November 2016

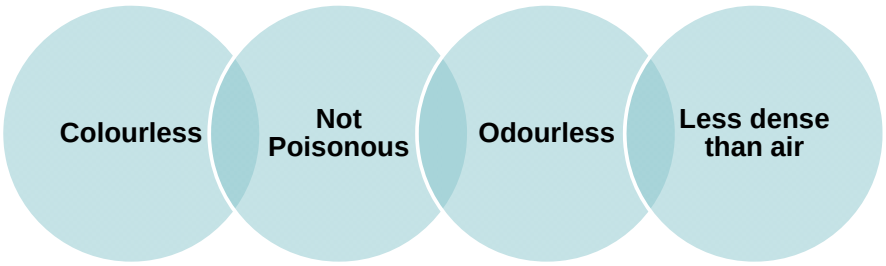
A Greener Future – Safe, Reliable and Clean Electricity Generation

Contents

Natural Gas Facilities in Lamma Power Station

Natural Gas

- Properties of natural gas



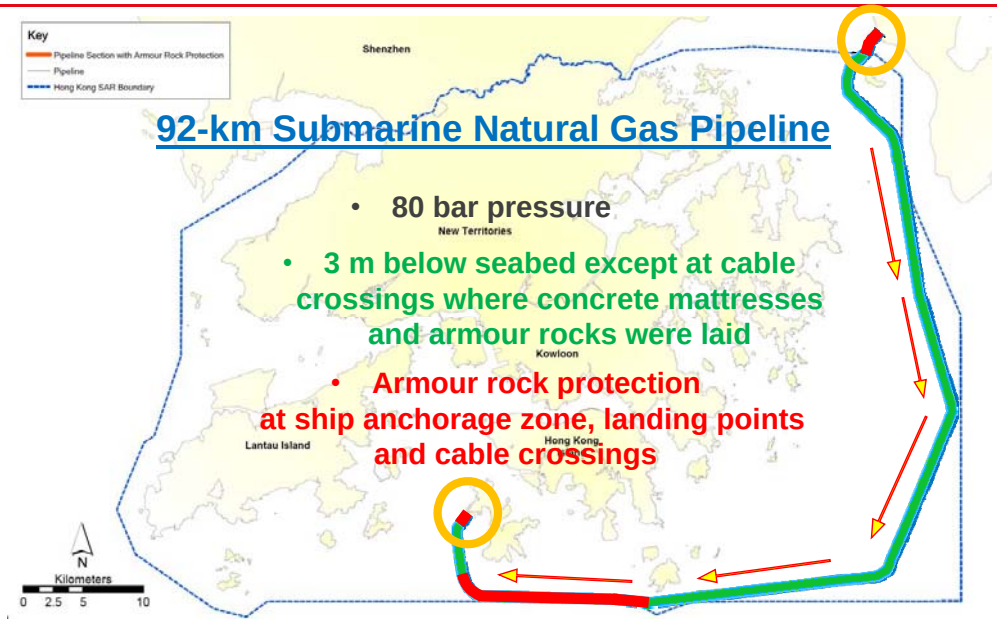
- Highly explosive: Explosive Limit 4-15 % by volume in air
- Orange flame during combustion
- Combustion products: H_2O, CO_2, small amount of Nitrogen Oxides (NOx)
- Calorific value: 48-56 MJ/kg
- Safe and reliable with appropriate safety management and controls

Natural Gas vs Coal as Fuel

	Coal-fired units	CCGTs*	Reduction %
Fuel type	Coal	Natural gas	
SO_2* emission (kg/MWh)	0.29 - 1.12	0.00004	99.98 – 99.99
NOx emission (kg/MWh)	0.66 - 2.37	0.32 (0.03 with SCR*)	52 – 87 (95 – 99)
RSP* emission (kg/MWh)	0.01 – 0.06	0.006	40 - 90
CO_2 emission (tonne CO_2 e/MWh)	0.81 – 0.84	0.38 – 0.42	50 - 53
Ash (kg/MWh)	20-26	0	100
Gypsum (kg/MWh)	7-11	0	100
Seawater Required for Cooling (m^3/MWh)	120 – 380	60 - 180	50 – 54
Note: Environmental performance varies between generation units, loading and averaging periods.			

SO_2: Sulphur Dioxide
RSP: Respirable Suspended Particulates
CCGT: Combined-Cycle Gas Turbine
SCR: Selective Catalytic Reduction

Submarine Natural Gas Pipeline



92-km Submarine Natural Gas Pipeline

- **80 bar pressure**
- **3 m below seabed except at cable crossings where concrete mattresses and armour rocks were laid**
- **Armour rock protection at ship anchorage zone, landing points and cable crossings**

Shenzhen Dapeng Guangdong LNG Terminal (GDLNG) → **92-km Submarine Natural Gas Pipeline** → **Lamma Power Station Extension Gas Receiving Station (GRS)**

LPS Gas Receiving Station

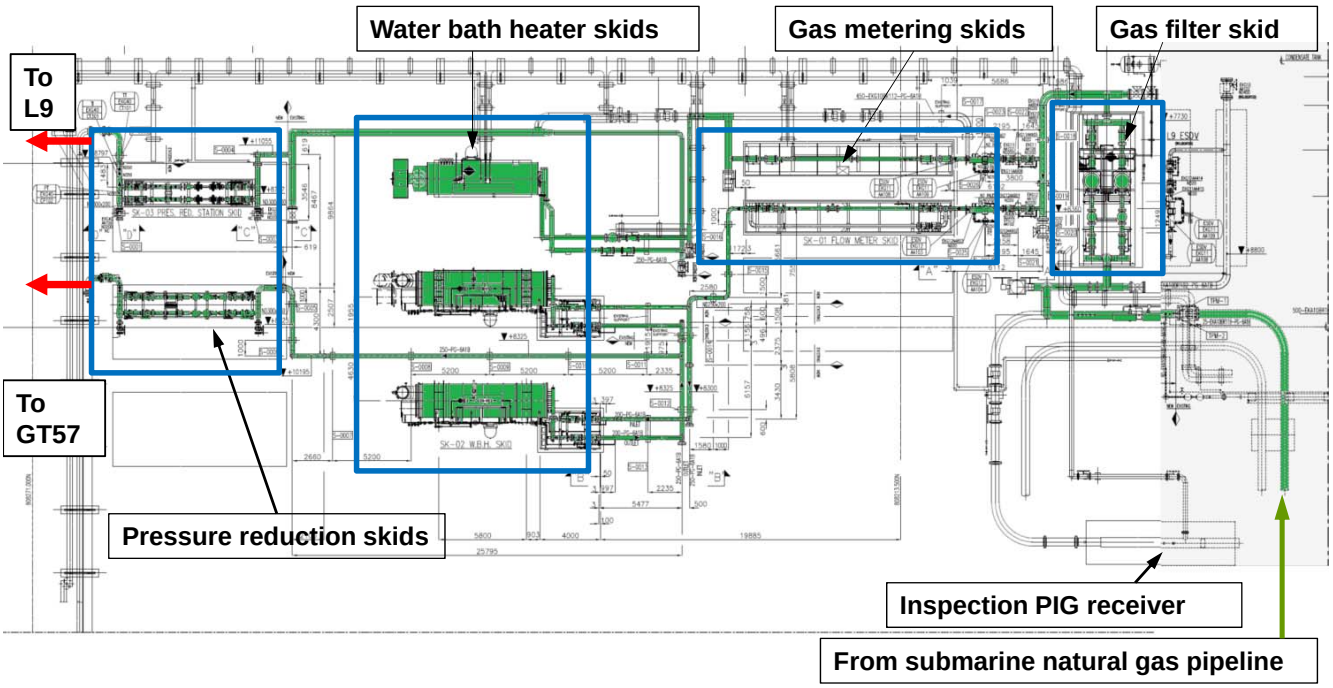
Lamma Power Station (LPS) Gas Receiving Station

L9 CCGT

Depeng Guangdong (GD) Liquefied Natural Gas (LNG) Terminal

GT57 CCGT

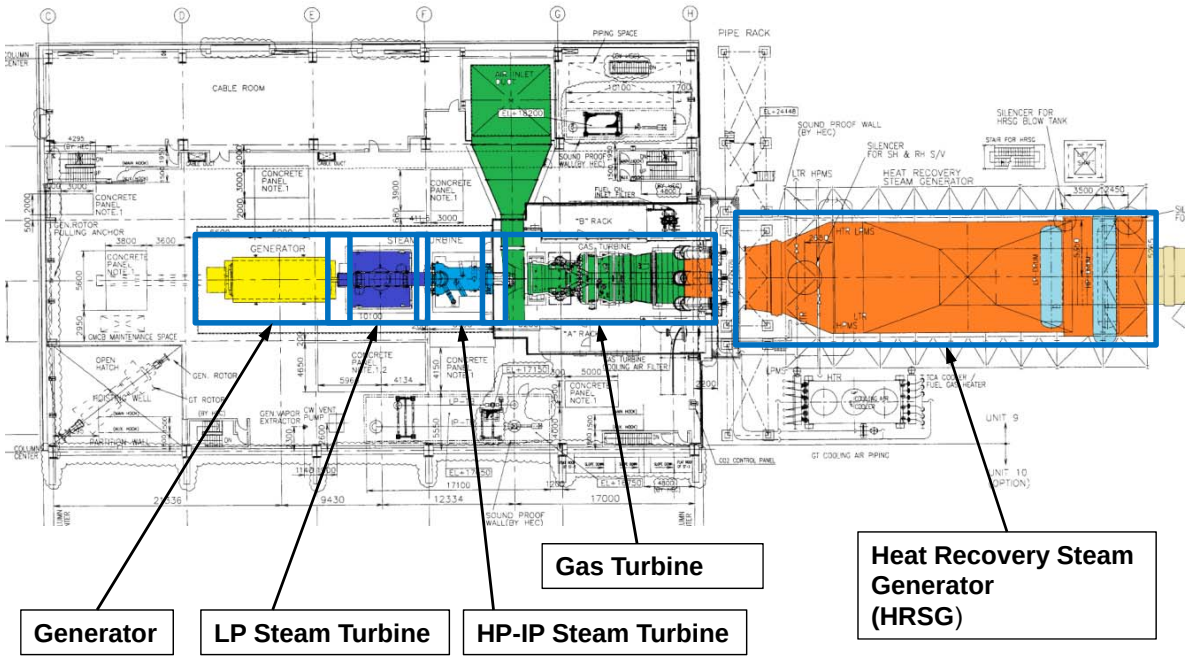
LPS Gas Receiving Station



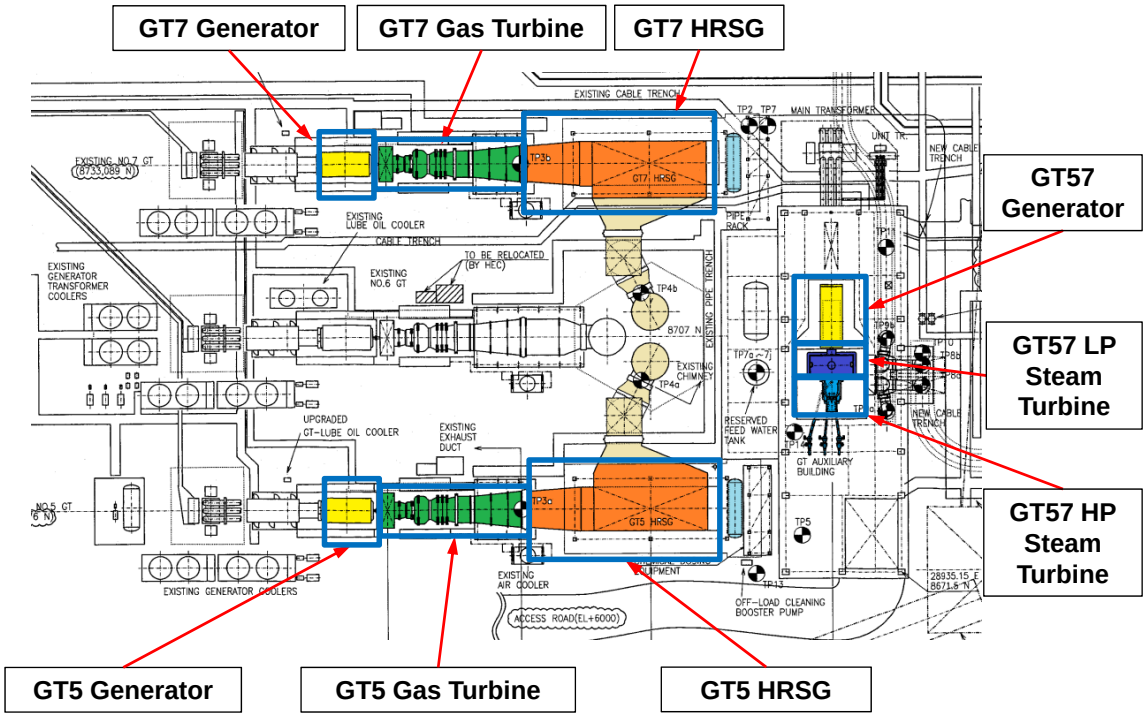
L9 & GT57 CCGTs

	L9	GT57
Configuration	Single shaft	2-on-1
Rated power	335 MW	345 MW
Nameplate Efficiency	55.3 %	43.5 %

L9 CCGT



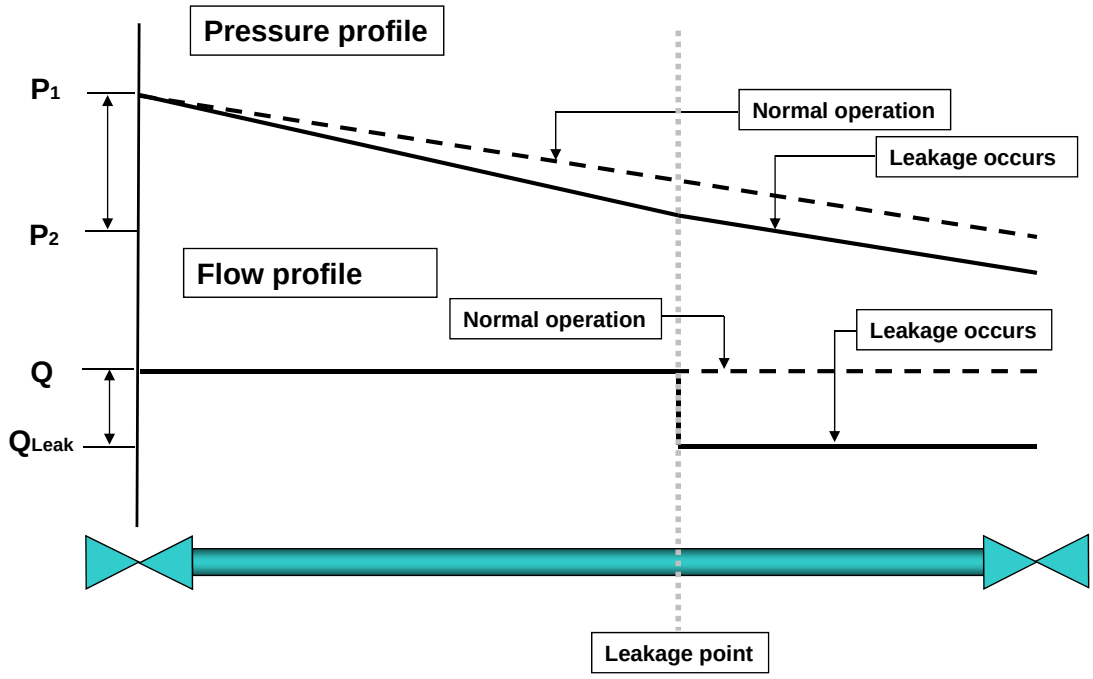
GT57 CCGT



O&M Experiences with Natural Gas Facilities

Submarine Natural Gas Pipeline

- Pipeline leak detection



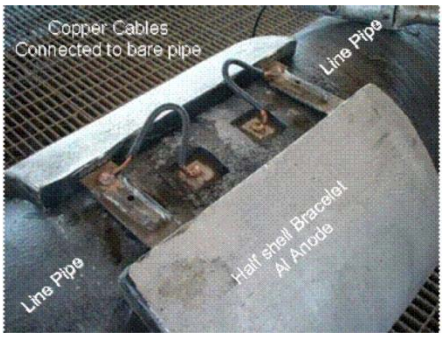
Submarine Natural Gas Pipeline

- Gas composition measurement

Composition	Unit	Specification	Average
Methane	mol %	≥84.0	88.774
Ethane	mol %	-	7.542
Propane	mol %	-	2.588
n- Butane	mol %	≤2.0 for C4 and heavier	0.454
i- Butane	mol %		0.562
i-Pentane	mol%	≤1.0 for C5 and heavier	0.004
Nitrogen	mol %	≤1.0	0.074
Hydrogen Sulphide	mg/Sm³	≤5	
Total Sulphur	mg/Sm³	≤30	
High Heat Value	MJ/m³	40.88	
Gas pressure	Barg	100 (max)	
Gas temperature	℃	16 (min)	

Submarine Natural Gas Pipeline

- Application of Anodic Protection on Pipeline



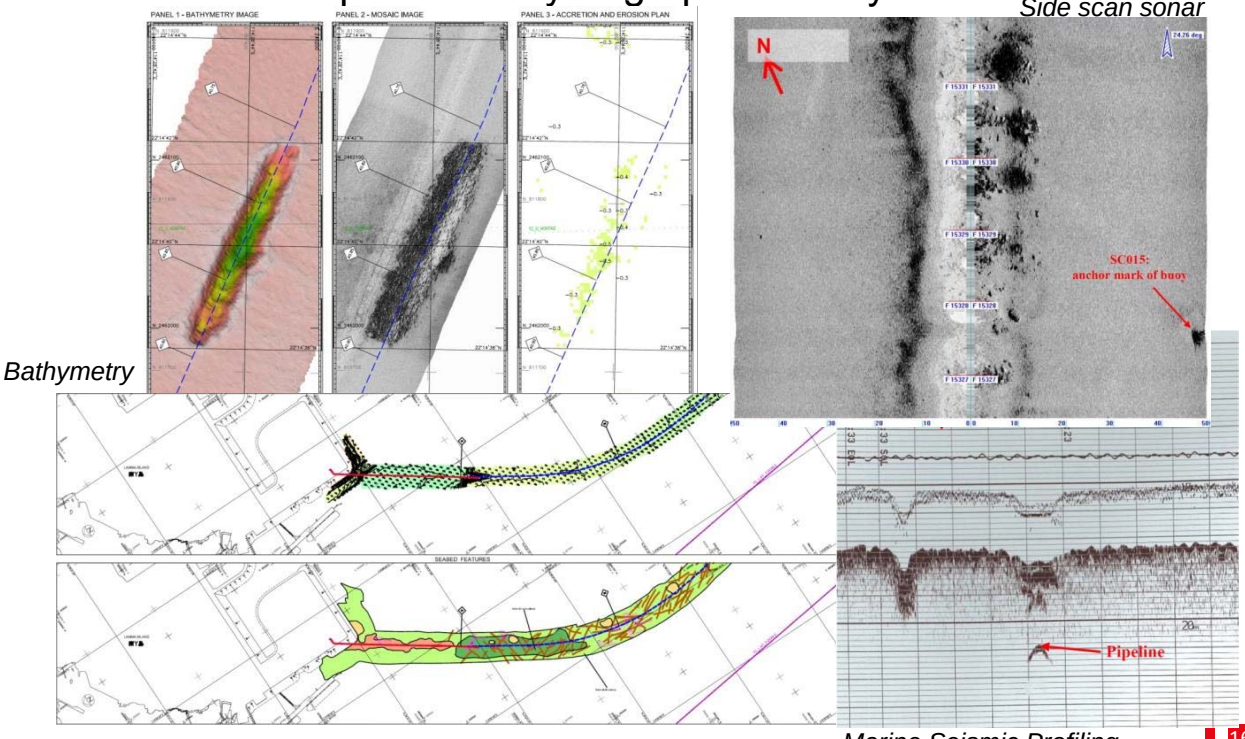
Aluminium Bracelet Anode

- Total number: *1,534*
- Installed at *every 5 pipe joint length* (around *61 m*) interval

Submarine Natural Gas Pipeline

- External inspection – Hydrographic survey

Bathymetry

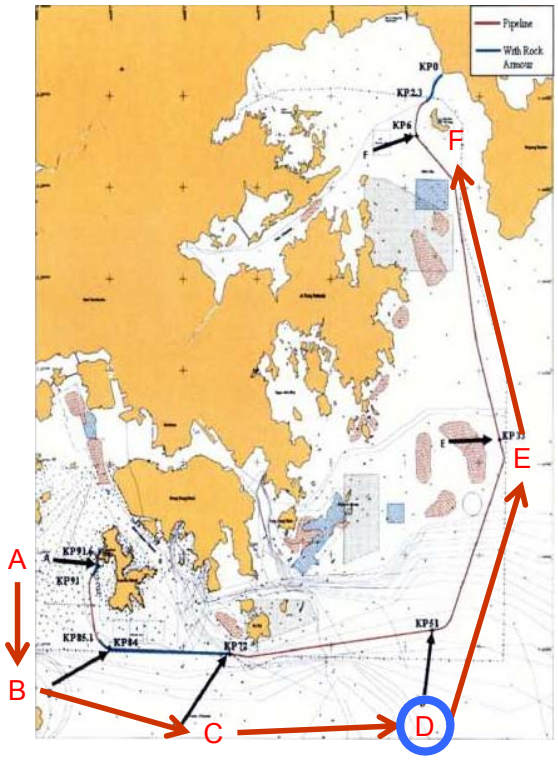


Side scan sonar

Marine Seismic Profiling

Submarine Natural Gas Pipeline

- Visual Patrol by helicopter



Inspection at Check Point D

Submarine Natural Gas Pipeline

- Frequency and purpose of inspection and assessment of submarine natural gas pipeline

Inspection	Frequency	Purpose
External Inspection	Hydrographic Survey: Every five (5) years, in 2006, 2011 and 2016	- Confirm the integrity of pipeline protective measures; - Measure the burial depths, location of the pipeline and changes in seabed levels in the vicinity; - Identify obstruction, third-party installed facilities and hazards.
Patrolling	Every six (6) months: by boat (2007); by helicopter (2008 to present)	- Ensure there are no anomalies observed on the sea which would indicate possible pipeline damages; and possible installation which would cause damages to the pipe
Ground settlement at GRS and along the pipeline	Every three (3) months	- Determine whether integrity of the pipeline on the land side is affected.

Submarine Natural Gas Pipeline

- Frequency and purpose of inspection and assessment of submarine natural gas pipeline

Inspection	Frequency	Purpose
Measurement of cathodic protection potential	Once every six (6) months at Dapeng LNG Terminal, Shenzhen; Once three (3) months at Lamma.	- Ensure pipeline external is receiving protection from sacrificial anodes.
Quantitative Risk Assessment (QRA) for Submarine Natural Gas Pipeline	Every five (5) years, in 2006, 2011 and 2016	- Risk assessment of the gas pipe due to changes in the marine traffic along the route of the gas pipe and in the vicinity of Yantian Port.
Safety Case Study	Every three (3) years 2009, 2012 & 2015	- Ensure safety measures are in place and potential hazards with the gas facilities including the submarine gas pipe that can cause major accidents have been identified and addressed.

Gas Safety in LPS

HEC 5-level Natural Gas Safety Framework

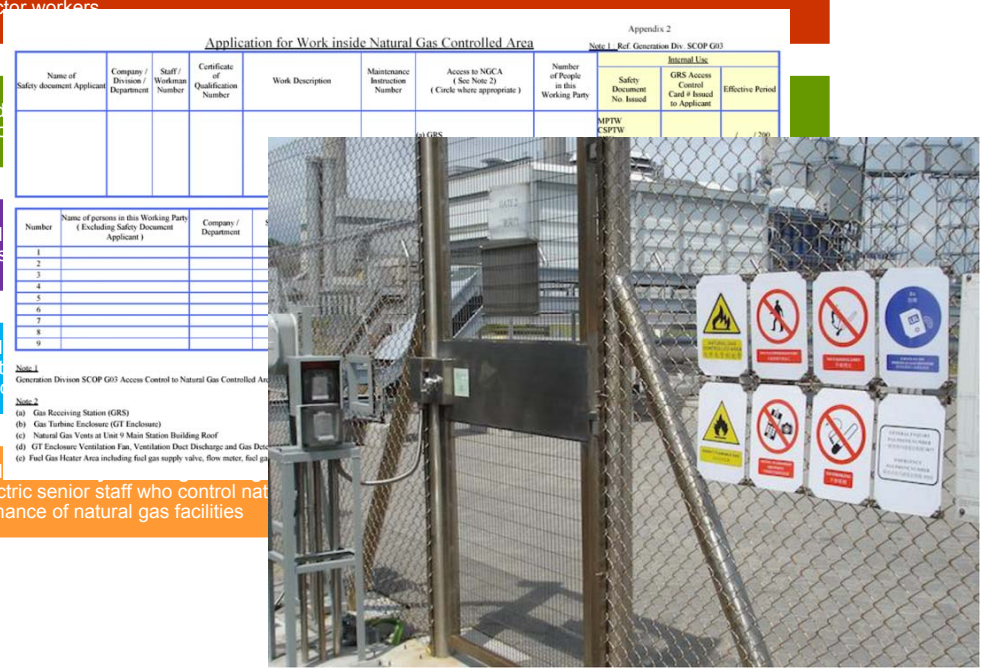
1 **General Information Training**
HK Electric employees normally not working in Lamma Power Station
Contractor workers
Visitors

2 **Site Ind**
HK Elec

3 **Natural**
Persons

4 **Natural**
Compet
constru

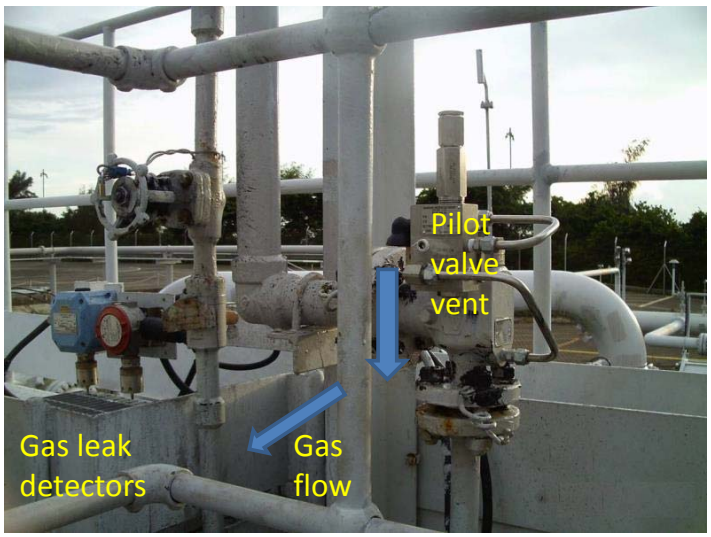
5 **Natural**
HK Electric senior staff who control nat
maintenance of natural gas facilities

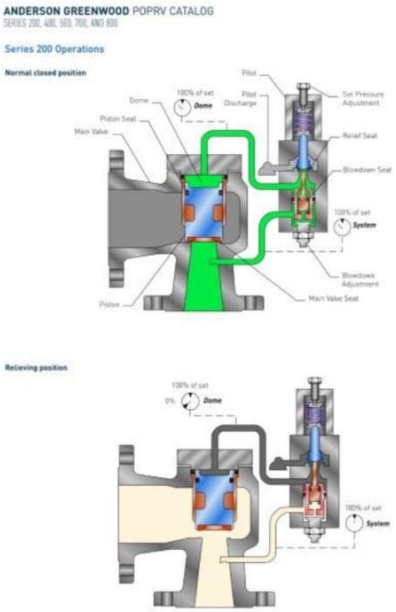


Gas safety in LPS

LPS Gas Receiving Station

- GRS tripping incident
- Failure of a safety valve's pilot valve
- All gas supply shut down

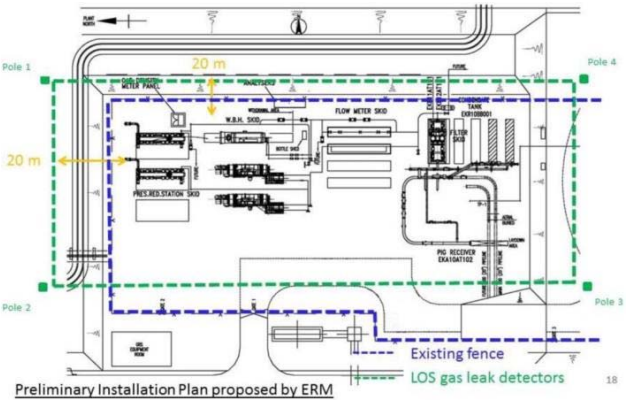




LPS Gas Receiving Station

- Modifications

Open-Path Gas Detector



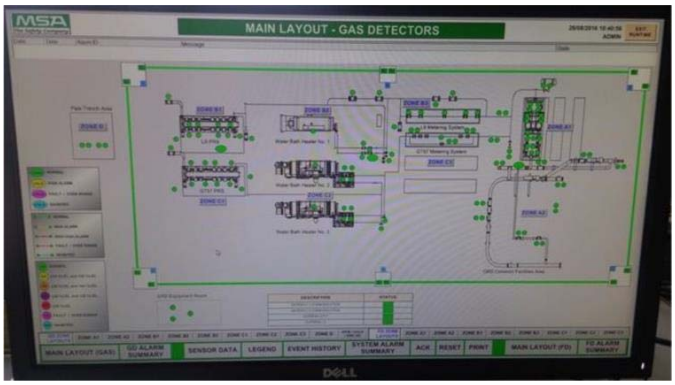
Preliminary Installation Plan proposed by ERM

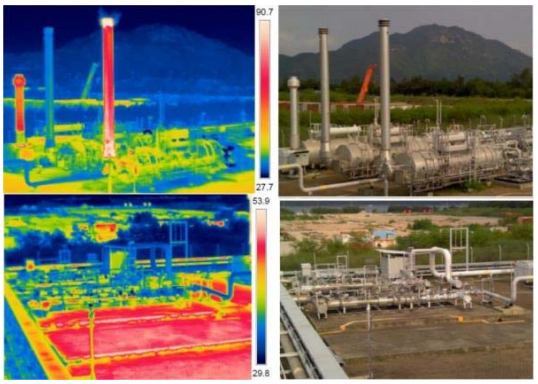
Acoustic gas-leak detector

LPS Gas Receiving Station

- Modifications

Vent pipe for pilot valve

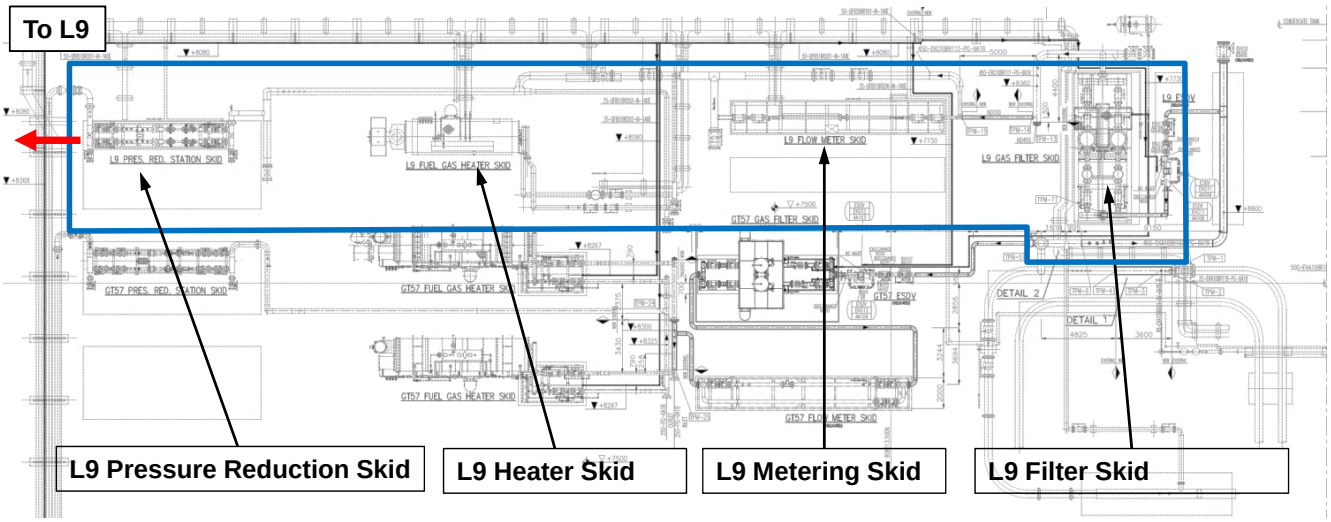




Infra-red imaging

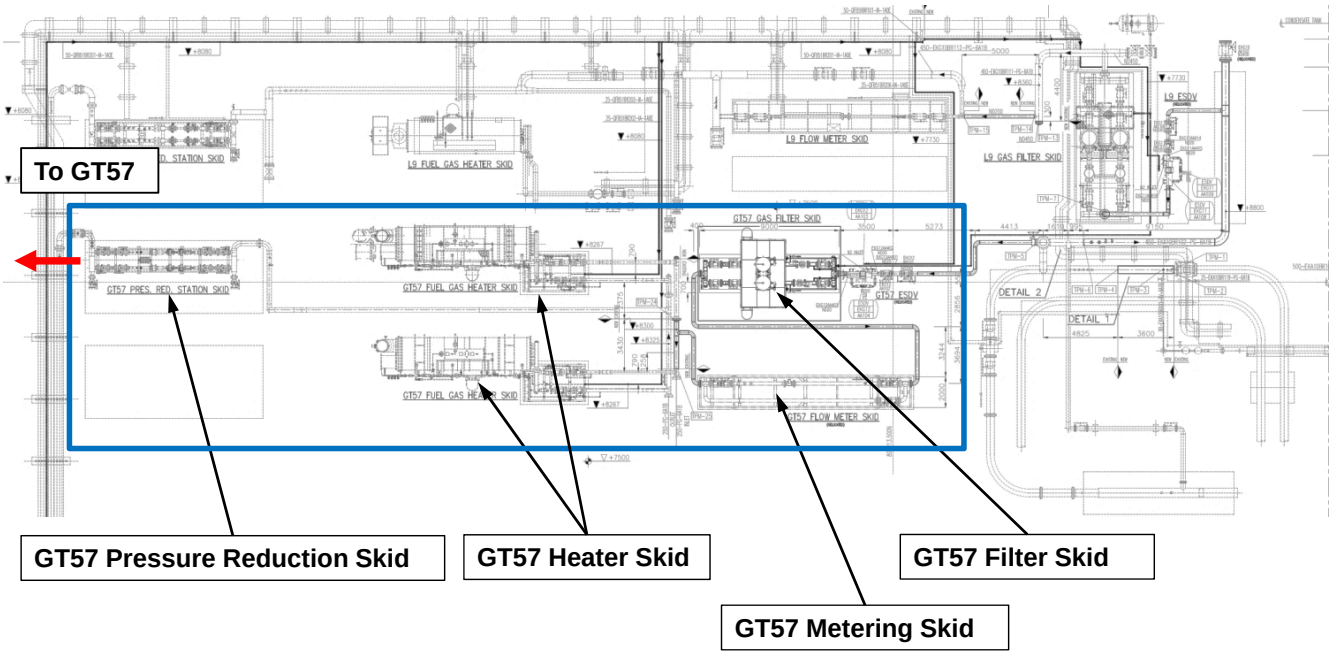
LPS Gas Receiving Station

- Skid for L9



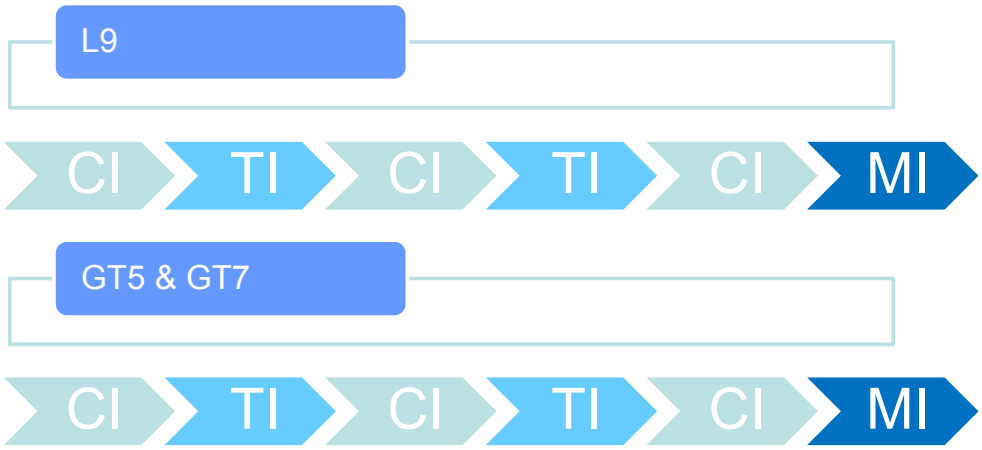
LPS Gas Receiving Station

- Skid for GT57



L9 & GT57 CCGTs

- Maintenance cycle – Long Term Parts Management



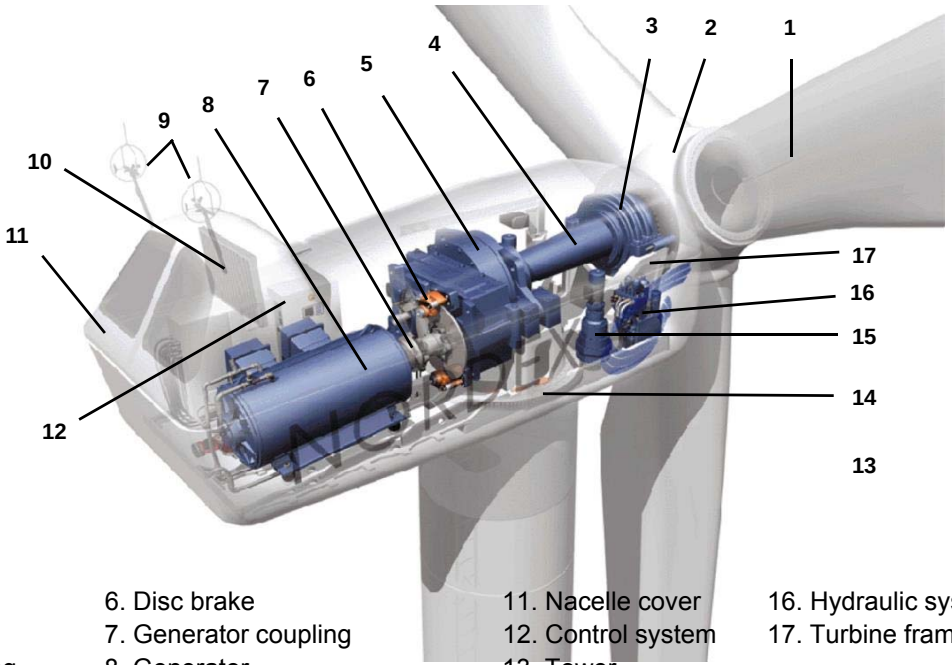
CI	• Combustor inspection
TI	• Turbine inspection
MI	• Major inspection

Electricity Generation from Renewable Energy in Lamma Power Station

Lamma Winds

- Lamma Winds is located at Tai Ling of Lamma Island

Technical Details of Wind Turbine



1. Blades
2. Hub
3. Main bearing
4. Main shaft
5. Gearbox
6. Disc brake
7. Generator coupling
8. Generator
9. Wind measuring system
10. Cooling radiator
11. Nacelle cover
12. Control system
13. Tower
14. Yaw bearing
15. Yaw drive
16. Hydraulic system
17. Turbine frame

Technical Particulars of the Wind Turbine

Wind Turbine Type	N50/800 kW
Number of Rotor Blades	3
Rotor Blade Diameter	50 m
Hub Height	46 m
Swept Area	1,964 m^2
Rotational Speed	15.3 / 23.75 rpm
Cut-in Speed	3 m/s
Cut-out Speed	25 m/s
Generator Output Voltage / Frequency	690 V / 50 Hz

Lamma Winds

- Generated over 8 million units (kWh) of green energy since its commissioning in Feb 2006

TFPV System

- 1-MW TFPV System installed at Lamma Power Station (since 2013)
- A total of 8,662 thin-film photovoltaic panels

Solar panels are located on the roof of buildings and ground level of Lamma Power Station

Technical Particulars of TFPV System

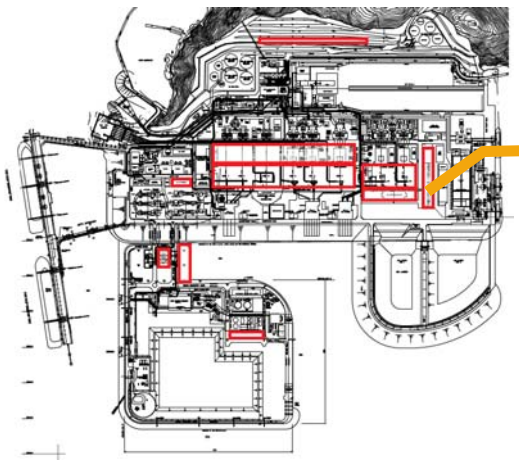
Development Phase	Phase 1	Phase 2	
Total Installed Capacity:	550 kW	450 kW	
Type of TFPV:	amorphous silicon	amorphous/microcrystalline silicon tandem junction	
No. of TFPV:	5,500	2,668	494
Maximum Output:	100 watts (each panel)	142 watts (each panel)	145 watts (each panel)
Voltage (Vpm):	76.96 V	121 V	122 V
Weight:	26.4 kg (each panel)	25 kg (each panel)	
Size:	1.4 m x 1.1 m x 35 mm (each panel)		

Technical Particulars of TFPV System

Development Phase	Phase 1	Phase 2
Inverter Power	10 kW & 12.5 kW	10 kW & 12 kW
Inverter Input Voltage Range (MPPT)	200 Vdc ~ 850 Vdc	220 Vdc ~ 470 Vdc
Inverter Output Voltage	3 phase 400 Vac	
Location:	Rooftops of Main Station Building and Boiler House	Rooftops of other plant buildings and open area at Lamma Power Station Extension
Designed Annual Output:	1,100,000 kWh	
Annual Emission Reduction:	915 tonne of Carbon Dioxide (CO_2)	

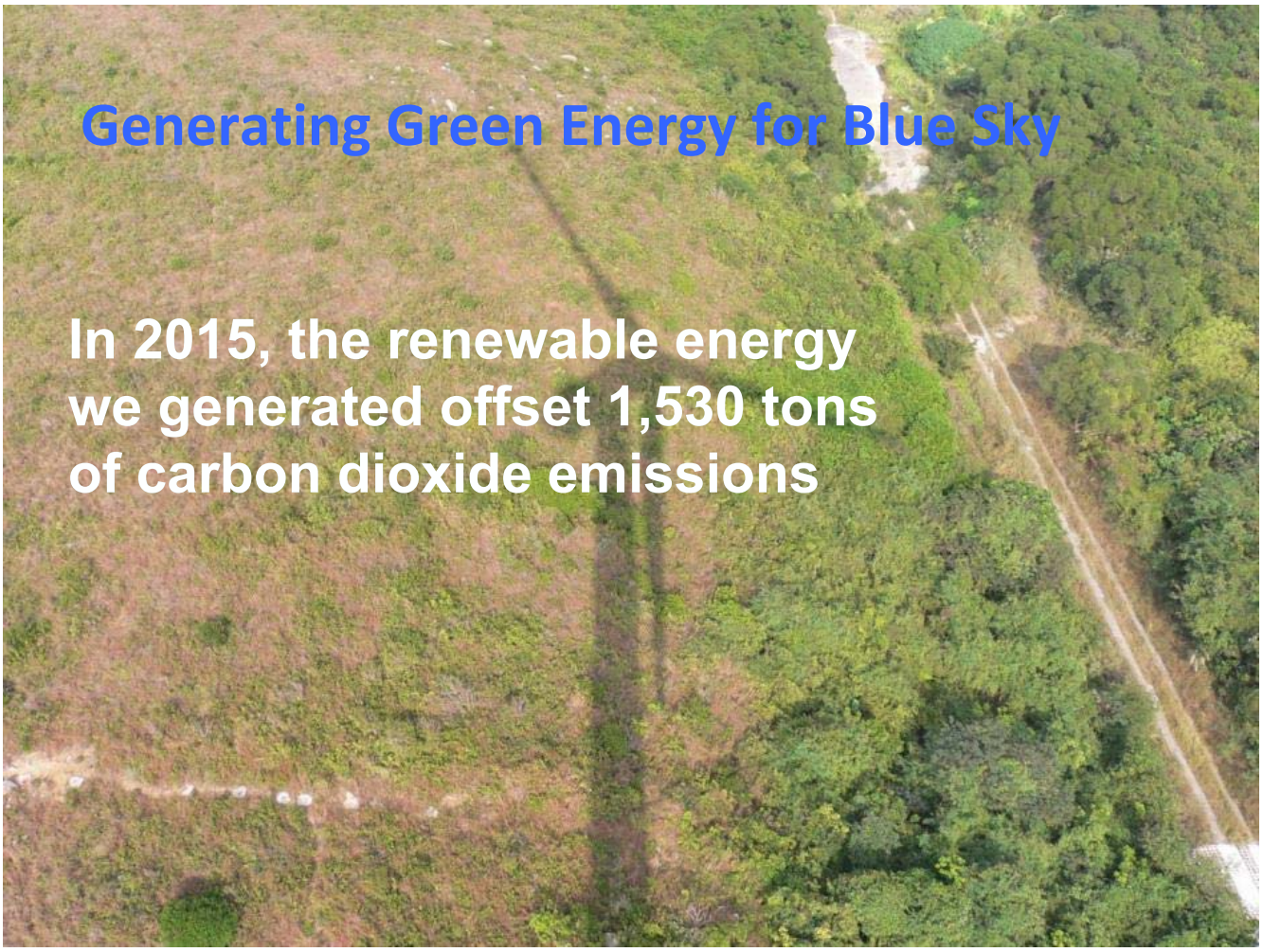
TFPV System

- Generated about 1 million units (kWh) of electricity per year
- *0.0085% of total electricity generated in 2015*



8,662 panels generate green power every day

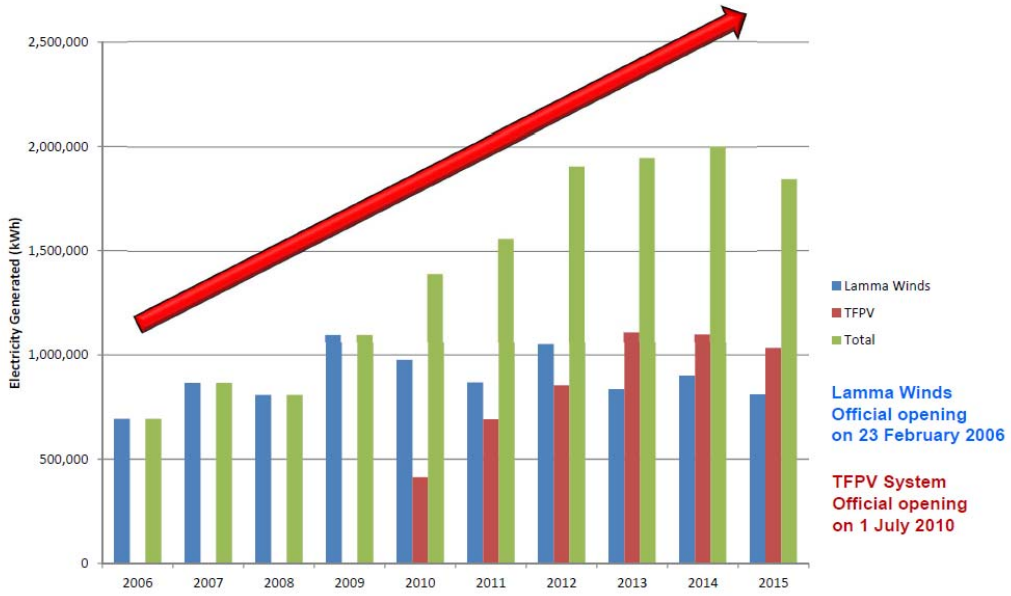
Total area: ~ 4 hectares (40,000 m^2)



O&M Experiences with Renewable Energy Facilities

Operation Experience with RE Sources

Application of RE in Lamma Power Station



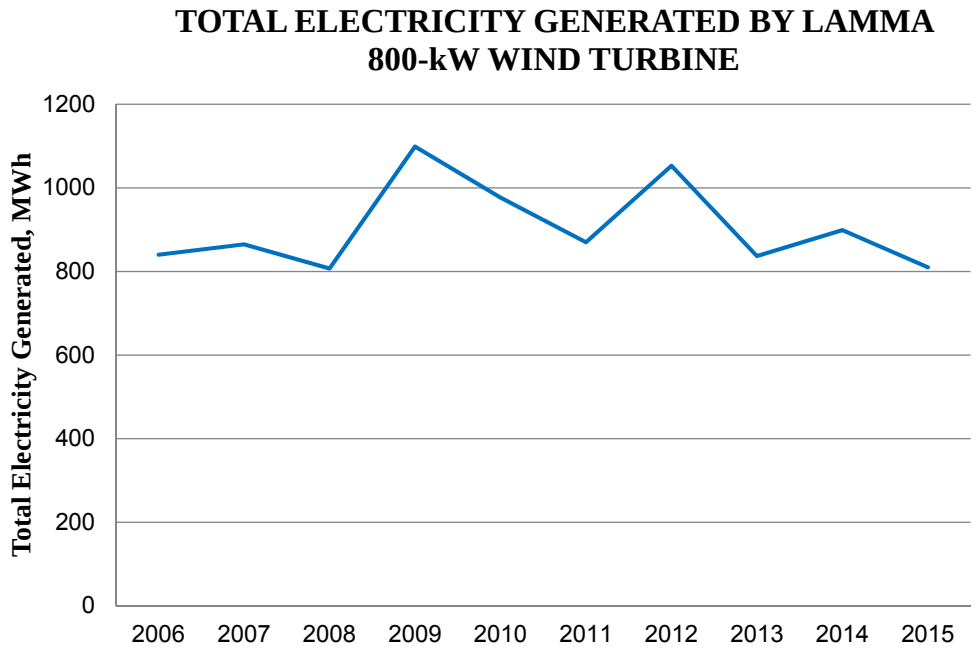
Operation Experience with Wind Turbine

Performance Data of Lamma Wind Turbine in Years 2006 to 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total Electricity Generated, MWh	694	865	807	1,099	977	867	1,053	836	900	811
Capacity Factor, %	11.6	12.3	11.5	15.7	13.9	12.4	15.0	11.9	12.8	11.6
No. of days with little of no Electricity Generated due to wind condition	12	18	30	16	18	15	15	33	15	22

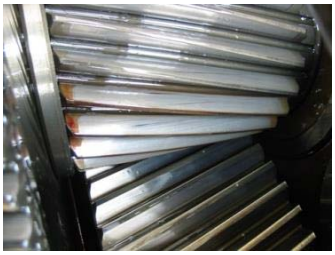
- *Outage due to defects or malfunction in 2015 = 170 hours (1.9 %)*

Operation Experience with Wind Turbine



Maintenance Experience with Wind Turbine

- *Scheduled Maintenance*
  - There are four types of scheduled maintenance for the wind turbine:
    - Type 1 Maintenance: Between 300 and 500 operating hours after commissioning
    - Type 2 Maintenance: Annual intermediate maintenance
    - Type 3 Maintenance: Annual main maintenance
    - Type 4 Maintenance: Maintenance after 5 years of operation



Maintenance Experience with Wind Turbine

- Damage and Detachment of Coupling Discs and Associated Connecting Shaft

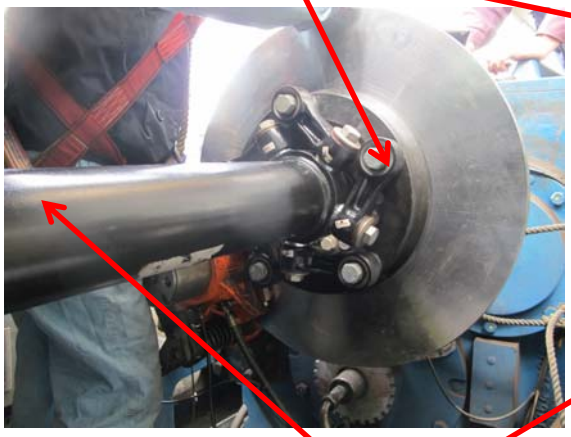
Broken Coupling Discs

Detached Coupling Shaft

Maintenance Experience with Wind Turbine

- New coupling set and disc brake set

Coupling Discs



Connecting Shaft

Maintenance Experience with Wind Turbine

- Cracks and wear found at blade tips

Cracks on blades

Wear on Leading Edge

Damage of Blade tips around Lightning Receptor

Maintenance Experience with Wind Turbine

- Refurbishment of Blade Cracks and Blade Tips

Blade Refurbishment

Maintenance Experience with Wind Turbine

- Damage of Blade tips around Lightning Receptor due to severe Lightning Strike

- "Communication Bus Terminal Module" Faulty

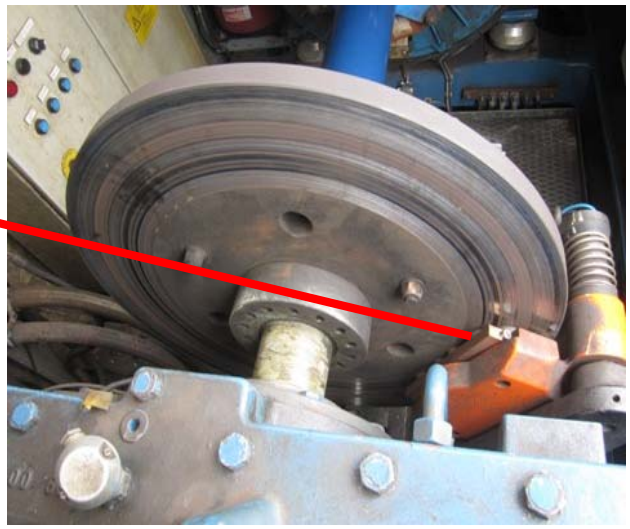
➢ Solution

- Communication modules (7 off)
- and control module (1 off) replaced

Damage of Blade tips around Lightning Receptor

Maintenance Experience with Wind Turbine

- Unscheduled Maintenance
  - *"Brake Wear Stop" Alarm*



Maintenance Experience with Wind Turbine

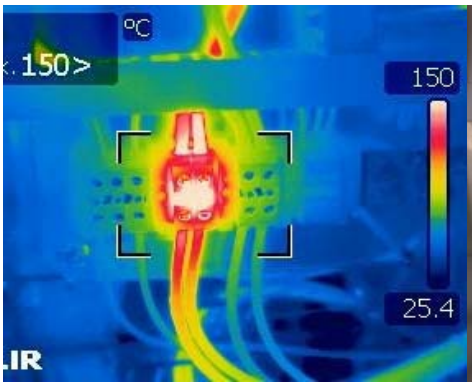
- Unscheduled Maintenance
  - *Manhole cover of Rotor Rub detached after typhoon*

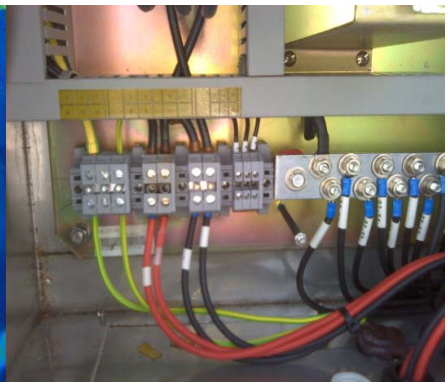
Maintenance Experience with TFPV System

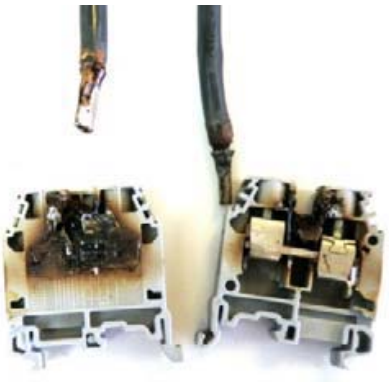
- Thermal-Image Scanning
  - Using infrared (IR) camera
  - Able to find out abnormal hot spots

Maintenance Experience with TFPV System

- Usage of Infrared Camera
  - Hot Spot at Terminals of PV Combiner Box

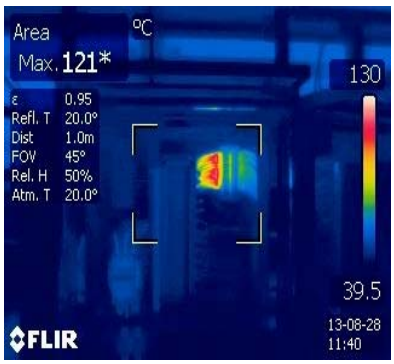


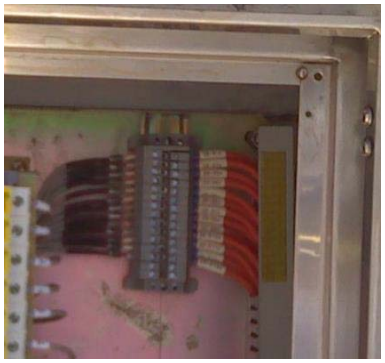




Maintenance Experience of TFPV System

- Usage of Infrared Camera
  - Hot Spot on Blocking Diodes in Combiner Boxes





Maintenance Experience with TFPV System

- Loosened screw due to vibration under strong wind
  - Frame of module detached under strong wind

➢ Solution:
- Replaced damaged modules
- Applied reinforced installation method

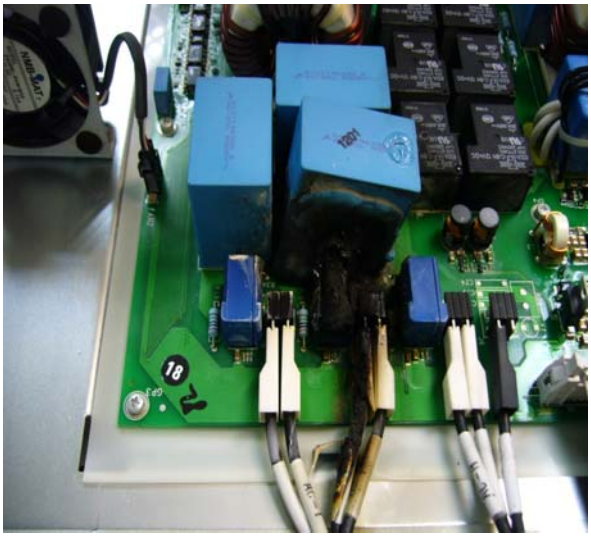
Maintenance Experience with TFPV System

- Inverter Switch fault
  - Bad contact at switch terminal

➢ Solution:
- Inverter replaced
- Screws at switch terminal tightened and checked

Maintenance Experience with TFPV System

- Inverter burn out
- Capacitor damaged due to humidity and AC voltage



➢ Solution:

- Inverter replaced
- Product upgraded with better resistance against humidity and AC voltage

Challenges in Utilizing Renewable Energy in HK

Challenges in Utilizing Renewable Energy

- Availability of space
- Availability of sunlight
- Local wind characteristics (quality)
- Lightning strikes
- Operation & Maintenance expertise

All panels are set to face south and are inclined at 22 degrees

Future Development

L10 & L11 Gas-fired Combined Cycle Generating Units

- 380-MW base-load units
- Nameplate Efficiency: 58.5%
- Commissioning Target: 2020 (L10), 2022 (L11)
- To replace the old and less efficient 2-on-1CCGT and increase the proportion of natural gas generation to 50 – 55 %

Construction is underway since January 2016

L10 & L11 Gas-fired Combined Cycle Generating Units

- Meet stringent new emission limits
- Equipped with
  - Selective Catalytic Reduction (SCR) system
  - Dry Low NOx combustion system

NOx

Thank You