Serving the LNG Industry

Case Studies – Electrical Drives

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Introduction

Case Study 1: Bish Cove - all electric

Case Study 2: Snøhvit - aero-derivative with waste heat recovery and electrical drive

Case Study 3: Conceptual arrangement for combined cycle at Kitimat with electric drive

Projects with Electric Drives in North America Have a Common Thread:

Freeport LNG, Oregon LNG and Kitimat LNG all started as import terminals

- Embrace of all-electric liquefaction plants supplied from a grid has been driven solely by the need to have minimal impact on import terminal environment permit

- Power supply from the grid requires careful assessment of the supply specifics:
  - Measurement of availability
  - Source of power supply (hydro, thermal, combination, others)
  - Location of power generators
  - Impact of the plant operation on the grid
  - Impact of the grid on LNG plant operation
  - Cost of new transmission line between grid and LNG facility
  - Cost of transmission line re-enforcement and power factor correction
  - Cost of new transmission line and generation upgrades
  - Schedule alignment
  - Grid supply tolerances (voltage, frequency, harmonics, out of range fluctuations).

All-electric, BC- Key Parameters

Power supply specification:

- Voltage: +/- 10%
- Frequency: +/- 5%
- Harmonics: as per IEEE 519
- Power factor: ≥ 0.95
- Transient out of range voltage or frequency: over a few cycles or milliseconds [1].

[1] VMS protects PWM or LCI

Plant impact on grid:

- No power flow into the grid
- Negligible harmonics injection from electric drive into the grid
- Current rush during start-up not to exceed steady state level
- Impact of VMS protection on grid must be tolerable.

PWM = Pure Wave Modulation; LCI = Load Commuted Inverter; VMS = Voltage Management System

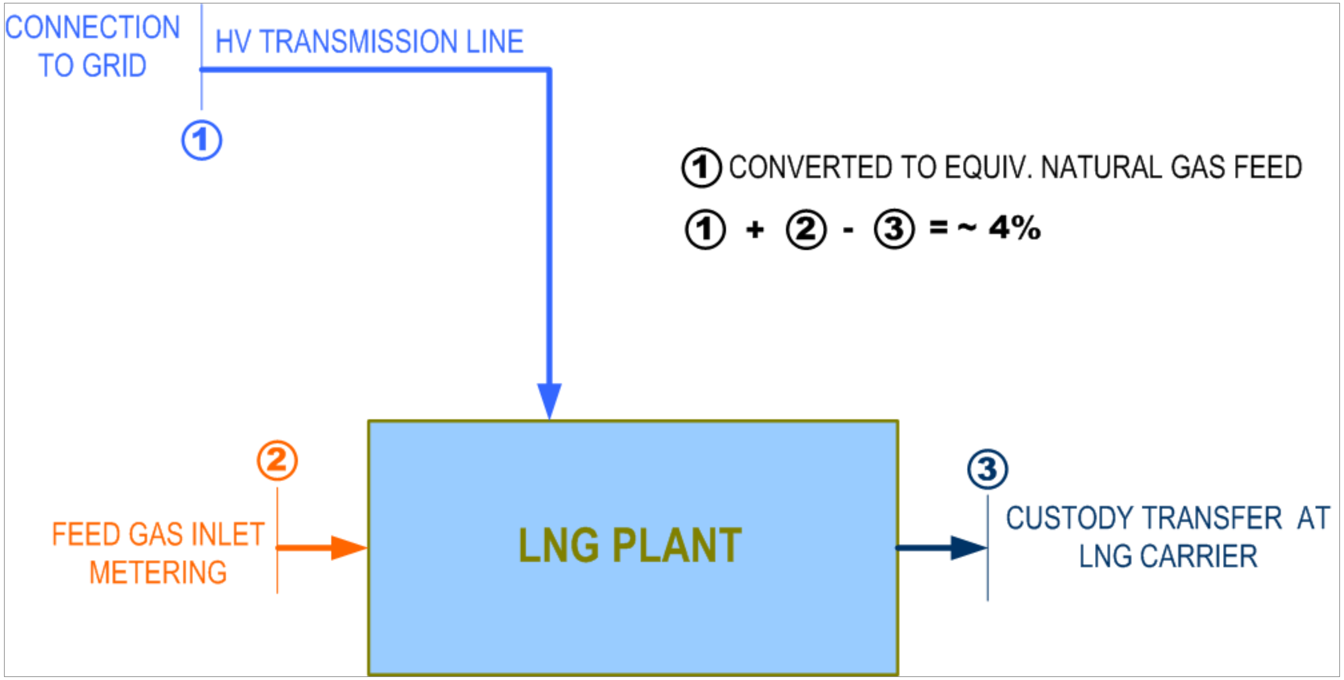
All-electric, BC – Electrical Drive Selection
Process Specifics

- Reference process: C3-MCR by APCI
- Motor line-up: C3, LPMR, MPMR, HPMR (*)
- Motor rating: > 30MW
- Motor type: synchronous
- Electrical drive: load commutated inverter (LCI) with harmonic filter

(*) Other motor line-ups or process may allow using PWM drive

All-electric, BC – Energy Consumption

Estimate by CDS



Energy Consumption Assuming Hydro Power

All-electric, BC - Factors to be Considered

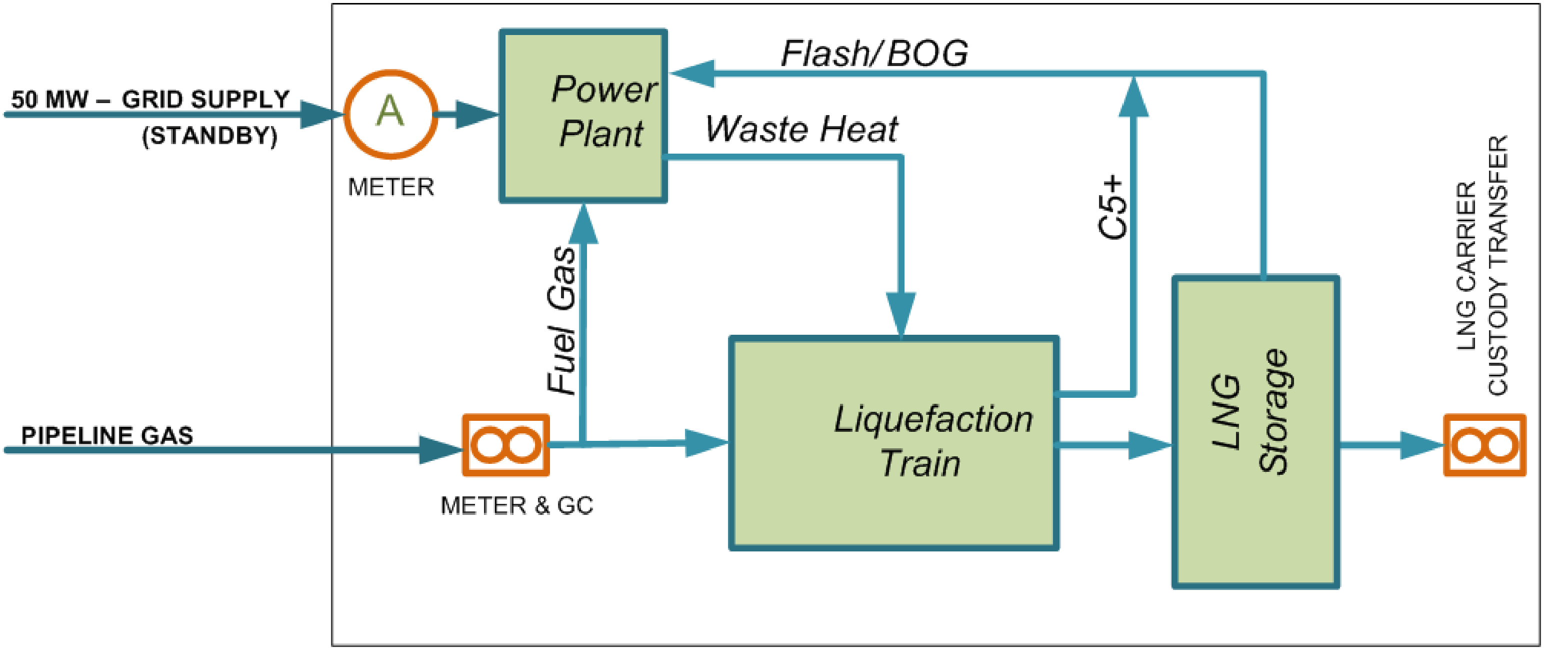
- Footprint requirements for HV substation and metering
- Foot print requirements for shunt compensation
- Footprint requirements of liquefaction train (LCI and harmonic filter need to be located in non classified area)
- During plant shutdown BOG is flared
- Duration plant operation, BOG has to be recycled for liquefaction. This creates N2 enrichment and adversely affects the liquefaction power.

BOG = boil off gas

BC - Aero-derivative Genset

Base Case - Train 1: 6 x LM6000 Sprint

Findings: meets power demand but only 50% of waste heat needed – liquefaction energy consumption: ~ 6.9%



STEADY STATE ENERGY CONSUMPTION: ~ 6.9%

BC - Electric Drive vs Direct Drive
Base Case - Train 1: 6 x LM6000 Sprint

Direct Drive:

- LM6000 not a good fit with compressor power rating for C3-MCR process
- Power generation is still required for complement of plant.

Electric Drive:

- Flexible choice to match motor to compressor
- No separate power generation is required.

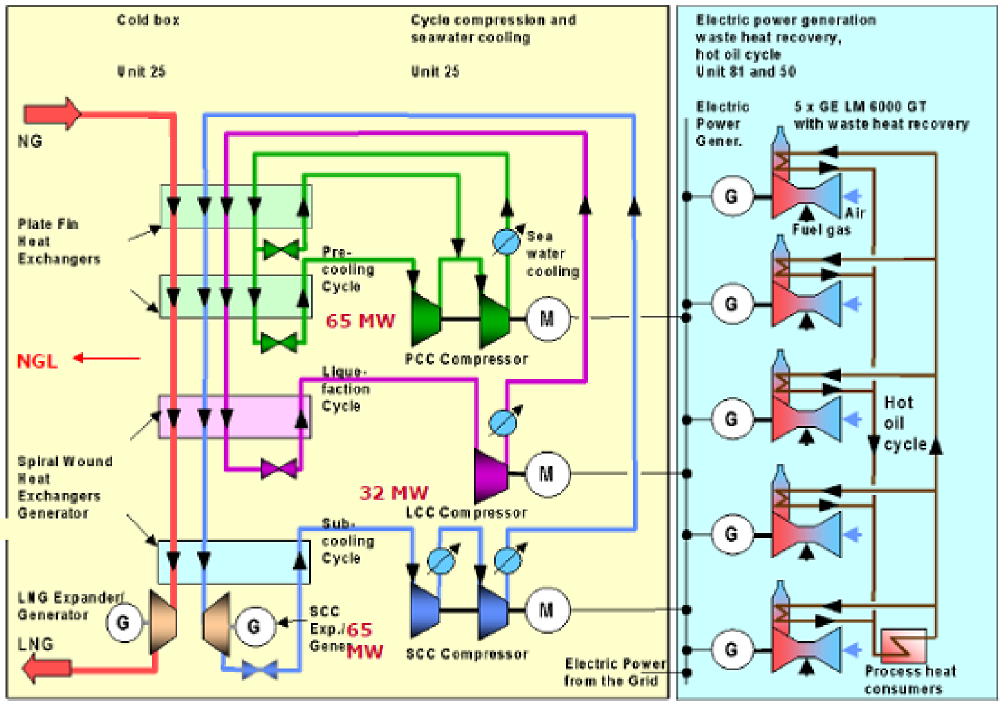
Snøhvit - Electrical Drive

One Train

- First to adopt electrical drives and waste heat recovery
- Five LM6000 gensets + 50 MW back-up from grid
- Heavy penalties for exceeding specified power demand
- Capacity: 4.2 MMTPA LNG
- First to recycle process CO_2 for sequestration.

Snøhvit - Electrical Drive

Liquefaction Energy Consumption: ~ 6%



- Well optimized for power generation and waste heat recovery for process and winterization
- Redundancy for both power and waste heat.

Kitimat – Four Train LNG Plant

Air Shed Modelling to Address Health Issues in Douglas Channel

Other issues need consideration:

- Greenhouse gas emissions
- Visual impact of wet plumes in shoulder/winter seasons
- Impact of pollution in the Kitimat-Terrace corridor
- Flaring in proximity of town potentially a news maker.

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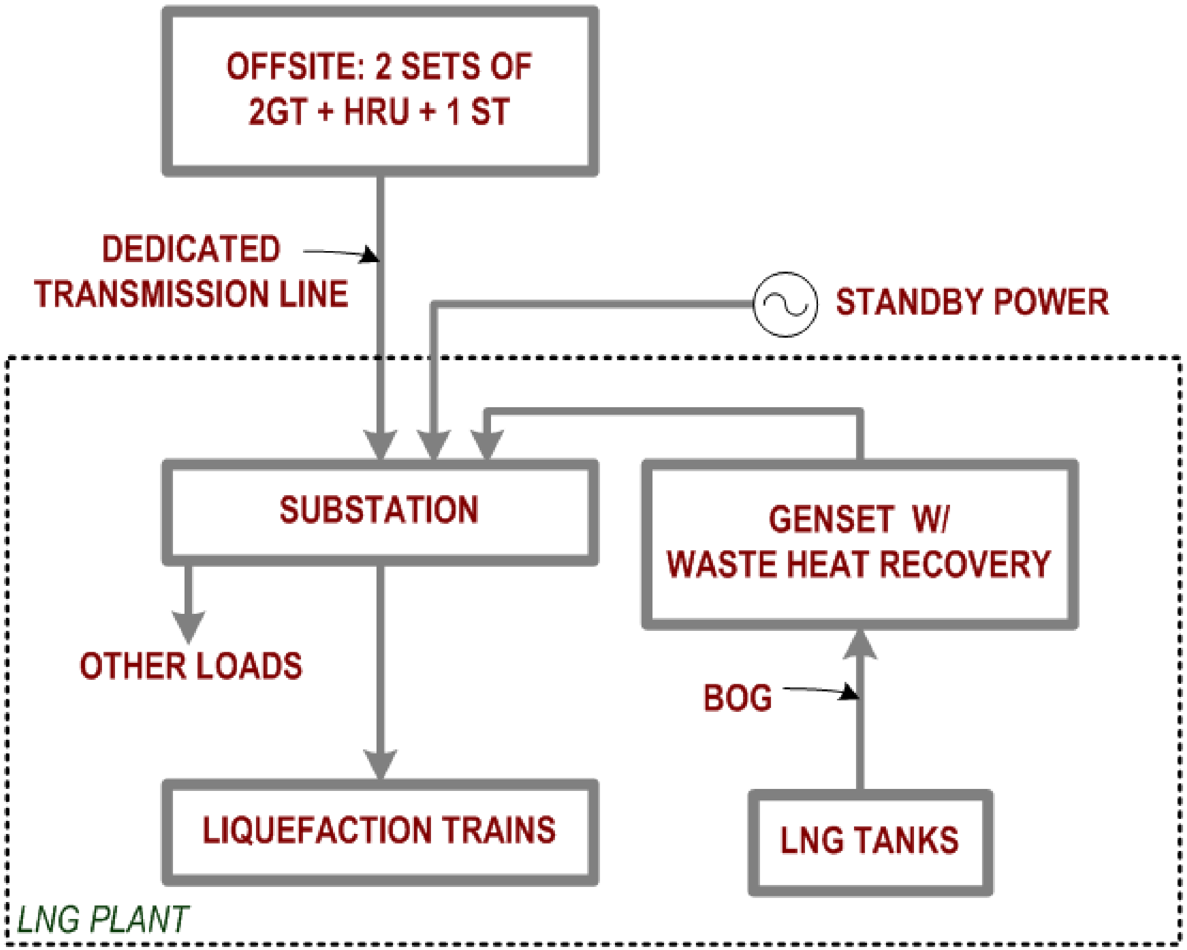
Kitimat – Four Train LNG Plant

Conceptual Arrangement to Reduce Emissions and
Move Air Effluents Outside the Douglas Channel Air Shed



Thank you

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