Emerging Trends in Distributed Generation

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Abstract

As electricity usage continues to grow, there is a growing trend towards distributed power generation, locating smaller power plants closer to the consumer load centers. However, a distributed generation plant has similar issues in today’s electricity networks as centralized power plants: the need for improved efficiency, reduced environmental impact (like emission control) and the flexibility to compensate for power fluctuations caused by power generation from intermittent renewable energy sources, particularly when these sources are connected to the distribution grid.

This session examines the use of industrial gas turbine solutions as part of a distributed power generation system that provides answers to the challenges mentioned above. As an example, distributed generation with gas turbines increases the possibility to utilize the waste heat from power generation, allows for fuel flexibility and at the same time offers a more flexible operation mode. Especially operational flexibility can be provided by small light industrial and aero-derivative gas turbines and their characteristics, such as fast response times via fast ramp rates, high availability and low maintenance downtimes due to the ‘core swap’ capability of specific gas turbine designs.

In addition to operational features, specific concepts like multiple or mobile unit applications, power on demand and smart grid integration help to solve regional challenges with solutions close to the consumers. Distributed power plants can also help optimize electricity network operation by providing voltage support, or reactive power and inertia to the local grid.

The session discusses specific market and customer challenges and explains concepts and project-specific solutions.
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Nomenclature

AC         Alternating Current (Power)
CAGR       Compound annual growth rate
CHP        Combined Heat and Power
DC         Direct Current (Power)
DG         Distributed Generation
GDP        Gross Domestic Product
IGT        Industrial Gas Turbine
IPG        Industrial Power Generation
LNG        Liquefied Natural Gas
O&G        Oil & Gas
OEM        Original Equipment Manufacturer
PG         Power Generation
1. The re-evolution of distributed generation

The definition of Distributed Generation (DG) is creating power close to or at the point of its use. This is actually how electricity was first delivered – small power plants served customers a relatively short distance away with low voltage DC based power distribution. The advent of industrial AC power over a century ago and the economies of scale of much larger power plants allowed the delivery electricity over very long distances. Today, electrical power distribution in most industrialized nations is accomplished by power flowing from very large power plants over massive high-voltage power grids radiating hundreds of miles from multiple sources. Coal fired generation and hydro-electric plants were the first developed, followed by nuclear and gas fired power generation.

Centralized power distributed over extensive electrical grids is still dominant but over the decades several economic, environmental, technological and legal factors have put negative pressure into this centralized system and it has led to the re-introduction and expansion of distributed forms of generation. The factors are:

- Environmental legislation and a focus on renewable energy
- Broad, diverse and growing needs for electricity
- Cost of expanding current electrical infrastructure
- Increased global availability of natural gas
- Development of distributed generation technology

The focus on the environment and associated legislation has had a two-fold effect. First, it has driven the number of coal fired production plans down significantly around the world (especially in the United States and Europe) and it has caused a general move away from nuclear power due to clean up costs and the hazards associated with them. Secondly, it has fueled the adoption of renewable, non-fossil fuel energy sources such as Wind, Solar, Fuel Cells and Geothermal power. The growing energy need and the cost of expanding the electrical infrastructure have also accelerated the trend away from a centralized grid dependent power system. Liberalization of electrical markets along with more sophisticated power demands in growing untraditional markets has made expansion uneconomical. Centralized power operators struggle to expand their infrastructure to keep up with demand and efficiency.

Growth in the capture of unconventional resources and fracking technology in North America has increased global natural gas supply. The rapid emergence of global Liquefied Natural Gas (LNG) / regasification industry has increased the supply of natural gas to regions of the world that were lacking. Substantial increase of supply with moderating global industrial demand has made natural gas a clean, efficient and affordable fuel source which is now more widely available than ever before. This has increased the value equation of gas fired distributed power generation in the form of gas turbines, reciprocating engines and micro-turbines all of which can operate in a decentralized fashion at a very high efficiencies.

The rate of development of distributed power generation technology - gas turbines, gas engines and micro-turbines has mirrored the rapid change in scope and needs of the electricity market. This paper will focus specifically on the emerging trends within the last 5 till 10 years within distributed generation as it relates to gas turbines between 3 and 66 MW. The rate of technology development of these power plants have advanced as fast as the markets they serve. In conclusion, the electricity market evolved from base load decentralized power in the 1800’s to centralized grid-based power in the last century shows now again a growing need for decentralized, specialized, on-demand distributed power.
2. Gas turbines as part of distributed generation concepts

The following section examines gas turbine developments as an important part of distributed generation concepts. The focus lies on examining the volume trends from 3 to 66 MW gas turbines in the industrial power generation (IPG) market. This range is typically used in DG concepts. From 2005 till 2011 sales of Industrial Gas Turbine (IGT) units grew at a compound annual growth rate (CAGR) of 10.8% with an abnormal peak in 2008. This was followed by a down-cycle through 2015, where the market contracted at 9.4% compounded annually. This decline bottomed in 2015 (Figure 1).

![Figure 1: Gas turbine volume trend (3–66 MW) from 2005 to 2015; based on sales volume of all industrial and aeroderivative gas turbines products sold into the IPG market from major OEMs.](image)

2016’s sales volume seemed to show a slight recovery and this upward trend is forecast to continue through 2020 barring any large macroeconomic shifts in the world economy. The < 70 MW industrial gas turbine market grew through most of the last decade but has declined in the present one (Figure 2).

![Figure 2: Seven year gas turbine volume trend (3 – 66 MW); based on sales volume of all industrial and aeroderivative gas turbines products sold into the IPG market from major OEMs.](image)
**Regional trends in recent years**

The market conditions that existed from 2000 to 2010 are markedly different from today. Countries of the major industrialized nations (North America, EU, and Asia) were focusing on building and expanding their infrastructure. The “BRIC” countries – Brazil, Russia, India and China were growing steadily and gross domestic products (GPD) levels were robust (Figure 3 and 4).

![Figure 3: Development of GDP in China [1]](image1)

![Figure 4: Development of GDP in Brazil [2]](image2)

Oil prices rose to record-breaking levels in the period between 2000 and 2013. Industrial demand was high and electricity operators met the need for power. In 2008 however, the financial crisis hit the world economy. Financial, banking and real estate markets suffered the most and many major companies failed as has been widely publicized. Project funding became scarce, consumption fell and industrial activity fell – all leading to decreased demand. This phenomenon took a few years to impact the power generation market due to its longer manufacturing and selling cycles. It is clear that the slow decline in orders for new power generation assets shown on the graphs above from 2010 till 2015 was a result of the major U-turn in global economy and the sudden slow down of growth in emerging economies. When the price for crude oil suddenly collapsed in 2014, the ripple effect pushed orders for IG Ts (< 70 MW) to its lowest point in a decade.

Following questions need to be answered in order to select the best suited technical solution for the different customer needs:

- So what does the future hold for the rest of the decade through 2020?
- What are the most recent emerging trends in Distributed Generation?
- What are some of the faster growing sub-segments of the market?
3. Regional growth of distributed generation concepts

In this section, we examine regional developments and regional growth and relate this to developments in the gas turbine market (Figure 5). In terms of volume, Asia has been the largest distributed power gas turbine market overall, led by Japan with high unit insulation of small gas turbines (< 6 MW). Many of those units are installed as back-up vs. base-load power which skews the analysis slightly but strong unit sales in Thailand and Indonesia still backs up Asia’s position. There is steady growth in Northern and Sub-Saharan Africa driven by volume in Egypt and Algeria, Nigeria, Ghana and Angola respectively. There has been very recent robust growth in Latin America and China over the last year - led by high unit volumes in the 42 to 66 MW segment. The North American, European and Central Asian markets appear to be contracting slightly as a result of the economic factors discussed in the previous section.

![Figure 5: Seven year gas turbine volume trend (3 – 66 MW) by region; based on sales volume of all industrial and aeroderivative gas turbine products sold into the IPG market from twelve major OEMs](image)

Most of the success of the first decade since 2000 was driven by positive macro-economic forces which reversed as the decade came to a close. Achieving success today and through 2020 will require specialization. Power demands need to be met whenever and where ever they arise. This type of requirement is tailor made for the distributed power product and especially for mobile and fast power.

There are two dynamics at play:

1. The world is becoming increasingly electrified and digital. In developed countries, almost everyone has a mobile communication device. The digitization of information through electronics, powered by electricity has become central to the way we live our lives. The information needed to manufacture, transact, communicate and live flows on powered networks. Digitization of information has become a pre-requisite for modern life. The need for electricity to serve the growing, complex and changing demands of industry and populations that rely on it is a global one. No access or limited access to electrical power is to live outside the confines of the modern world, a condition that will likely not be tolerated anywhere.

2. Despite its increasingly central importance, electrical power is still a scarce resource, and especially so in some regions of the world. There may be some electricity and some services but
there is a clear lack of a robust electrical infrastructure discussed in the opening paragraphs. There is still, for various reasons, the inability to deliver electricity to segments of populations reliably, if at all. There still are regions whose industries are hobbled by poor quality or insufficient power today.

**A leap into the future**

Whenever electricity demand is higher than the potential generation level, additional power generation capacity or increases in power efficiencies are needed. North & Sub-Saharan Africa, the Middle East as well as regions in Latin America and Southeast Asia lag behind most industrialized nations in electrical generation capacity [3].

![Figure 6: Generating capacity in Asia, Latin America and Africa from 1990 till 2014 [3]](image)

Thirteen percent of the world’s populations live in Sub-Saharan Africa but it represents almost half of the world’s population without electricity. In 2040, Sub-Saharan Africa’s electrical consumption is forecast to be 400% of its 2010 levels. Southeast Asia has about one quarter of the world’s population but represents almost 1/3 of those without electricity. A growing population and a growing demand for electricity has in some cases outstripped countries’ ability to supply. This is due to geography and the challenge to match generation and infrastructure to population growth. The result is that segments of the population are left unserved and other segments of the population are facing blackouts, brownouts and simple don’t have access to service. Other regions, such as Latin America face similar, but partially also unique challenges based on their existing generation capacity and infrastructure characteristics. The World Bank expects Latin America’s power consumption to double by 2030. As the population grows, larger segments of it are moving into the middle class and which drives up electrical consumption per person. However much of the infrastructure is older and cannot keep up with the increase and geographical spread of the demand. A lot of the original base load generation plants in South America were hydro-electric and with a changing climate (less rainfall), many countries in the
area are not only facing the challenge of building out distribution infrastructure but having the ability to produce enough power from existing resources.

Forecasts predict that the needs of these regions will mirror those in the more industrialized world and as information technology makes the world “smaller” access to reliable electricity will be demanded. For the economic growth to continue, all regions mentioned above will need massive amounts of power generation in order to avoid “power vacuums” and “emergency situations” where power is needed desperately and does not exist. As a result, fast and mobile power solutions are required to answer regional demand.

4. The fastest growing segment of distributed power market in range of 20 to 50 MW

We have identified why the distributed power market contracted overall after 2010 but closer study of the data revealed a significant trend in the range of the 20 to 50 MW IGT space between 2010 and today. Overall industrial gas turbine sales declined gradually from 2010 till 2015. In the 20 to 50 MW power generation space however, one sub-segment fell dramatically as another expanded exponentially. The core power output requirement was the same but the way in which the power was being used was very different. Between 2010 and 2015 the number of units sold into traditional, stationary 20 to 50 MW IPG fell by 70% (Figure 7).

![Figure 7: IGT sales 20 to 50 MW to traditional IPG customers with standard lead times. Including simple cycle, CHP, and combined cycle.](image)

However, during the same time period the number of units sold into mobile gas turbine applications increased by 150% (Figure 8). Specific project requirements these applications dictated that power be delivered urgently on a short cycle time and fast track basis.
And where was this power needed?

It was needed in the same regions with insufficient capacity as discussed in previous section (Figure 9). Asia Pacific, Latin America, Middle East and North Africa were the regions that required power on a fast-track, or emergency basis. These are the regions with growing populations and growing demands that will see a large investment in electrical power infrastructure in the coming decades.

Mobile gas turbine units worth US $15 billion were sold into this space in 2015. This market requirement has been slowly growing over the past 15 years with a CAGR rising from 6% in the early 2000’s to 13% in 2010 to over 20% in recent years.
5. Siemens’ answer to the need for fast mobile power

The SGT-A45 TR mobile unit addresses the growing market for fast power especially for the regional needs in Africa or Southeast Asia with less developed infrastructures. With an electrical generating capacity of up to 44 MW, this aeroderivative gas turbine is the highest power output mobile gas turbine genset in the world. The SGT-A45 TR is packaged for rapid deployment and can be installed in less than two weeks. Its design features outstanding power density, high fuel efficiency and excellent operational flexibility (Figure 10).

![Figure 10: SGT-A45 TR gas turbine utilizes proven aeroderivative technology to deliver excellent performance, high efficiency and operational flexibility](image)

The standardization and modular design of the package enables rapid deployment and installation (Figure 11). Each unit is pre-assembled and tested at the factory in order to verify operation and performance and minimize the scope of commissioning work needed at site. Each mobile unit is mounted on trailers designed for transport by air, land or sea. The self-contained, plug-and-play design and full factory testing reduce the installation time needed at site to only two weeks at maximum. With these features, the SGT-A45 TR mobile power plant solution can rapidly deploy and begin feeding the power grid. The SGT-A45 TR gas turbine can run on gas or liquid fuels, and transition smoothly between both fuel types while in operation. This provides greater flexibility and ensures continued operation in case the main fuel supply becomes unavailable. Low NOX emissions can be achieved with optional water injection, which also boosts the unit’s power output particularly in warm climates.
The SGT-A45 TR package is built with durable industrial components capable of prolonged operation and demanding duties. The aeroderivative gas turbine can generate full power in less than nine minutes from start without need for auxiliary systems to maintain the unit in an operationally ready standby mode. In the event of a shutdown, the unit can be restarted at any time to restore power quickly, as it has no "hot lockout" restrictions.

Figure 11: Pre-assembled, plug-and-play designed units mounted on trailers for minimum installation time at site
6. Conclusion

As electricity usage continues to grow, there is a growing trend towards distributed power generation, locating smaller power plants closer to the consumer load centers. There are distinct regions of the world that face the two-fold problem of very high future forecasts in electrical demand but presently low electrical production capacity. These areas will be electrified over the next few decades. However, in the interim there has been and will continue to be a need for power on a very fast track, short cycle basis. Siemens responds to this need for critical power and offers with the SGT-A45 TR a 44 MW aeroderivative gas turbine for mobile power generation.

Industrial and aeroderivative gas turbines solution are part of a distributed power generation system that provides answers to the distinct regional market challenges. Especially operational flexibility can be provided by small light industrial and aero-derivative gas turbines and their characteristics, such as fast response times via fast ramp rates, high availability and low maintenance downtimes due to the ‘core swap’ capability of specific gas turbine designs. In addition to the operational features, specific concepts like multiple or mobile unit applications, power on demand and smart grid integration help to solve regional challenges with solutions close to the consumers.

References

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