All electric LNG plants
Better, safer, more reliable - and profitable

Power and productivity
for a better world™

Abstract

Electric drives normally have a better impact on the environment and greater flexibility than gas turbines in compressor applications. However, increased availability, better control, improved energy efficiency, and shorter delivery times are even more attractive benefits – and they are now well documented. Although electric drives require a higher initial investment than conventional gas turbine drives, they also have much lower operating expenses, and that leads to large savings when electric drives are factored in at an early stage in the plant's design. These savings result from increased up-time, lower maintenance costs, increased shaft power efficiency, lower fuel gas consumption, and increased emissions control.

ABB recommends the use of its All Electric Drive systems to free up the mutual sizing constraint between the refrigerant compressors and the gas turbines and thereby improve the configuration of power generation and process heating, overall energy efficiency, operational flexibility, and maintainability. ABB's Power Management System unifies control over the entire power generation system.

The All Electric Drive systems deliver benefits for any high energy consuming process within the gas value chain, including processing facilities, compressor stations, LNG liquefaction plants, and CO_2 injection.

Håvard Devold, Tom Nestli & John Hurter,

More efficiency plus less downtime equals huge savings

A modern 6–8 MTPA (million tons per annum) LNG liquefaction plant typically requires four large compressors with 60–80 MW of rotating shaft power. This power can be provided by either gas turbines or electric drives.

As shown in Table 1, the two types of drive systems demonstrate some radically different characteristics (data up to end of driving shaft).

Comparison of gas turbine and electric drive characteristics

Characteristics	Gas turbines	Electric drives
Weight and space	Light unit but space and weight consuming auxiliaries	Similar to that for gas turbines
Minor maintenance cycle	4,000 hours	25,000 hours
Major maintenance cycle	20,000 hours	100,000 hours
Minor maintenance duration	6 – 10 days	1 – 2 days
In operation system MTBF	≈ 4,000 hours	> 25,000 hours
Control response	Slow	Medium to quick
Efficiency	Narrow peak range	High over wide range
Logistics (delivery time)	3 – 4 years	1 – 2 years
Average operational efficiency	25%	40%

Table 1 Comparison of gas turbine and electric drive characteristics

This article discusses the benefits of the all electric plant in detail and describes the ways those benefits are realized. The initial cost (CAPEX) for an All Electric Drive facility is typically higher than for a gas turbine drive facility. But, as the example later in this article shows, the All Electric Drive system can save 3–4 times the CAPEX value on an annual basis. Typical payback time for the All Electric Drive system may be as low as four to five months!

Plants throughout the gas value chain are increasing rapidly in size. For example, an LNG process train designed with capacity of 4 MTPA has a shaft power requirement of 35 – 38 MW/MTPA. At 4 MTPA, the daily value of produced LNG is about $1.5 million. As will be shown later, the use of an All Electric Drive system reduces the shaft power requirement, while improving regularity, improving plant safety, and lowering both operational and capital costs.

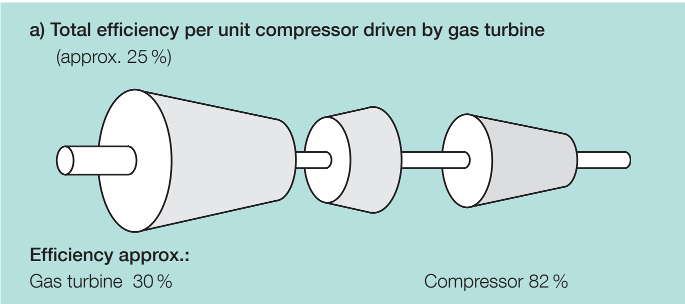
Where does the electric energy come from?

For LNG plants, except in rare cases, electric energy is not available from a nearby power station or reliable public grid. However, it can be produced in the plant itself by utilizing large commercial power generation gas turbines in the 100+ MW range. In a combined cycle power plant, the fuel to electric energy efficiency is much higher than that obtained if operating in single cycle with modified aircraft turbines in the 25+ MW range (which is the typical configuration when a gas turbine is used to drive a compressor directly). Local power generation is sufficient to cover the needs of an All Electric Drive system. A 4 MTPA LNG facility has a power requirement equal to an industrialized city of about 100,000 inhabitants. Thus, it would be attractive for most general utility companies to provide the power by extending their existing (triple cycle) facilities, e.g. with a gas-for-power outsourcing arrangement. In the developing world, the facility can provide electric power to rural areas and emerging industries. This would allow the power requirement to be optimized over more consumers and available sources.

Lower taxes, lower energy consumption

A variable speed industrial gas turbine in the 25 MW range driving a compressor train typically has an efficiency of up to 30 percent. However, this efficiency is reached only at peak performance. Even if some process trains are stopped to optimize operation of the others, the average operational performance quickly falls to about 25 percent.

A corresponding electric drive system achieves an efficiency of around 95 percent over quite a wide range. In addition, the efficiency of gas turbine driven power generation is typically about 47 percent, but climbs as high as 55 percent for a combined cycle plant and more than 80 percent with triple cycle (district heating or water desalination). Thus, even in a configuration that is not fully optimized, where the efficiency of the gas turbine is about 25 percent, an electric drive system achieves 36 percent (see Figure 1).



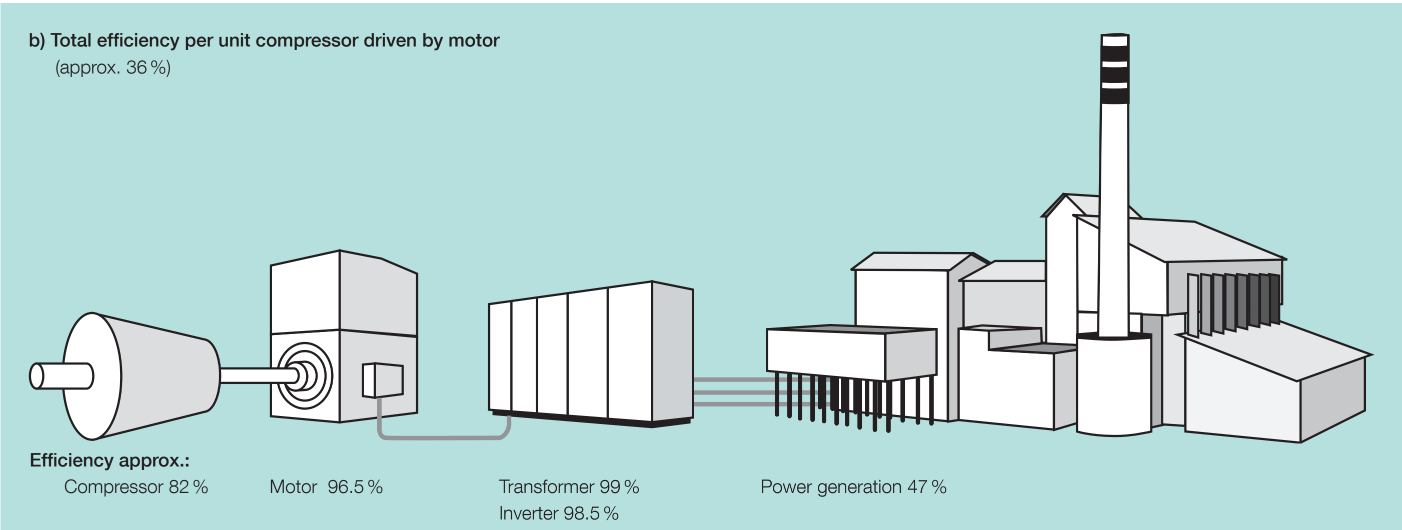


Figure 1 Efficiency per unit of centrifugal compressor driven by motor and gas turbine indicates total efficiency for motor and gas turbine driven systems, respectively

In the 6.25 MTPA LNG facility described in the example on page 6, and assuming a power requirement of 200 MW, a gas turbine driven system consumes 650 million SCM (standard cubic meters) of natural gas annually, whereas an electrically driven system consumes only 450 SCM of natural gas. The 30 percent difference in fuel consumption allows another $45 million of gas to be sold (at $200/ton) and means carbon-dioxide emissions are reduced by about 360,000 tons.

Under the current European Union carbon dioxide emission quota regime, an All Electric Drive system saves about 14 Euros per ton (as of mid-May 2006) or $6 million annually.

Hence, the savings in taxation and consumption of fuel gas at the prevailing market prices adds up quickly.

Ten more onstream days per year

The average minimum maintenance interval for gas turbines is six months or 4,000 hours. The turn-around time is typically a week for inspection and additional time for actual maintenance work. Further, the in-operation mean time between failures (MTBF) is also in the range of 4,000 hours. This interval is significantly lower than that required for the compressor or turbo expander. For our discussion, we can consider the gas turbine drive system the major contributor to unavailability with about three weeks annually required for periodic planned maintenance and another three weeks for unplanned corrective maintenance.

A gas turbine driven train configuration is normally N+1; that is, all the drives required for full capacity (N) plus one spare drive. This configuration provides one backup unit in case a primary unit fails or has to be maintained. The CAPEX due to the redundancy is balanced by the gains made from increased uptime. For a 5+1 system this means that at least one train will be in maintenance for about 57 percent of the time. While planned shutdowns can be delayed, an unplanned shutdown can occur with a probability of about 6 percent resulting in a capacity loss of 20 percent until at least one unit can be brought back on line – in roughly ten days. The result is about 12 lost stream days per year in total capacity.

The electric drive system typically has a minor maintenance interval of three years or 25,000 hours [1], [2]. The in-operation MTBF is higher than this interval, and also higher than the driven equipment. Thus, the electric drive system has a limited contribution to the overall system MTBF, with availability higher than 99.9 percent. The drive is air or water cooled, and the support systems (lube oil, cooling water, and instrument/purge air) are simpler and less failure prone than those for gas turbine systems. They also require much smaller volumes than support systems for the compressor, so the electric drives can be fed from the compressor systems at minimal additional costs. Sound levels, important in the labor safety regulations of some countries, are also much lower.

On the other hand, we must factor in the possibility that power can be interrupted during operation of the All Electric Drive system. Power interruption in an All Electric system will typically lead to a shutdown of the entire plant. For this type of system, we therefore have to factor in unavailability figures for the entire plant.

With all these factors considered, the net gain is approximately ten onstream days for the all electrical over the gas turbine drive system, leading to large savings, as will be shown later.

ABB also offers a thermal and electrical power management system and an asset management system to monitor and diagnose the condition of equipment. Together, these systems move maintenance from periodic/preventive to predictive. An all electrical system is well suited for predictive maintenance, which has been demonstrated to lower maintenance costs by up to 80 percent [3] and decrease downtime due to planned and corrective maintenance by about 75 percent (ABB benchmarking). Of course, the nature of LNG plant operation requires that maintenance and shutdown be planned. Predictive maintenance can most often not be applied between planned shutdowns, but can be used in connection with them.

Better surge performance and safety

The main operating parameters for a compressor are the flow and pressure differential. At lower flow, there is a minimum pressure differential before the compressor surges. Recirculation is used if variations in flow are expected or if there's a difference between common shaft compressors. The surge response is determined by the volume of the recirculation system, the surge loop response, and the overall system response time. A faster speed control response time improves surge performance and allows the system to operate with less recirculation.

An electric drive system significantly increases the response time and offers a much wider efficient operating speed range than a gas turbine. As a result, the electric drive system balances power requirements faster and better between different sections of the process. Tighter control means higher overall process efficiency and safer operation, with increased overall efficiency and less wear on equipment due to excessive stress.

In addition, recirculation causes energy loss and increased fuel consumption. The All Electric Drive system can operate with significantly less recirculation than a gas turbine driven example due to tighter and faster control. In, for example, a five-train operating scenario where two trains are out of balance, and one of two compressors on three trains is out of balance, and in which the recirculation is 5 percent, an All Electric Drive system will save 3.5 percent or another $5 million/year in fuel consumption.

ABB has patented a “no surge” principle whereby compressors can be safely controlled in surge even without recirculation facilities. Although the no-surge principle is not currently operating in any plant, the information gained from ABB’s research is currently enhancing control over surge, helping to avoid recirculation during normal operation, and opening up opportunities for reduced anti-surge equipment costs and operation in subsea applications.

Unified power management

ABB’s All Electric Drive system is enhanced by a Power Management System (PMS) that handles dynamic electric load balancing, rotating reserve, and fault restart. The Power Management System unifies control across the entire power system, including generation, motors, transformers and switchgear, taking into account the operational requirements and priorities of loads including large compressors. This unified system simultaneously balances and controls these critical systems within the optimum process envelope, achieving increased productivity, stability, and safety.

A full shutdown in an LNG plant creates both a safety hazard and a major loss of production. It takes up to 48 hours to come back on line, or more than $7 million in lost production for the 6.25 MTPA plant of the example on page 6. The Power Management System uses a network matrix representing its “knowledge” of the electrical network topology and dynamic state and a network determination function to calculate the electrical network contingencies. This calculation is performed within milliseconds to adjust power control, load shedding, and re-synchronization/restart functions and to prevent a full shutdown.

In case the plant is connected to an external utility grid, the power exchange with the external grid is optimized based on a sliding 15-minute power demand forecast that predicts imported (or exported) power and compares it with contractual agreements, time of day, average and peak demand, etc., and then adjusts internal power generation or consumption accordingly.

OPEX savings of 70 percent or more

A straightforward replacement of gas turbines with electric drives is valuable. But even more value is gained if the plant configuration takes full advantage of the characteristics of electric drives.
For example, gas turbines are generally available either in two sizes: less than 30 MW variable speed units or large 100 MW or more fixed shaft speed units. Electric drives are available in wide power and speed ranges up to 100 MW. Thus, the All Electric Drive system has much wider design flexibility in terms of size of trains, compressors per train shaft, and the possibility to separate smaller essential units. The plant design should take advantage of the opportunities presented by the All Electric Drive system.

- The average size of each train can be increased and the number of trains can be reduced. This change is possible because electric drives increase the overall uptime and reliability of trains significantly.

- Safe and stable operation can be maintained over a wider range of process states. Because electric drives have a wider control range and because the number of shafts and compressors per shaft are reduced, plant stability and uptime both improve. Most plants do not allow emergency shutdown during operation, as this represents a safety hazard. Also the plant restart time would be 50 hours or more. With electric drives, the plant can go to a production hold idle recirculation mode.

- The possible sources of power are wider. The plant can generate its own electric power or use outsourced electric energy. Power surpluses and demands in the area should be studied to take advantage of rotating reserves and off peak times. The All Electric Drive system can get power from hydro, nuclear, or triple cycle grid power.

- The overall efficiency of such a plant can lead to OPEX savings of more than 70 percent for the scope of work discussed in this paper. For LNG plants industry goals are currently to reach a 7.2 percent ratio of field gas consumption to LNG production. An All Electric Drive system is the only way to reach that ratio.

Conventional 6 x 30 MW GT + El 2 x 30 MW GT

200 MW Combined Cycle + 4 x 40 MW drives

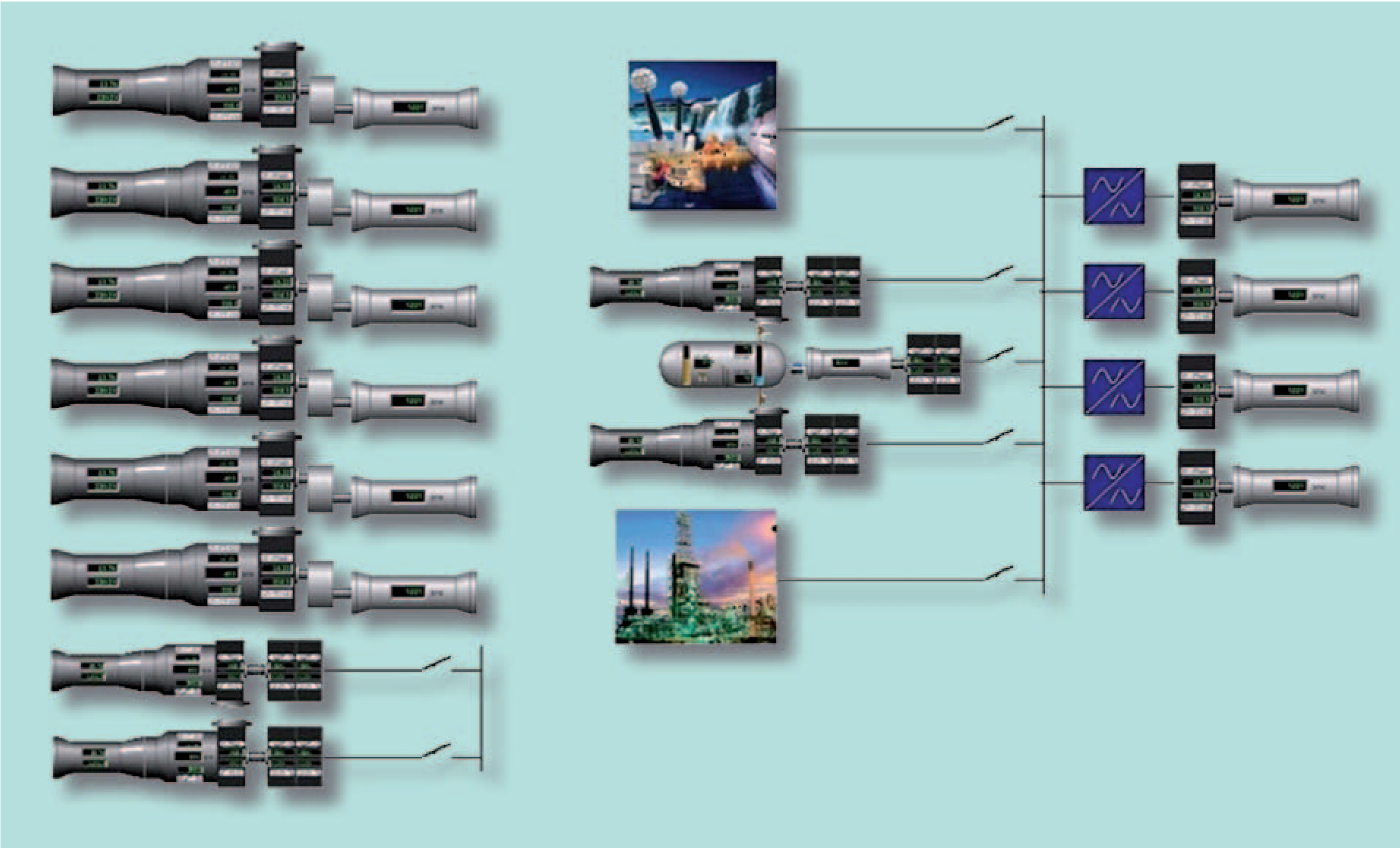


Figure 2 Reference system gas turbines vs. all electric

Typical design case: $97 million/year savings

As an example, consider a 6.25 MTPA LNG plant with shaft power requirements of 32 MW/MTPA. Figure 2 shows a simplified diagram of the main components of a conventional gas turbine system and of an All Electric Drive system. The following discussion assumes a requirement of 150 MW for the main trains and 50 MW of electrical power, including smaller electric drives with a 1.75 TWh annual shaft energy requirement.

The conventional gas turbine system has six 30 MW gas turbine driven trains in a 5+1 configuration plus two 30 MW electrical power generation units.
The All Electric Drive configuration has four 40 MW trains, fed by a 200 MW power plant that's designed to capitalize on the efficiencies of electric drives. In addition, we have included three 10 MW smaller drives for both systems. The calculations in Table 2 are based on the maintenance cycles and efficiencies given previously and on standard values for gas energy content and emissions. With an All Electric Drive system, the effect of tighter control and better balance results in lower recirculation losses with an estimated benefit of $5 million/year. Maintenance, unavailability, and reduced downtime benefits typically give ten additional production days equaling $36 million/year. Figures are indicative and provided to show the relative impact of benefits; they will vary based on the actual design and various constraints. The cost of gas turbines is currently volatile and highly influenced by delivery times. It can be significantly higher than shown.

Annual savings using an All Electric Drive system

Characteristics	A. Electric Drives	B. Gas Turbines	Difference
CAPEX system cost[1]	Main drives $30 million Power plant $35 million Aux. drives $7 million	Main GT $25 million Power plant $14 million Aux. drives $7 million	$26 million
LNG production	6,250,000 tons/year	6,250,000 tons/year	
Maintenance costs	$5 million/year	$10 million/year	$5 million
Shaft power efficiency	36%	25%	
Fuel gas consumption	450 mmSCM	648 mmSCM	200 mmSCM
CO_2 emissions	800,000 tons	1,160,000 tons	360,000 tons
CO_2 quota cost where applicable (EU)	$13 million	$19 million	$6 million
Value of fuel gas	$100 million	$145 million	$45 million
Ten additional production days	$36 million	0	$36 million
Recirculation losses	0	$5 million	$5 million
Annual savings			**$91 – 97 million**

Table 2 Annual savings using an All Electric Drive system

[1] main drives, auxiliary drives and power generation

This calculation clearly demonstrates the value of an All Electric Drive system. The example further shows that the payback time for the additional initial investment is merely a few months.

Conclusions

With the added safety and operational benefits, as well as shorter delivery times and flexible design parameters, an All Electric Drive system is easily the logical choice, with a payback time of only four to five months. The reduced fuel consumption and greenhouse gas emissions lead to large savings in operational expenditure in addition to being environmentally sound. In this context, the environmental impact becomes an important added benefit, but even without considering this aspect, the economy of the All Electric Drive system makes it highly attractive.

References

[1] Shu, S., Christiano, F., Harrison, M.: “Electrical motors look attractive for Angola LNG,” Oil&Gas Journal, Oct. 2002.

[2] Kleiner, F., Kauffmann, S.: “All Electric Driven Refrigeration Compressors in LNG Plants Offer Advantages,“ Gastech 2005.

[3] ARC strategies, October 2000

Contact us

ABB AS
Center of Excellence LNG
Process Automation Division
NO-0604 Oslo
Phone: +47 22 87 20 00
Fax: +47 22 87 23 27
E-Mail: lng@no.abb.com

www.abb.com/oilandgas

ABB Switzerland Ltd
Medium Voltage Drives
CH-5300 Turgi
Phone: +41 58 589 27 95
Fax: +41 58 589 29 84
E-Mail: mvdrives@ch.abb.com

www.abb.com/drives