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Centralised Power Plants for Industries – Technology Selection

Naveen Devkaran
Electrical Engineering, DAVIET Jalandhar
Punjab Technical University, India

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I. INTRODUCTION

Many industries having major electrical power demand requirements tend to construct and operate their individual power generation plants. This leads to each facility having to build facilities that should have a certain number of installed units of certain capacity to have adequate spinning reserve (in order to avoid load shedding) that can be utilized in case of a trip in one of the running machines.

If a geographical area that is allocated as in industrial zone is having several individually owned and operated industrial plants that are required to source their own power supply if the local grid facilities are insufficient in terms of capacity and ensuring availability, then it leads to each industrial facility building their own power generation facility. This philosophy leads to inefficient power generation for the industrial zone. It is techno-comically better to have one centralized power plant for the entire industrial zone.

This paper evaluates various available technologies that can be utilized to optimize the number and rating of required machines for such a Centralized Power Plant.

II. POWER PLANT DESIGN CONSIDERATIONS

A. *General*

When selecting the power generation technology to be employed, the following parameters need to be considered:

- Demand load profile
- Design life of power generation technology
- Ambient conditions
- Soil Topography and Geology
- Access to cooling water
- Fuel quality, quantity, and infrastructure
- Access to electrical infrastructure
- Fuel efficiency
- Proven technology
- Main equipment manufacturers
- Minimum and maximum number of generating units
- Operational flexibility
- CAPEX and OPEX
- Constructability

Natural gas has been considered as the main fuel for this evaluation. For the purposes of this paper, the natural gas quantity required at the Centralized Power Plant has been considered as available.

The technology considered for power generation has assumed to be the most up to date but also with a proven track record. Technology with little operational experience or in the experimental or validation stage has not been included in the technology selection.

For this paper it has been considered that any single failure in the Centralized Power Plant shall not impact the production of any facility. However, partial power outage in any facility for a couple of hourshave been assumed to be acceptable, as long as there is no total black out in that facility.

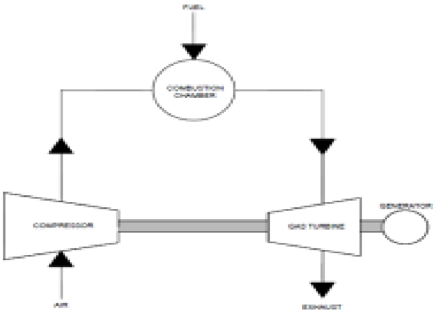
B. *Technologies Considered*

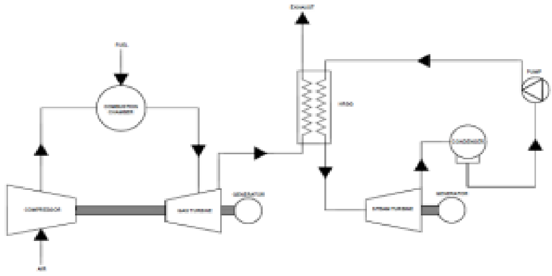
In order to meet the load demand required, three technologies have been considered as the base units for power generation, namely:

- Gas turbines
- Reciprocating engines operating
- Conventional thermal steam

i. Gas Turbine Plants:

The gas turbine-based plant are categorised as open cycle plant (OCGT) and the combined cycle plants (CCGT). The high-level schematic of both these types of plant are indicated.





In the CCGT plants, the GTs is coupled with a heat recovery steam generator (HRSG). Steam raised in the HRSG is driven through a Steam Turbine (ST) for generation of further power. The exhaust steam is condensed using a cooling system such as a once through water cooling system, cooling tower or an air-cooled condenser.
General comparison of OCGT and CCGT is tabulated below:

Parameter	**OCGT**	**CCGT**
Efficiency	Up to 35%	Up to 55%
Maintenance	Less requirement	More due to steam cycle
Reliability	High	Lower due to more components
Availability	97 to 99%	94 to 98%
Water Requirement	Lower	High
CAPEX (Capital Expenditure) (USD/kW)	Lower	Higher
Emissions	Higher	Up to 30% lower compared with OCGT of same size
Footprint	Around 50% less than CCGT for equivalent power	Large footprint

Both OCGT and CCGT plant could be applied to meet the electricity requirements of the facilities. The key driver between the selections of the OCGT over CCGT is typically associated with the gas quantity and quality available and the cost of the gas. Secondary elements in the decision making of one type of plant over the other are parameters such as land and water availability, operation flexibility and reliability, maintenance, availability of suitably qualified staff, etc.

ii. Reciprocating Engine Plants:

Reciprocating engines for power generation are categorised as:

- 4 stroke high speed (1 to 4 MW)
- 4 stroke medium speed (5-18 MW); and
- 2 stroke low speed (15-50 MW, stationary land based applications).

A reciprocating engine plant offers higher operational flexibility when compared to the OCGT or CCGT plants. Reciprocating engines are more efficient that OCGTs but less efficient than CCGTs.
The reciprocating engines have been compared to the GT based plant and the thermal steam plant later. The medium and slow speed engines can be combined with HRSGs and STs to form combined cycle plants.

iii. Thermal Steam Plants:

Based on steam parameters, there are two major types of conventional power plants; subcritical and supercritical plants. Supercritical plants use steam at temperatures of 600-700°C and have an efficiency of 40-45%. Subcritical plants on the other hand use steam at temperatures around 540°C and have an efficiency of 35-40%. Super critical technology offers higher efficiency when compared with sub critical technology, however they require increased frequency of maintenance.

C. *Technology Selection*

To carry out technology selection for a certain load requirement the detailed comparison on different parameters has been done below that will guide to select the right technology (type of plant) for a facility.

A comparison of the parameters listed in table below for a use in industrial hub indicates that gas turbine-based plant are preferred solution mainly due to the following:

- A GT based plant has the lowest footprint for the same power output compared to the other technologies
- Although not the best, a GT based plant has good operational flexibility
- GT based plants are commonly used in the industry for large power generation where the main fuel is natural gas and have a proven track record; and
- Considering the price of gas to be used a GT plant has a lower specific generation cost than reciprocating and conventional steam plant.

Two main types of GT based power plant have been considered:

- Open Cycle Gas Turbine (OCGT); and
- Combined Cycle Gas Turbine (CCGT)

To enable a direct comparison of the two types of plants, it is necessary to narrow down the suitable class of GTs that could be employed. As such, GT screening and selection must take place. To establish the range of suitable GTs, the list of GTs currently available on the market were taken from the Gas Turbine World Handbook 2013 (2013 GTW Simple Cycle Specs, Gas Turbine World 2013 GTW Handbook, Pequot Publication, Volume 30, pg 66 to 76, 2013).

Parameters	Gas turbines	Reciprocating Engines	Thermal Steam
Power Output Unit Size	1 to 375MW	4 stroke high speed 1 to 4MW 4 stroke medium speed 5 to 18MW 2 stroke low speed 15 to 50MW	Few MW to 1100MW
Typical fuel burning capability	Natural Gas/ Light Oil	Various types of oil as well as natural gas	Various types of oil as well as natural gas
Dual Fuel capability	Yes	Yes	Yes
Typical Unit Efficiency	20 to 40%	Around 40%	Nearly 40%
Typical Plant Efficiency	OCGT 25 to 38% CCGT 50 to 58%	42%	Nearly 40%
Typical Plant Yearly Availability	Around 91%	Around 88%	Around 88%
Typical Plant Yearly Reliability	Around 97%	Around 93%	Around 95%
Effect on Power Output with higher ambient temperature	Significantly reduces	Minimum effect	None
Effect on efficiency on part load operation	Significantly reduces	No impact	Significantly reduces
Typical Operating Range	OCGT 50 to 100% CCGT 60 to 100%	50 to 100%	40 to 100%
Peak Load Capability	OCGT – Good CCGT **-** Poor	Moderate with 4 stroke Poor with 2 stroke	Poor
Load Change Capability	Ramping up and down is limited and is typically around 14MW/min	No major issues	Ramp up rate of around 4MW/min
Footprint for 500MW plant	Around 90,000 sq m	Around 130,000 sq m	Around 175,000 sq m
CAPEX	Taking X for CCGT, then OCGT is 0.65X	1.25X	1.5X
OPEX (Operating Expenditure)	Taking Y for CCGT, then OCGT is 1.4Y	2.7Y	Nearly Y
Start-up Time	OCGT around 15min	12 to 20min	Around 90min

	CCGT around 90min		

The full list of GTs was screened based on the following criteria:

- Frequency: 50 Hz machines have been considered.
- GT capacity and footprint: GTs with a capacity at ISO of more than 30 MW was selected. The aim to minimize the number of machines for producing same amount of power
- F-Class and higher class of GTs are excluded. GTs higher than E-class offer higher efficiencies, achieve higher compressor pressure ratios, operate at elevated combustion temperatures and use more hard wearing, exotic materials for greater heat resistance. They are, however, considered to be too sophisticated and sensitive for application in industrial facility and for a power plant operated by non-power generation company. The F-class GTs were also eliminated from the screening as a loss of a GT would cause a large (250 to 325 MW) loss of power in one event of GT unavailability.
- Original Equipment Manufacturers (OEMs): For the purposes of this paper GTs from the OEMs have been considered; namely, Alstom, GE, Mitsubishi Heavy Industries (MHI), Rolls Royce and Siemens. All other suitable GT manufacturers use the design and manufacturing licenses from the abovementioned OEMs.

The aim of this screening was not to select the preferred GT or OEM but to provide a range of GTs that could be suitable.

Model	First Year in service	ISO Base Rating (kW)	Efficiency	LxBxH (ft)
Alstom				
GT11N2	1993	113,600	33.3%	43x18x33
GT113E2	2012	202,700	38%	36x18x18
GE Energy Aeroderivative				
LM2500 +RC	2005	36,024	37.2%	65x10x23
LM6000PC	1997	43,339	40.1%	65x14x15
LM6000PG	2008	53,500	39.8%	65x14x15
LMS100PA	2006	103,200	43.6%	130x20x54
LMS100PB	2010	100,400	44.1%	130x20x54
GE Power and Water Heavy Duty				
6B 3 Series	1978	43,000	33%	121x23x33
6F 3 Series	2003	77,577	35.6%	95x66x33
9E 3 Series	1992	128,183	34.1%	115x79x39
Mitsubishi Heavy Industries				
MF-221	1994	30,000	32%	25x12x11
M701D	1981	141,090	34.8%	41x17x17
Rolls Royce				
RB211-H63WLE	2010	42,473	39.3%	61x13x16
Trent 60DLE ISI	1996	63,512	43.2%	97x15x62
Trent 60WLE ISI	2011	66,000	41.5%	97x15x62
Siemens Energy				
SGT-700	1999	32,214	36.9%	63x15x13
SGT-800	2010	50,500	38.3%	56x15x13
SGT5-2000E	1981	172,000	35.3%	46x41x28

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[3]. GE White papers and technical data on website