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[Effects of Variation of Fuel Gas Composition and heating value on Gas Turbines in Korea]

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Background

Currently, the world high heating value natural gas market is decreasing and low heating value natural gas such as PNG and Shale gas market is increasing now. Commonly natural gas trade is based on calories, however South Korea government and Korea Gas Corporation (KOGAS) have been adopting volume based trade that is easy way to charge a gas cost. In other word, Korea import natural gas based on calorific value and supplies natural gas with volume based system. Precondition of volume based trade system is that calorific value of all natural gas must be constant going through process of calories control, then supply natural gas in volume units. Kogas has imported high heating value natural gas with high cost to set the standard calorie value 43.54MJ/Nm^3 (10,400kcal/Nm^3) system that supplies constant calorific natural gas. It has become a burden on consumers. Therefore Korea domestic natural gas heating value system was needed to change that was promoted over a period of adjustment from standard heating value(43.54MJ/Nm^3) system to range of calories 41.9MJ/Nm^3 ~ 44.4MJ/Nm^3 (9,800kcal/Nm^3 ~ 10,600kcal/Nm^3) system after 2015, and keeping the lowest calories 42.28MJ/Nm^3 (10,100kcal/Nm^3) since 1st July 2012.

Table. 1 Composition and Heating Value of Conventional Gas before July 2012

CH_4	C_2H_6	C_3H_8	$I\text{-}C_4H_{10}$	$N\text{-}C_4H_{10}$	$I\text{-}C_5H_{12}$	$N\text{-}C_5H_{12}$	N_2	CO_2	LHV (MJ/kg)	LHV (MJ/Nm3)	HHV (MJ/kg)	HHV (MJ/Nm3)
91.332	5.363	2.136	0.459	0.476	0.015	0.002	0.217	0.000	49.304	39.205	54.592	43.542

Table.2 Composition and Heating Value of LNG which are supposed to supply to power plant

Items	CH_4	C_2H_6	C_3H_8	$I\text{-}C_4H_{10}$	$N\text{-}C_4H_{10}$	$I\text{-}C_5H_{12}$	$N\text{-}C_5H_{12}$	N_2	LHV (MJ/kg)	LHV (MJ/Nm3)	HHV (MJ/kg)	HHV (MJ/Nm3)
Average	92.562	5.039	1.622	0.322	0.283	0.012	0.001	0.159	49.446	38.754	54.778	42.859
Momentary	96.649	2.907	0.376	0.037	0.024	0.002	0.000	0.005	49.850	36.883	55.312	41.030

Low Limit												
Momentary High Limit	89.718	6.250	2.680	0.546	0.623	0.019	0.005	0.159	49.243	39.976	54.491	44.378

Aim

This study is aimed to review effect of calorie variation for conventional gas turbine and pre –adjust Gas turbine to prevent problem of operation and safety due to gas composition and heating value variation. To improve calorie value system a previous research has been performed by KOGAS, KEPCO and government about since 2006. Also brief preview of interchangeability study had been done with gas turbine manufacturer as necessary. Before implementing a calorific value range system, we put the warm-up period of about two years. Promotion team that organized by KOGAS, Power Generation Company and related company jointly made questionnaire and asked response to gas each turbine manufacture.

Methods

According to change of this heating value system, KOGAS and Power Generation Company have requested effect of calorie system change on conventional gas turbine and how to pre-adjust Gas turbine action. The main content of query include that is it the acceptable range as compared with the conventional gas that GT effects of efficiency, output, emission, combustion dynamic and etc. are caused by heating value variation?

In addition, review of effect of low heating value natural gas as power plant fuel is needed because high heating value market is consistently. Previous studies[1)] presented with the implementation range of calories system, increase 0.20% gas turbine weighted average power, decrease 0.03% weighted average efficiency for power plant and increase 0.19% weighted average power, decrease 0.16% weighted average efficiency for combined cycle power plant.

-Main factor of reviewing effect of variation of fuel composition on Gas Turbine

○ MWI(Modified Wobbe Index**)**

There are various way to judge the fuel interchangeability standard. It is considered Wobbe Index(WI) to figure out sensitive difference of output variation in burner and range of design between future gas and conventional gas calorific value. However, the index is suitable for diffusion flame combustors. Modified Wobbe Index has been reported that more appropriate for lean premix combustors[1)] and most of the manufacturer use the MWI and WI_{net} as output index.

$$Wobbe\ \ Index = \frac{LHV}{\sqrt{S.G}}$$ ----------------------------------(1)

$$Modified\ Wobbe\ Index = \frac{LHV}{\sqrt{T}\sqrt{S.G}}$$ ------------------(2) [3)]

LHV:Lower Heating Value of Gas Fuel(MJ/Nm^3)

$\sqrt{T}$ gas: Absolute Temperature Fuel Gas(K)

$\sqrt{S.G}$: Specific Gravity of the Gas Fuel relative to Air

$$WI_{net} = LHV_{mass} \times \frac{\rho_{gas(T)}}{\sqrt{\frac{\rho_{gas(T)}}{\rho_{air(0°C)}}}}$$ ---------------------------(3) [4)]

WI_{net} : Wobbe Index based on lower heating value of the fuel
LHV_{mass} : Lower Heating Value
$\rho_{gas(T)}$: Fuel gas density at gas temperature T
$\rho_{air(0°C)}$: Air density at 0°C (1.293 kg/m^3)

Although it is slightly different for each gas turbine manufacturer, typically it is determined that there is no impact on the output within the range of ±5% MWI about the calorific value changes. If the fuel meet the basic operation criteria of judgment as follows, it is possible to be used as gas turbine fuel although the calorific value is changed. [3)]

◦robustness to auto-ignition, flashback and LBO(Lean Blow-Out)
◦emissions compliance
◦acceptable combustion dynamic pressure

Because gas turbine combustors have a narrow acceptable window, fuel specification is regulated to maintain the combustion stability and restrict the variation of composition. Depending on the change of calorific value regulation, if the value of new gas MWI is far away from design MWI, high instability and risk of LBO have a negative impact on life expectancy of the hardware. Therefore, instability and emission should always keep an acceptable range. When fuel is changed by calorie system change, it is possible to be one-sided control such as tuning combustion parameter, especially combustion instability and emission, within acceptable limits. If such action is not done on time, it could be larger risk such as combustion instability, emission and LBO on combustor. Moreover, gas turbine occurs on hardware damaged, shutdown and potential risk like trip and runback. Combustion system should well control through manual tuning or auto-tune system.

Results

-Countermeasure for the Effects of Variation of Fuel Gas Composition

The gas turbines operated in Korea have been supplied about 100units over made in Alstom, GE, Siemens, MHI, and Hitachi. The action plans for the effect of changing calorific value on the gas turbine are different for each GT manufacturer. Fuel study results and adjust plan are followed. For a gas turbine of A company, the future gas composition that consist of over 9 vol% of C2+ and H2 is limited due to the dangerous of flashback. This is related to the structure of gas turbine. For the 2stage combustor models, expansion processes occur twice in 1st combustor and 2nd combustor then spin the turbine. Since the temperature after the turbine is fixed to set point in this process, set point must be adjusted for the case of C2+ and H2 are greater than 9%. The adjustment by GC needs 15 minutes, but set point set is completed with fuel flexibility package using infrared sensor in 20 seconds. It is almost real time optimization. If the C2+ and H2 condition were satisfied, the fuel would be compatible when the WI variation is less than 10%. For a gas turbine from B company, although fuel would change very slightly in the future when analyzed composition of fuel used for the past few years, combustion system tuning is recommended for ignition and NOx emission. For a gas turbine from C manufacture, some tuning need to maintain an acceptable operating range because operating point is far from MWI ±5%, possibility of high instability and Lean Blow out negatively affect hardware life. For a gas turbine from D company, most of the on-site combustor tuning is required to decrease pressure perturbation and NOx emission or the design change of combustor fuel supply nozzle and control valve is required. Except specific models of A company most of gas turbine has a similar structure with a lean premix combustors thus combustor tuning is required to decrease pressure perturbation and NOx emission when the fuel composition changes.

In general, design range of WI or MWI is established each manufacturer. For example, in the case of company C, range of MWI is ±5%. The fuel that shown table1 and table2 may be determined that there are no problem because variation is small compared to conventional fuel. However if conventional fuel operating point already exist nearby ±5% boundary, fuel can cause problems even if small variation. There exist site that operating condition at present get out of even ±5% boundary. In the case of such a site, it is impossible to review effect of variation of calorie value. In order to ensure the stability of GT, installation of auto-tune to overcome variation of heating values, controlling fuel supply temperature and changing of fuel nozzle are necessary. If the current operating conditions has already get out of design range, it is impossible to classify that the problems are from whether simple fuel composition effect or combined problem getting out design condition. Thus this issue is many controvertible. When linked to the cost of compensation, situation can go up to litigation. In fact, in the USA the lawsuit was proceeded between LNG import and gas pipeline company. Issue contents are max/min Wobbe index, max/min heating value; limit value of hydrocarbon composition, limiting value of insert gas composition concentration and MWI change rate[2)]. To determine this contents Gas supplier, LNG importers Power Company were present the design Wobbe index range and gas turbine manufacturer were present the Modified Wobbe Index range. Through this process, designated the standard interchangeability range for each fuel composition and based on this determined the cost compensation.

Conclusions

After reviewing effects of heating variation on gas turbine we have established the countermeasures and subsequently pre-adjust plan. In some of GT manufactures final meeting is ready to prepare. As change from standard calorie system to gas calorie band system,

Two manufactures' GTs of five manufactures have no effect on the amount of heating value variation. Other two manufactures' GTs are needed to tune for the new fuel gas, further more the remaining manufacture's GT model, each unit must implement autotune in order to accommodate the new fuel, even though it is not required for these model of GTs, it recommended due to the expected fuel variation. There are in possession of a debate on the autotune installed.

There is an uncomfortable situation due to regulation changes in the field, through this process to clearly the effect and characteristics of fuel variation on GT, it seems that opportunity that begin to pay attention not only variation of fuel composition but also related other factor to operate GT like efficient operation and effective maintenance.

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