INSTITUTION OF MECHANICAL ENGINEERS HONG KONG BRANCH
EVENING LECTURE ON 13/7/2021 "NEW GAS POWER FOR HONG KONG: HK ELECTRIC L10 EXPERIENCE SHARING"

Coal to Gas Evolution

The lights on Hong Kong Island has been kept on for 130 years, thanks to the highly reliable and economical electricity supplied by The Hongkong Electric Co., Ltd. (HK Electric). All HK Electric's power comes from Lamma Power Station (LPS), the HK Electric's powerhouse at the west corner of Lamma Island opposite to Hong Kong Island. LPS remarked the heyday of coal-firing power generation, and its eight (8) Mitsubishi Heavy Industries, Ltd. (MHI)-supplied sub-critical coal-fired units were the backbone of generating the continuous power from 1982 to the mid-90's.

However, the coal-firing generation era came to the end in 1997, when the Environmental Protection Department of the government (EPD) prohibited further new coal-fired unit to be built in Hong Kong. Since then HK Electric has embraced the cleaner and more energy efficient gas-firing generation, and the gas journey is on-going.

When the first gas-fired combined cycle unit (CCGT), the MHI-supplied L9 built on the reclaimed land nearby LPS, Lamma Power Station Extension (LMX), commissioned in 2006, it contributed 15 % of LPS total power generation capacity and reduced HK Electric absolute carbon emissions by 8 % at that time (by using 2005 as baseline). Subsequently, HK Electric converted two (2) of its seven (7) open cycle oil-firing gas turbines into a gas-fired 2-on-1 CCGT, namely the GT57, boosting the gas-firing generation contribution to 30 % and driving the LPS carbon emission further down by 13 % (absolute against 2005 baseline). 2020 saw half of the power generation shared by gas achieved with the latest CCGT, L10 on LMX, put in operation and, with the commissioning of two (2) more CCGTs by 2023, 70 % of HK Electric's generation will be met by gas and the HK Electric's carbon emissions will be reduced by 40 % absolute against the 2005 baseline.

Gas to Power Transformation

When F-class-based open cycle gas turbine (GT), represented by Brayton Cycle, can do above 40 % of thermal efficiency, conventional sub-critical steam plant under Rankine Cycle can hardly exceed 40 %. It is when two cycles are coupled together with GT, Steam Turbine (ST) and Generator sharing the same shaft, even under the same process conditions [e.g. GT Turbine Inlet Temperature (TIT) of 1,400 °C and GT exhaust at around 650 °C] the thermal efficiency can raise to around 55 %, as L9 has achieved with 335 MW capacity. Should the power train be reconfigured to GT and Generator sharing the same shaft and ST couples with Generator through a Synchro-Self-Shifting (SSS) Clutch, as in the case of L10 by using even more advanced F-class GT, the thermal efficiency and capacity can increase to 58 % and 380 MW respectively.

Technology advancement has permitted TIT to exceed 1,400 °C in F-class GT and reach 1,600 °C in the latest J-class GT by referencing to the product portfolio of MHPS (i.e. former MHI), improving the combined cycle thermal efficiency from the F-class 55 % to the J-class 60 %. Although higher GT class represents higher CCGT capacity,

the HK Electric load profile and operation regime does not favour high capacity units, leaving F-class the optimum GT class for HK Electric.

EPD licenses L10 to emit nitrogen oxides (NO_x) within 5 parts per million (ppm), which is a highly stringent emission limit. Although L10 has been endowed the most technologically advanced F-class GT on the MHPS shelf, M710F4, with Dry Low NO_x Combustor, which pre-mixes natural gas and air compressed in around 1:17 ratio before combustion and facilitates uniform low flame temperature to minimise NO_x formation at 50 ppm, the outstanding NO_x suppression to 2.5 ppm is attained with post-combustion treatment by Selective Catalytic Reduction system (SCR).

SCR locates inside Heat Recovery Steam Generator (HRSG), the equipment of transferring the GT exhaust heat to the steam cycle for ST to do work, between the high pressure steam evaporator and the intermediate pressure steam evaporator. Inside SCR is platinum-based catalyst in 30 modules that facilitates ammonia, homogeneously sprayed from 5,936 nozzles in Ammonia Injection Grid for optimum reaction, to reduce NO_x into nitrogen and water. Ammonia, classified dangerous goods in Hong Kong legislation, is in-house generated by Urea-to-Ammonia Conversion System, which first dissolves the non-toxic urea pellets into urea solution and then utilises the GT exhaust to pyrolyzes the urea solution into ammonia and water.

L10 from Construction to Completion

After L9 in 2006, HK Electric committed another CCGT, L10, in end 2013 after gaining government approval. Following competitive global tender, the MHI succession company, Mitsubishi Hitachi Power System (MHPS) won the L10 electrical and mechanical (E&M) supply contract, which was signed in January 2016. Piling commenced in January 2016 and civil superstructure excavation in November 2016. Main Station Building (MSB) structural erection began in August 2017, followed by major equipment arrival to site in April 2018. Synchronisation was achieved in October 2019 and after four (4) more months of testing and commissioning, commercial operation was announced in February 2020.

As the HK Electric gas-firing journey goes on, the latest CCGT under construction in LMX, L11, is targeted synchronisation and commercial operation in December 2021 and April 2022 respectively. Simultaneously, another new CCGT in LMX, L12, is planning to receive its power train in April 2022 for commercial operation in July 2023.

The L10 project was not without challenges. The tight construction schedule was demanding on its own to manage. The parallel construction of L10 and L11, which are physically separated by merely an access road within the already compact LMX, resulted in complicating civil works and E&M interfacing. Adverse weather conditions in both Hong Kong and Japan delayed the construction and equipment supply, and the coronavirus pandemic intricated the entire project in an unprecedented way.

Aside the above difficulties which required extensive management efforts to manage and co-ordinate, various technical issues also came to HK Electric surprise. For decades, the assets in LPS and L9, were constructed as “equipment”, which were not subject to the statutory structure design approval administered by Buildings Department of the government (BD). In L10, however, for the first time BD considered HRSG “building”

that had to fulfil all the requirements for human occupation, in spite of HRSG was MHPS-proprietary design for unmanned operation. HK Electric and BD negotiated intensively to agree over the HRSG structural design.

In addition, the high temperature air handling process of UTAC was the first of its kind to HK Electric and the induction fans, which induces GT exhausted hot flue gas for decomposing urea solution to become ammonia and water, suffered from excessive vibration. It look HK Electric and MHPS much time and effort to redress the problem with replacements which build quality was given extra scrutiny and controls.

The MSB structure was of design and build unconventional in Hong Kong. Many large size reinforced bars packed to form a highly compact structural lattice in order to give the turbo block structure sufficient strength to withstand the loads from the over 1,000 ton power train rotating at 3,000 revolutions per minute.

L10 Reflection and Future Projection

L10 was a ground-breaking project for HK Electric. Not only is L10 sign of HK Electric and Hong Kong overall commitment to the low carbon economy, it is also Hong Kong's pioneering CCGT with superior NO_x supressing performance. It also opened the chapter of HK Electric generation business transformation. While HK Electric made the fundamental fuel switch from oil in 1970s to coal in 1980s, L10 has begun the switch from coal to natural gas in the 21st century, for the 21st century world.

The L10 project was also a whetstone of HK Electric. It sharpened a new generation of HK Electric professionals to be experienced and capable to deliver further CCGTs, keeping the know-how of completing power plant projects in-house. L10 showcased the potential and competence of the next generation of engineers in Hong Kong.

Institution of Mechanical Engineers Hong Kong Branch thanks Mr. David S.N. Li and Mr. Johnny K.L. Kwong, both are Chief Mechanical Engineer, Projects Division of HK Electric, for their candid and insightful sharing on 13/7/2021.

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