Drive Selection for LNG FPSO

PROMOR

INTRODUCTION

Recently oil and gas exploration has gone into deep drilling and oil/ gas fields have been found quite far from shore. So far oil has been monetized and gas has been either flared or re-injected. The flaring of gas is prohibited to limit greenhouse gasemission as well as energy conservation. Gas injection leads to loss of approximately 10% of gas equivalent energy. This has necessitated developing small to mid-scale LNG FPSO. There are challenges and opportunities in implementation of LNG FPSO and many prospects are progressing.

One of the challenges lies in the correct selection ofthe drive for LNG refrigeration compressor. Although both mechanical drive as well as electrical drive is applied on land based LNG plant, the situation is quite different and it is to be fully understood before selection of drive on LNG FPSO.

The findings on drive selection and their impact with economic and operational advantages are discussed below.

ABSTRACT

So far there is no LNG FPSO in operation. The firstSHELL FLNG is under fabrication at SHI – Korea. This is expected to be producing in Western Australia in year 2015. SHELL has used GE steam turbine drive for their compressor. This selection is more applicable to SHELL FLNG being a new built large scale LNG production facility. This may or may not be a correct solution if LNG FPSO is a conversion project.

The boundary conditions of LNG FPSO are the building blocks for arriving at suitable drive for refrigeration turbo compressor utilized on small to mid-scale LNG liquefaction plant on board LNG FPSO. It has limited space, complex motion, standalone power generation, inherent difficulty for providing maintenance support and limited operating staff. These factors are well known to FPSO provider and all of them will agree that drive should be simple, robust, reliable and cost effective.

We have three types of choices available for such large compressor ie steam turbine, gas turbine and electric motor. Although steam turbine is more robust, reliable and simple; it has a big foot print, more weight and above all low thermal efficiency. If thermal efficiency is the major criteria then the steam turbine is ruled out otherwise it is the best choice for overall reliability.

Now the comparison focuses on the remaining drivers and their characteristics.

All gas turbines by nature of their physics and design have inherent limitations when compared to equivalent electric motor.

- High thermal and mechanical stresses which results in more wear & tear and reoccurring service requirements
- Complexity and sensitivity of machine due to numerous very tight clearances and tolerances between stationary and rotating parts
- Require specialized utilities to be available to start and accelerate loaded compressor
- Reduced power output at high ambient temperature
- De-rating require bigger size gas turbine for the selected compressor and it may be worse with discrete GT rating.

None of the above applies to electric motor VSD drive of equivalent rating. This does not mean the electric drive becomes the natural choice. There are many factors which need to be evaluated and each case has their merits in selecting the correct drive.

BASIC SELECTION CRITERION

There are several parameters which need to be considered for evaluation before finalizing the driver selection for Refrigeration compressor on LNG FPSO. These parameters are listed below:

- Foot Print Size
- Weight
- Starting Methodology
- Hazardous Area "Ex" use
- Thermal Efficiency
- Ease of Operation
- mpact on Other System
- Availability
- Economic and Operational Advantage

Drive Selection for LNG FPSO

- Comfort Factor
- Marine Environment Use
- Cost- CAPEX
- Life Cycle Cost
- Future Redeployment

These parameters are mapped to depict the reality of driver on conversion LNG FPSO project. The case study used for LNG liquefaction process with SMR technology suitable to produce 1.2 MMTPA to 2.0 MMTPA LNG on the typical VLCC.

The redundancy in production stream is considered for improved availability. However after evaluating many factor it is decided to have approximately 30 MW single driver for two stage turbo compressors on each stream. However for other liquefaction technology ie Gas expansion, DMR, C3MR or Cascade, compression duty is expected to bedifferent.

The case study configuration is shown below in Fig-1A-B-C for all three possible drivers:

FIG_1-A GAS TURBINE DRIVE (GT)

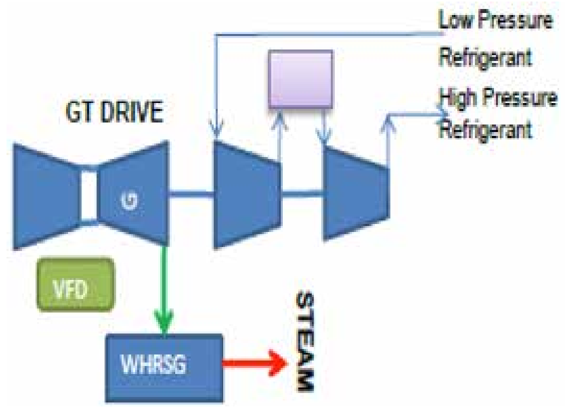


FIG-1B STEAM TURBINE DRIVE (ST)

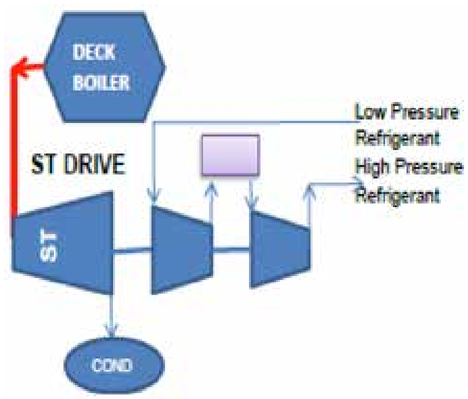
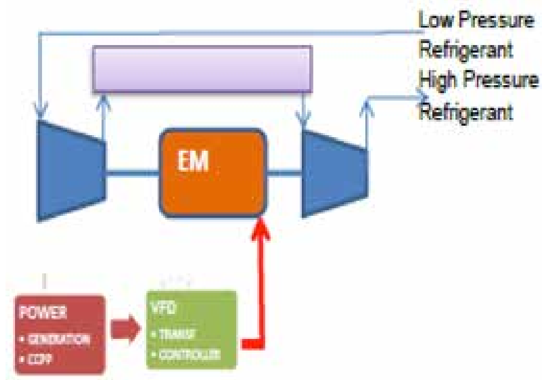


FIG 1-C ELECTRIC MOTOR DRIVE (EM)



FOOT PRINT

The foot print is one of the factors to be considered on LNG FPSO as real estate is on high premium and each space of plan area used has impact on the capex as well as opex. The plan area in square meter and weight in tone used by all three drive solutions are listed below in table-1.

Table-1:

Sr	Drive Type	Plan-M²	Weight
1	**GT DRIVE**		
2	A. Main GT Skid	92.2	58
3	B. Fuel Skid	24	10.6
4	C. Lube Oil Skid	18	6
5	D. Starting Devices	4.5	6.5
6	E. Auxiliaries	8.5	4.5
7	Total	**147.2**	**85.6**
1	**ST DRIVE**		
2	A. Deck Boiler	256	493
3	B. Main ST Skid	32	42
4	C. Condense + Aux.	36	6
5	D. Lube Oil	24	6.5
6	E. Feed Water	18	10
7	Total	**366**	**583**
1	**EM DRIVE**		
2	A. Main Motor	19.2	61.6
3	B. VSD	14.5	11.5
4	C. Filter	2.5	2.0
5	D. Transformer	43.7	64
6	E. Auxiliaries	3.85	4.2
7	Total	**83.75**	**143.3**

For electric drive we need electric power generation plant. The foot print of power source should beconsidered in case of electric motor drive option. Power source could be Gas turbine or Gas engine or combined cycle cogeneration power plant as the case may be. In either case there is additional foot print for power generation which is substantially large close to steam drive. In reality the EM drivehas least foot print in process area followed by GT drive. The ST drive has highest foot print area.

WEIGHT

The weight of equipment shall be considered while evaluating the drive option. The more weight means more supporting steel and installation cost apart from reducing on storage capacity.

It is evident that EM-Drive option has minimum weight per kW. With power generation consideration the EM drive is close to ST drive but may exceed depending upon the power generation concept adopted. The ST drive has highest weight per kW. The GT drive has lowest weight per kW.

STARTING METHODOLOGY & SPEED CONTROL

Gas turbine does not have self-start capability and need variable speed drive (VSD) for starting. GT of this size needs at least 3.5 MW VSD for starting. Depending upon configuration and coupling, the VSD power will vary from 12% to 20% of GT power. Hence we need to have some reserve or adequate power plant to start the GT drive. The speed control is limited and turn down is limited via speed control with GT drive.

Steam turbine does start by itself and does not require additional facility. However we need to have boiler in operation before starting steam turbine. There is an associated time delay for startup in case boiler is down. The major advantage is in terms of turn down and speed control which can be easily achieved in steam turbine.

THE EM drive is quickest for starting as long as electric power is available. For such large power requirement synchronous motors are used as electric drive which produced substantial torques for a given mass. Synchronous motor is electronically controlled by VSD to provide sufficient starting torque at starting and normal operation. Fully loaded compressor can be started. This is a very valuable asset in case of process trips and turn down and there is no need to depressurize the compressor before startup again (No loss of refrigerant) and cryogenic equipment does not warm up if quickly started. Full production is instantly available.

HAZARDOUS AREA IMPLICATION

The refrigeration gas compressor is a classified Zone-2 hazardous area and its driver system need to be suitable for use in this area. The steam turbine is best suited for use in hazardous area and with minimal risk. However there is a risk involved due to high pressure and super-heated steam handled in process area.

Both GT drive as well as EM drive has been used in this area and similar application. The risk of using GT drive is more than EM drives in hazardous area due to more igniting components and associated fuel gas. Both require special treatment for use in hazardous area.

THERMAL EFFICIENCY

The interest in EM drive emerged partly from the observation that high overall efficiency can be easily achieved. The waste heat from all gas turbine would be exploited while retaining independence between process and utility equipment and system.

Normally the thermal efficiency of gas turbine is in the range of 30~36 %. The efficiency of EM drive is more than 97%. The thermal efficiency of power generation can easily achieve 48~51% with combined cycle power generation. The ST drive is least efficient. The comparison of thermal efficiency for all the three drives is stated in table-2 below:

Table-2:

DRIVER	EFFICIENCY
ST	24 ~ 27
GT	30 ~ 36
GT + CHP	40 ~ 45
EM + VSD	97
E Power CC - GT	48 ~ 51
E Power DF engine	40 ~ 47

The GT efficiency is ambient temperature sensitive and need to be considered accordingly. For equatorial location GT will have less efficiency.

It can be easily observed that the thermal efficiency of steam drive is lowest among three alternatives and that is the main reason for its restricted use in LNG plants. However LNG FPSO needs steam and EM requires larger power generation system which can impact the decision.

EASE OF OPERATION

There will be least impact on the system with steam turbine drive as it has self-start capability and turn down is possible in some limited range. EM drive is second best choice for ease of operation as it can start, accelerate and run with minimum impact of power generation. This also helps in turn down to a large extent. It can start fully loaded compressor. This helps a lot in operations and quick start-up.

EM large drive will have harmonic challenge as well as startup power requirement on power generation system

A high level comparison between GT and EM drive reveals following:

- Waste heat recovery from all gas turbines exhaust improves thermal efficiency and lower GHG emission for EM.
- Eliminates asset down time and shutdown / maintenance cost as availability of EM drive is higher than GT drive.
- Reduce flaring by avoiding depressurization and quick start as EM drive can start at full load.

In short EM drive is better than GT drive for ease of operation and it helps in production increase.

IMPACT ON OTHER SYSTEM

Each drive have impact on the other system If ST is the drive we need boilers to generate steam and issues with high pressure and high temperature steam to be considered. This will call for multiple marine boiler and lot of cooling water demand

If GT drive is selected it will have impact on gas conditioning unit with compressor fuel gas as well as adequate starting mechanism.

If EM is used, it will require electrical power source of adequate size, VSD and HV cabling in hazardous area. It will have harmonics and start up issues with power supply system.

All the drive need cooling water but in varying quantity while ST need maximum and EM needs minimum Similarly all the drive need instrument air but in varying quantity while ST need maximum and GT needs minimum.

The lube oil is also consumed in varying Quantity.

AVAILABILITY

The availability is a key factor on drive selection as it leads to production loss. Based on the OREDA 2009 data the various drive have different availability in offshore environment as indicated in table-3 below:

Table-3:

DRIVER	AVAILABILITY
ST	97.25
GT	96.36
EM + VSD	98.35
E Power CC	99.55

It is clear that EM has the highest availability compare to GT and ST.

ECONOMIC AND OPERATIONAL ADVANTAGE

The major economic advantage from EM drive compare to GT drive are listed below for evaluation in individual case

- Utilize waste heat from all GT exhaust thusachieving lower GHG emission in a simple wayand without complicating the equipment used in the process area.
- Eliminate asset down time and shut down maintenance cost associated with GT drive
- Phase cost associated with combined cycle capability to a later date
- Reduce fuel gas consumption both from Opexperspective
- Segregate combustion and convective heat recovery unit from high pressure process area to some safe area.
- Reduce flaring by avoiding refrigerant depressurization and enabling quick start.
- No de-rating or thermal efficiency loss due to high ambient temperature.

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COMFORT FACTOR

The comfort factor for operating the system is very important. Different skill has different level of comfort for the drives. Generally ST drive is more comfortable than EM or GT drive. However a more skilled operator can handle either with ease. In any case it is important that local operator skills are considered while selecting the drive. Further it is important that service support is also considered while selecting the drive. Some places the service support is easily available while other places it may take quite some time like Africa. A simple robust solution is preferred in places of less support.

MARINE ENVIRONMENT USE

Most of the marine personnel are more familiar with steam system and ST drive is very handy to them. The GT drive is relatively new and have more precision component which may impact maintenance/ operation. The EM motor part is reliable and robust but VSD part is another challenge not so proven for large capacity. The manufacturers have limited experience and range to offer in marine environment. This has to be considered while selecting the drive.

LIFE CYCLE COST

The life cycle cost has two components ie CAPEX and OPEX. The ST drive solution has lowest capex and GT has highest capex. The variation is approximately 7%~15% based on discrete value of power requirement.

The opex is sensitive to fuel price and type of drive applied ie availability. If the basic fuel price is assumed as unity per kWH the relative opex among three drives is shown in table-4 below for 1.0 MMTPA plant.

Table-4:

DRIVE	OPEX
ST	410
GT	390
EM	250

The opex difference will increase or decrease depending on fuel price.

FACTOR TABLE

In order to select the correct drive on a particular case the factor table should be prepared and each parameter is weighted (10Points) for the application as illustrated below in table-5 except Thermal Eff.

Table-5:

PARAMETER	GT	ST	EM
Foot Print	5.7	2.3	10.0
Weight	10.0	1.5	6.0
Start Cap	5.0	10.0	8.0
Ex Use	5.0	8.0	10.0
Thermal Eff	29.0	20.1	40.2
Ease of Operation	5.0	10.0	8.0
Impact on Other System	8.0	10.0	5.0
Availability	5.0	8.0	10.0
Economic Operational	8.0	5.0	10.0
Comfort factor	5.0	10.0	8.0
Adaptation to Marine	5.0	10.0	8.0
Life Cycle Cost	8.0	5.0	10.0
Vendors Support	5.0	8.0	8.0
Factor Sum	103.2	107.9	148.20
Total % Select	**60.7%**	**63.5%**	**87.2%**

These factors can be worked out for any liquefaction compressor drive application on LNG FPSO as illustrated. This will help in making most appropriate and efficient solution.

Promor Pte Ltd has the experience and capability to provide the efficient solution for small to midscale LNG FPSO.