycle efficiency but also to meet flexibility requirements while maintaining the robustness and reliability of the existing design heritage – which meant e.g. avoiding the application of risky new technologies.

Large generation projects represent large assets with huge 3-digit million figures of long term fixed capital. To go for such an investment it is crucial to focus on the following main topics:

- Maintaining functionality and performance
- Ensure low maintenance cost and service downtimes
- Maintain competitiveness in the market (e.g. merit order)

The Siemens 8000H product line is designed to serve all these needs.
In general the SGT-8000H design does not add complexity to the plant in form of additional systems, vessels or other equipments compared to e.g. a 4000F. In the long run, every system that has to be maintained and serviced, can fail and lead to downtimes and repair efforts.

While the typical long term service contract does cover the gas turbine, and possibly steam turbine and generator, the responsibility for all other systems will go over to the plant owner after the warranty phase. In the long term any need for (additional) hardware, will amount to a significant effect in the business case of a plant owner by increased maintenance cost and lost revenues due to unexpected downtimes.

One great feature of the SCC-8000H power plant solution is its design for serviceability, going far beyond the service of the turboset alone. More than two decades of Siemens combined cycle power plant design in combination with many O&M customers led to a deep knowledge within Siemens, how to actually design a plant in such way that every aggregate, system or measurement location can easily be accessed and maintained. In combination with preventive or condition based maintenance schemes this gives a long term advantage to the plant owner. A prominent example is the Siemens single shaft layout.

Besides the plant design, the maintenance features of the gas turbine itself, of course, also ensures low service downtimes – not only in case of scheduled maintenance but especially for unscheduled service activities. Apart from the blade path features as outlined above the unique Siemens rotor design actually allows rotor maintenance to be conducted on site.

Due to the rotor assembly with a central tie rod and self-centering rotor discs with Hirth serration (see pictures), the rotor can be destacked on site and put back into the engine without the need for shipment to a factory and test-run in a balancing pit. This eliminates the need to secure a spare rotor to avoid long periods of downtime. The rotor-destack feature has been proven on the 4000F fleet – as an additional check, after the prototype testing of the SGT5-8000H in Irsching Siemens did a complete rotor destack on site. This served to test the tools, establish procedures and train personnel to do such maintenance.
Siemens possesses extensive experience, spanning over 60 years, in the design, manufacture, operation and maintenance of its range of gas turbines. All Siemens Field Service Engineers are comprehensively trained in house, continually assessed, and are qualified to ISO 9002 standards. Only Siemens employed engineers are provided with a ‘capability passport’ that records all of the training, qualification and competency skills that the individual employee has successfully completed during her/his career with Siemens. The ‘capability passport’ is the customer’s assurance that the engineer who was sent to site is fully conversant with the engine type and has the necessary up-to-date skill-set to properly maintain customer’s turbine. Many of Siemens field staffs are qualified across engine types and technical disciplines, with extensive experience in the maintenance of your particular type of installation.

Siemens has the processes and expertise in place to ensure that necessary repairs do not lead to a slow down of customer’s operation. By cooperating closely with the customer, Siemens anticipates potential maintenance requirements and subsequently plans time- and cost-effective ways to implement those. Whether the issue is replacing a defective valve, unblocking a pipe or overhauling a turbine, the customer can rely on Siemens for fast, effective and comprehensive maintenance that will keep customer’s productivity at its maximum.

- Strong knowledge base
- Highly skilled OEM specialists
- Strong operations and maintenance teams
- Customer specific training

- Strong engineering base
- Planning and preparation procedures
- Best in class implementation

- Harmonized knowledge base for global services
- Globally harmonized data base: data sheets, specs, procedures, etc.
- On-site quality systems supported by central functions

- Integrated tool process for best performance
- In-house engineering & design, validation and maintenance
- Outage specific tool sets, Special tools and customer tools for optimized service
Projects and processes

Occupational safety and health management are key elements of Siemens’ sustainable strategy and an integral part of the business processes. Siemens, therefore, develops central projects and processes that are then applied locally in conjunction with programs that are individually adapted to the respective business activity. Occupational safety and health management are an integral part of Siemens’ Business Conduct Guidelines, internal monitoring systems, and risk management and internal control systems. In addition, occupational safety is part of an international framework agreement between Siemens AG, the Central Works Council of Siemens AG, IG Metall and the global union IndustriALL.

Culture of safety

In the past, occupational safety was often characterized by focussing on technical protective measures, an approach which achieved considerable success. Siemens is convinced, however, that further improvement can be achieved only through an actively practiced occupational safety culture and optimum working conditions – in every country and for all Siemens employees as well as those of Siemens’ contractor partners. Both as a company and as individuals Siemens is responsible for ensuring that the working environment is safe at all times and for every employee. At present, local best practices exist, which Siemens can build on. Siemens will achieve sustainability, however, only through a global and consistent approach. And Siemens are convinced that this approach will greatly benefit Siemens’ customers worldwide.

Customers, suppliers and regulatory authorities expect high safety standards. Safe behavior is governed not only by complying with laws, regulations and procedures, but also by the personal values of managers and employees. Therefore, Siemens launched the Zero Harm Culture @ Siemens Program in fiscal 2012 to improve safety performance. It contains three principles:

- Zero incidents – it is achievable.
- Health and safety – no compromises!
- We take care of each other!

In the last decade and following market developments, the business relationships between customers and original equipment manufacturers (OEMs) of power plants have shifted toward longer-term cooperation. This is particularly due to the rapid development of high-efficiency components, for example gas turbines, using the most advanced technologies and materials. The more sophisticated power plant components become, the more attention is required during operation to avoid the risk of abnormal behavior. This conclusion has led to new forms of cooperation between customers and OEMs. Siemens Power Diagnostics™ Service is one important outcome of this development. With new high-performance equipment being introduced in the market, customers require Operation and Maintenance
(O&M) programs and Long-Term Programs (LTP). These programs are designed to cover the greater part of the equipment lifetime or the entire combined-cycle plant – occasionally even including some risk-sharing of certain repair costs with an OEM.

With both types of programs, customers are able to better plan operational costs during the service program period. At the same time, the boost in information technology facilitates the secure transfer of large amounts of data over long distances – thus enabling the OEM to use remote monitoring to help customers detect possible impending operational problems. This can minimize unplanned outages and maximize power generation availability.

### Power Diagnostics® services …

- Regular documentation of machine conditions
- Access to the Siemens Expert Network
- Early detection of operating issues
- Information for proactive corrective measures
- Condition-based maintenance
- Flexible operation
- Efficiency / Availability / Reliability Improvement
- Timely repair planning
- Risk sharing, extended warranties
- Performance related payment
- Cost savings

### 6. Operation & Maintenance Concepts

Increasing electricity demand and environmental concerns have emphasized the need for power plants to operate cleaner and more efficiently. As a result, power plant developers, owners and operators are creating new strategies and examining a wider range of options that will enable them to:

- Cut operating costs without endangering the quality and reliability of their product
- Maximize online performance
- Reliably meet changing daily requirements
- Reduce unscheduled downtime to nearly zero
- Meet even more demanding environmental and safety standards
- Compete successfully in an increasingly competitive market
- Generate higher profits.

Whether an independent power producer, a public utility or a manufacturer producing their own power, Operation and Maintenance Services (O&M) by OEM can help to boost the operating efficiency, reduce down time, mitigate risk, widen competitive edge, maximize performance and increase profitability.
With more than a century of service to the power generation industry, Siemens brings to every project a tradition of experience, quality and expertise. In fact, Siemens’ O&M fleet experience totals more than 21,500 MW worldwide. That translates into advantages for the customers, including access to a wealth of management skills, the very latest in power generation technology, extensive O&M knowledge and much more.

Siemens Energy offers innovative solutions to meet customers’ needs, including:
- Performance-based contracts for availability, output and efficiency
- Payment plans based on the plant’s operating hours
- O&M Services with a two-phase approach to long-term quality plant performance.

A successful relationship begins during the pre-operational phase of plant construction. Ideally, this initial phase encompasses a period of about 12 to 18 months prior to scheduled commercial operation. During this critical preparatory phase, Siemens can provide:
- Plant staffing
- Comprehensive personnel training, supported by the use of state-of-the-art power plant simulators
- Operations and maintenance reviews to finalize customization of project specific requirements
• Development of site-specific procedures and management techniques for practices and processes that encompasses plant organization, procurement, operations and maintenance, safety and security requirements, as well as quality control and communications
• Initial spare parts selection, supplies and materials purchase, including balance-of-plant spares and consumables
• Procurement of tools, supplies and shop equipment
• Procurement and set up of a plant management system or computerized maintenance management system and predictive maintenance program
• Plant start-up and testing support
• Communication with the project turnkey supplier and plant owner at every stage of pre-operation activities to help ensure on-time commercial operation.

Operation and maintenance phase begins with plant commercial operation. To maximize operational performance from day one, Siemens provides experienced personnel to manage and operate the plant. Then, as day-to-day operation continues, Siemens can provide:
• Development of an annual operating plan
• Plant administration and accounting
• Coordination of power production interfaces (i.e. fuel supply, operating permits, power dispatch directives and other activities)
• Maintenance of warehouse and office supplies, as well as materials and services relating to plant operation
• Scheduling and performance of routine and major equipment planned maintenance
• Parts repair and replacement
• Support owner’s interaction with local government/regulatory officials as necessary
• Community relations to maintain the plant’s image as a “good citizen” in its community
• Administration of subcontractor services
• All required reporting as mutually agreed upon with the plant owner
• Online diagnostics and monitoring as appropriate
• Best access to plant upgrade opportunities as new products, methods and techniques become available.
7. Conclusion

With a performance-based market structure, when plants are managed as profit centers, it is necessary to strategically improve efficiency, optimize capacity, minimize costs and maintain a high reliability in order to be competitive - especially when it comes to aging plants.

Unexpected outages of combined-cycle plants can result in high costs for repair and replacement, reduce plant availability and cause a loss in net revenue.

Providing flexible maintenance programs, Siemens ensures a significant enhancement of customers’ profitability.
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References