FPSO Training Course

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Session 2.1 - Fuel, heat, power and gas strategies

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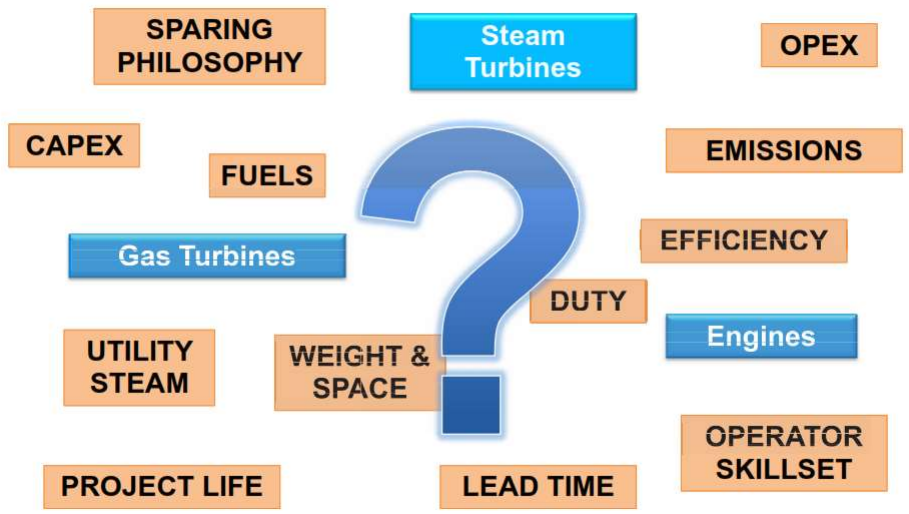
Agenda

- Considerations
- Gas handling
- Fuel strategy
- Electrical power and process heat
- Heat sources & transmission
- Mechanical drive configuration
- Power Generation equipment and process heat strategy

Considerations



Gas Handling

Gas Handling

- Is there sufficient associated gas to meet all fuel requirements throughout field life?

Surplus:
- Export,
- Inject,
- Flare (consents).

Deficit:
- Import,
- Alternative fuel.

- May encounter both in field life (generally gas rate decreases faster than fuel demand).
  - If there is existing infrastructure in the region, it may be possible to import and export gas to/from the same pipeline.

Fuel Strategy

Fuel Strategy

- Options:
  - Associated gas,
  - Imported gas,
  - Produced oil,
  - Imported liquid fuel (diesel).
  - Imported electrical power.

- Selection of multi-fuel capability (dual-fuel/tri-fuel) has multiple advantages:
  - Start-up & commissioning - when there may be no gas available from the field;
  - Fuel availability – ability to switch between fuel types when there are process upsets or when moving between periods of gas surplus and gas deficit.

- The selected fuel strategy will influence the selection of equipment drives (electric motors/ turbines / reciprocating engines).

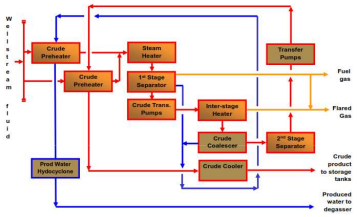
Electrical power and process heat

Electrical power

- Early in the design process it will be necessary to develop a "Load List".
  - All continuous and intermittent electric power consumers are included.
- The main power generation system is sized based on a combination of continuous and peak loads.
- The selected power generation system must have sufficient spinning reserve to allow for start-up draws from the largest users:
  - Motor start-up draws can be 4-5 times larger than normal consumption.
- The load list needs to consider the whole FPSO, not just topsides users:
  - Integrate topsides with the marine systems.
  - Consider emergency generator / essential generator / UPSs etc. & their loads.
- The main consumers of electrical power on an FPSO are likely to include:
  - Gas compressors;
  - Crude offloading Pumps;
  - Water Injection pumps. (these can be oversized and turned off during offloading – overall injection volume can still be achieved but power generation requirements will be reduced).

Process Heat

- Heat is required for the following systems:
  - Crude heaters / stabilisation,
  - Glycol regeneration unit (plus MEG and amine potentially
  - Fuel gas heater,
  - Cargo heating,
  - Heat tracing.



- Provided by:
  - Heat recovery/integration,
  - Waste heat recovery,
  - Fired heater,
  - Steam – particularly where high temperature or large heat load required or for conversions with pre-existing steam system,
  - Electric heating – fuel gas heater, easy to control, power from shore?

- Usually summarised in a 'UTILITY CONSUMPTION' document (will also include cooling, instrument air etc.)

Determining power and heat requirements

- Load List;
- Utility Consumption Summary.

- EARLY information will be incomplete so estimates will need to be made:
  - Other Projects;
  - Early modelling (Que$tor, HySys);
  - Appropriate contingency.

  Documents will evolve through the project – decisions based on it often cannot change.

- Need to ensure that **instantaneous** heat and power and heat requirements are determined and met throughout field life - rather than rated capacities, design cases ('max gas', 'max oil' etc.)
  - How often do we see design heat and material balance cases called 'max power', 'max heat' or 'max heat: power ratio'?
  - Don't forget start-up!

- However, the process engineer can – to some extent - manipulate power and heat requirements:
  - NGL recycles, separator pressure selection;
  - Increase vessel size gives, all else being equal, increased residence time allowing operation at a lower temperature

Heat sources and tranmission

Waste Heat Recovery

- Power generation exhausts contain significant thermal energy that is available for recovery;
- Waste Heat Recovery Units (WHRUs) are heat exchangers that recover some of the thermal energy in exhaust streams;
- Different drivers will reject different quantities of heat (for a given fuel input) at different temperatures;
- Ensure that the exhaust temperature leaving the WHRU is AT LEAST 120°c to avoid water condensation and corrosion.

Heating Medium Options

- Hot Oil:
  - 200+ ℃;
  - easy to make up & control;
  - the oil is expensive.
- Hot water with/without glycol:
  - 150- 200 ℃;
  - easy to make up & control;
  - fluid can also form cooling medium with integration benefits (e.g. make-up);
  - may not be suitable for cold environments.
- Steam:
  - 200- 400 ℃;
  - more complex control;
  - offers greater potential for integration of marine & topsides systems;
  - likely to be a higher pressure system with capex implications

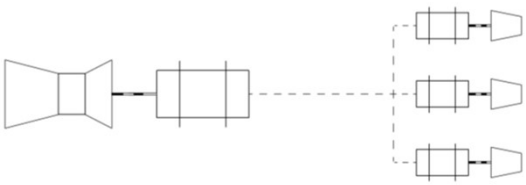
- Consider integration with heat sources.

Waste Heat Recovery

Mechanical drive configuration

Mechanical drive configuration

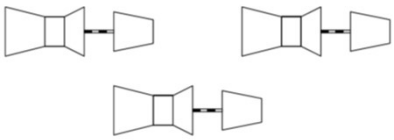
- **Centralised power generation with electric motor driven equipment**:



- Allows for ease of start-up and commissioning;
- Electric alternators and electric motors are non-complex and require little maintenance;
- This configuration will give larger main power generation requirements, and is likely to increase overall weight and space but, heat recovery is easier.
- Variable Speed Drives can be utilised with electric motors: they are heavy and there is some evidence of limited robustness however these limit power draw on start-up and provide speed control.

Mechanical drive configuration

- **Distributed direct mechanical drives**:

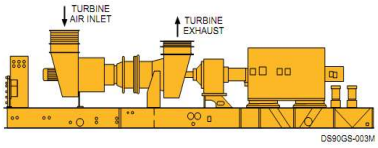


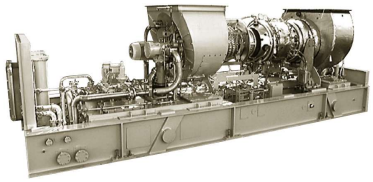
- Reductions in overall weight, space and cost (the electric motors have been eliminated and the size of the main power generation unit will reduce);
- More complex system which will be more difficult to start-up and commission.
- There will be a larger amount of complex rotating equipment with high maintenance requirements;
- It may be difficult to recover waste heat when the mechanical drives are distributed throughout the topsides.

Driver Selection

Gas turbines

- Very high power output for a small skid footprint.
- Can be brought on line quickly.
- High level of reliability if run on good quality gas/liquid fuel.
- Major failure of turbine power unit is expensive.
- Power unit is relatively small and can be changed out relatively easily.
- Sensitive to inlet air quality (e.g. dust).
- De-rating for high ambient air temperatures.
- GT's are usually housed in acoustic enclosures.





Gas turbines (2)

Turbine	Power	Efficiency
Solar Saturn 20	1MW	~25%
Solar Centaur 40	4MW	~28%
Siemens GT 200	7MW	~32%
Solar Mars 90	10MW	~33%
Siemens GT 400	13MW	~36%
Solar Titan 130	15MW	~36%
Solar Titan 250	22MW	~39%
GE LM 2500	24MW	~37%
RR RB211	28MW	~40%
GE LM 2500+	29MW	~39%
GE LM 6000	43MW	~40%

Reciprocating Engines

- Large engine/driver foot print (relative to a gas turbine of comparable output).
- Excellent fuel type and quality capability.
- High level of reliability,
- Large diesel engines used for main power require pre heating before starting and cannot therefore be brought online quickly.
- High noise and vibration levels.

Reciprocating Engines (2)

Engine	Power
Cat 3512B HD	1MW
Wärtsilä 32 12V32	5MW
Wärtsilä 32 18V32	8MW
Wärtsilä 46 12V46	11MW
Siemens SGT 500	16MW
Man BW V48/60CR	22MW
Man BW K60MC-S	28MW
Man BW K80MC-S	41MW

- Efficiencies typically 45%.

Steam Boilers & Turbines

- Less efficient.
- Very reliable if properly operated.
- Require careful preheating prior to starting and cooling when stopping.
- Boiler can be fired on any fuel and is more tolerant to inerts.
- Require boiler water treatment and large quantities of condensing water.
- Large space and weight requirements.

Driver Selection

	Gas Turbine & Alternator	Diesel Engine & Alternator	Steam Boiler & Turbine
Fuel Types	✗	!	✓
Fuel Availability	!	!	✓
Robustness	!	✓	✓
Maintenance	!	!	✓
Operability	!	✓	✓
Space / Weight	✓	!	✗

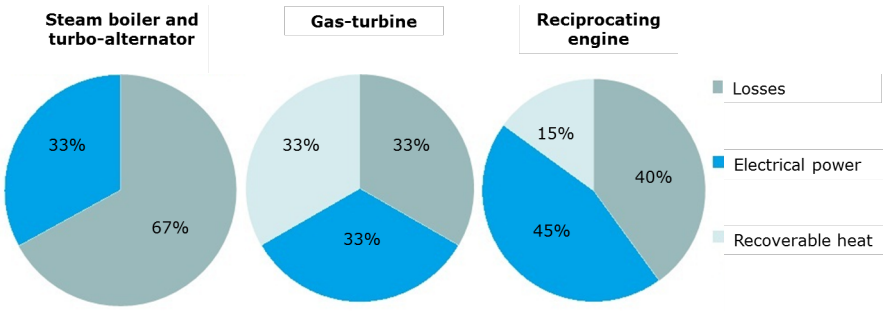
Other factors to consider include emissions, efficiencies, capex, opex, potential for certain types & sizes of power generation to be located in hull machinery spaces or on the poop deck to save on topsides deck space...

Fuel, heat and power strategy

Fuel, heat, power & gas strategy

FUEL	POWER GENERATION	ROTATING MACHINERY	PROCESS HEAT	GAS HANDLING
Associated gas	Gas Turbine	Gas Turbine	Waste Heat Recovery	Use as fuel
Crude / condensate	Reciprocating Engine	Reciprocating Engine	Fired Heater	Gas export
Imported gas	Steam Turbine	Steam Turbine	Electric Heating	Gas injection
Imported diesel	[Power import]	Electric motor	Steam	Flaring

Rules of Thumb



1 mmscfd gives 4 to 5 MW electrical power

20 te/day of diesel gives 4 to 5 MW electrical power

What's different with an FPSO?

- Degree of integration between topsides & hull systems:
  - Power generation (topsides & marine).
  - Heating medium (topsides & cargo).
  - Conversions & redeployments may have existing marine systems that can be re-used.
- Remote locations where breakdowns & maintenance can significantly reduce uptime:
  - Maintenance burden.
  - Equipment sparing.
  - Reliability.
- Remote locations where fuel gas import from pipelines or neighbouring facilities may not be possible.
- Potential for certain types & sizes of power generation to be located in hull machinery spaces to save on topsides deck space.
- Potential for redeployment after field life.

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- For further information on our services go to:
  - www.crondall-energy.com

- Any questions?