UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF ADAPTIVE CONTROLLED NATURAL GAS TRANSMISSION WATER BATH HEATER USING MATHEMATICAL MODEL

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ABSTRACT

Water bath heater has wide application in natural gas transmission industry. It is used for eliminating Joule-Thompson effect. In natural gas transmission, moving natural gas properties may vary from one location to another. It changes as it flows through long pipeline, or flows through an orifice in pressure reduction section in the *citygate* station. The flowrate is usually inconsistent depending on consumptions at the consumer end. Natural gas calorific values and its other properties may also vary when the system receives natural gas supply from different sources in upstream of the network. The climate change and day night change also give effect to its temperature. These nonlinearity of flow has a major effect on controller performance of the water bath heater. A small number of controller model and brand that is specifically designed for water bath heater in industry has motivate this research. Most of them are only dedicated to control bath temperature and not the process gas. This thesis explores application of adaptive control in water bath heater. Available options of adaptive control scheme and adaptation mechanism have been reviewed. Model Reference concept has been adapted combined with an adaptive set point regulation method selected as an adaptation method. The development of the controller is prepared based on practicality and current set up of this equipment in industry. A mock-up model of water bath heater is designed and fabricated using electrical heating element to represent firetube. A process gas mock-up is represented by continuous flowing air that is supplied by laboratory compressed air supply. The thermal process theory provides a way to obtain the process model of the water bath heater mathematically. An adaptive set point regulation algorithm and the model reference are prepared to work with Proportional Integral Derivative (PID) controller in basic Labview programming platform. Data acquisition is done using USB-6001 links to thermocouples on bath and coil outlet and voltage regulator between the power-supply to the heating element. Uncontrolled heating test was first conducted to get a benchmark curve. A test run using ordinary PID controller was then conducted as comparison. With the same test parameter, the controller with adaptive set point model reference controller was tested as the main focus of the study. Using the basic Labview package, the model reference can only be written in the form of mathematical expression. Due to this limitation, the adaptive set point regulation algorithm was formulated. The set point adjustment mechanism adjusted the set point input by adding up the error between model response and actual response so that during undershoot (less than set point), the control output will be augmented while during overshoot (more than set point), the control output will be diminished. This situation provides continuous tracking to make the actual response follows the set point and model reference. Its capability to augment the controller response during rise time and diminish excessive overshoot without disturbing the operation of the current PID controller scheme is a reasonable improvement for current set-up in the industry.

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CHAPTER ONE
INTRODUCTION

1.1 Background

Natural gas is an important fuel used by most countries in the world nowadays. Leidos, Inc. [1] reported that there has been 623 billion standard cubic meters of natural gas demand by Asia and Oceania region in year 2011 and this amount is projected to increase to more than 2,831.7 billion standard cubic meters by year 2030. It is a preferred option of fuel because it is environmentally friendly compared to other fossil fuel. Natural gas is often described as "clean burning" fuel because it produces fewer undesirable by-products per unit energy than coal or other petroleum fuels. Like all fossil fuels, its combustion emits carbon dioxide, but at about half the rate of coal per kilowatt hour of electricity generated. It is also more energy efficient.

In Malaysia, natural gas is as important as in other parts of the world. Malaysian Gas Association [2] reported that the natural gas production in 2013 was approximately 0.176 billion standard cubic meters per day, increasing from 0.170 billion standard cubic meters per day in 2012, contributed by higher production in Peninsular Malaysia and Sarawak. Malaysia's domestic gas consumption increased by about 5.7% to reach 0.071 billion standard cubic meters per day, from 0.068 billion standard cubic meters per day in 2012. At domestic price of about RM12.99 per billion joules (regulated price in 2013), it is equivalent to about RM34.25 million per day as paid by domestic customers in 2013. Due to concern to the high cost of fuel forces continuous researches to be done on every operational aspect to find ways to minimize any kind of losses that could lead to reduction cost of operation.

In natural gas production, gas wells operate at very high pressure of between 345 to 1,034 bar gauge and a flow pressure in tubing is in excess of 207 bar gauge. As pressure reduced to the appropriate pipeline pressure, the big different may cause severe problem in the downstream pipeline. At the point where gas flows through a wellhead choke valve, gas pressure begins to reduce. The gas becomes cooler as the pressure reduces while liquid and hydrate start to form in the pipeline due to condensation. A formation of gas hydrate is one of the major concern in natural gas flow assurance [3].