Adoption of Frequency Control of LNG Pumps

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Back Ground

Tokyo Gas is planning to raise gas sendout pressure at the Negishi LNG Terminal from 2 MPa to 3 MPa. As the planned increase is only small, raising the pressure by 1 MPa, a study was made of whether the pressure could be raised by increasing the head of the current in-tank low pressure pumps (LP pumps) instead of installing new pot-type high pressure pumps (HP pumps). The advantage of this approach is that expenditure on installation of additional piping, pipe racks, and associated foundation work for the HP pumps can be reduced.

The current (pre-upgrade) system and the two approaches to raising the pressure are shown in outline below.

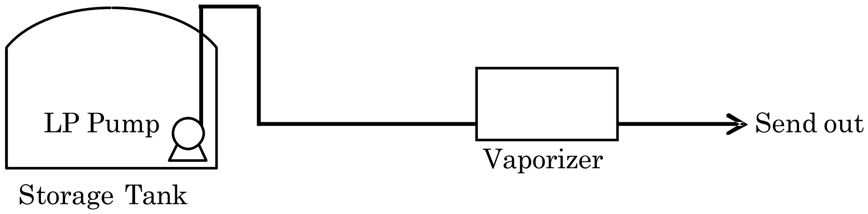

Figure 1-1. Current system

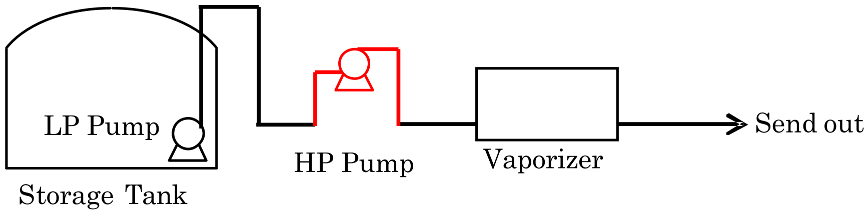

Figure 1-2. Typical approach for raising pressure: Adding HP Pump

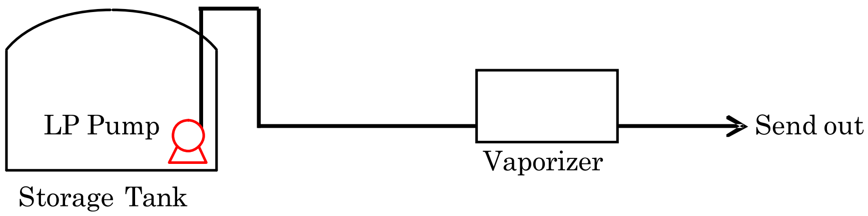

Figure 1-3. Alternative approach: Raising LP pump head

We proposed combining the increase of the head of the LP pumps with adoption of frequency control of the pumps by means of inverters in order to control the pump discharge pressure and so control line pressure.

Aims

One problem posed by raising pressure by increasing the head of the LP pumps is that the design pressure of piping from the LP pumps to the open rack vaporizers (ORVs) is based on the current 2 MPa sendout pressure, which means that there is little margin for handling the pressures required for sendout at 3 MPa. In particular, pump characteristics are such that pump pressure rises above the rated point in the low flow range, resulting in the design pressure of pump barrels and piping being exceeded at low flows. Our aim was to find a solution to this problem and verify its applicability.
The solution that was devised was to combine the increase of the head of LP pumps with adoption of frequency control of the pumps by means of inverters in order to control the pump discharge pressure and so control line pressure. Fitting inverters to enable frequency control of pumps is already common practice for general-purpose pumps, but there are few instances where this approach has been adopted for LNG pumps. Moreover, in most cases, inverters are used with the aim of saving energy, and there are very few instances where the aim is pressure control. There are also very few instances where inverters are utilized for high-voltage LNG pumps. (See table.)

Table. Instances of pumps utilizing inverters

Examples	Details
Case 1	LNG-LP pumps (3 pumps) Purpose: Line pressure peak control Motor rating: 400 V/160 kW Inverter: With noise filter
Case 2	LNG terminal LNG-HP pumps (4 pumps) Purpose: Energy saving and output adjustment

Methods

As noted above, there are few instances anywhere in the world of LNG line pressure being controlled through pump frequency control using inverters. The aim of our study was to effectively utilize existing piping having a low design pressure, and to control the pressure of LNG, which is a highly incompressible fluid, within a narrow range while ensuring the necessary pressure for sendout. This presented a significant technical challenge.

A further problem involved in controlling the frequency of pumps using inverters is the electrical corrosion of pump bearings. Surge voltage generated by installation of inverters gives rise to potential difference between rotors and stators, and sparks are generated when insulation breaks down. These sparks occur on the rolling contact surfaces of bearings, which is where the gap between rotors and stators is smallest. Generation of sparks causes damage to bearing rolling surfaces, and as the damage increases, it causes abnormal noise and vibration in the pumps and eventually interrupts operation. This phenomenon is called electrical corrosion, and a study was made of actual equipment to check for its occurrence.

To confirm that the pressure of LNG could be controlled within a narrow range, we performed a dynamic simulation study. We also conducted pressure control tests on actual plant to verify the accuracy of the simulation.

Results

(1) Investigations into electrical corrosion

One of the problems presented by controlling the frequency of pumps using inverters is the electrical corrosion of pump bearings. Surge voltage and other factors produce potential difference between rotors and stators, and sparks are generated when insulation breaks down. These sparks occur on the rolling contact surfaces of bearings, which is where the gap between rotors and stators is smallest. Generation of sparks causes damage to bearing rolling surfaces. The metallographic structure and hardness of the parts affected by the heat of sparks differ from those of the unaffected parts around them, and there is a risk that the damage may develop into delamination. When the electrical corrosion progresses, it may cause fluting (corrugation) on the surface, resulting in abnormal noise and vibration, and eventually preventing the bearing from functioning. Because of their electrical characteristics, electrical corrosion is more likely to occur in large capacity motors. The likelihood of occurrence differs according to the electrical characteristics (insulation performance) of the fluid being pumped.

With LNG pumps, there are few instances of large capacity pumps converted to use inverters, so we investigated pumps already operating with inverters in order to save energy, and also pumps where we added inverters to pumps that were already operating on a commercial power supply. After operation, these pumps were dismantled and their bearings closely examined. Before conducting the tests on the pumps where we added inverters, filters were installed in order to reduce the risk of electrical corrosion. Our investigations found signs of electrical corrosion on the bearings of 1 out of a total of 5 pumps. This demonstrated the possibility of electrical corrosion occurring in LNG pump bearings. The bearings that exhibited signs of electrical corrosion belonged to a pump that did not have a filter installed.

(2) Investigations into pressure control

Controlling the line pressure of LNG, which is a highly incompressible fluid, within a narrow range presents technical challenges. Consequently, it was necessary to verify our ideas before adopting this approach in actual plant. For that reason, we conducted investigations using the following steps.

1) Simulation

2) Testing in actual plant to verify the accuracy of the simulation

The simulation modeled actual plant, including pressure variations due to startup and shutdown of pumps operating in parallel, pressure variations due to a pump tripping during operation, and pressure variations due to a shutdown of the ORV that provides the demand for the LNG downstream from the pump. The control constants for the frequency control were used as parameters for the simulation. The conclusion from the simulation study was that it should be possible to control variations in line pressure to within approximately 0.1 MPa.

In order to confirm the accuracy of the simulation methodology, we tested frequency control using inverters on a pump in actual plant. Actual plant testing was performed by aligning conditions with those already used in the simulation, and conducting tests where we varied the pump frequency and measured the variations in pressure. We also conducted tests to confirm controllability under sudden variations by adjusting LNG flow control valves. Through these tests, we confirmed that it was possible to control line pressure using frequency control.

Nevertheless, some cases were observed where the pressure variation behavior in actual plant differed from that in the simulation. We suspect that one factor in the uncertainty is changes in vapor-liquid equilibrium occurring in residual gas in the line when the pressure varies.

Conclusions

This new approach provides a groundbreaking method of modifying processes at LNG terminals for minimal outlay. Introduction of this technology at LNG terminals that are already in operation should make it possible to achieve energy savings. We are confident that the discoveries and knowledge gained in the verification process of this technology can contribute significantly to future studies of LNG terminal processes worldwide.