Design Features of Power Supply and Instrumentation Circuit for Mutual Inductance Type Liquid Metal Level Sensor

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1. Introduction

In liquid metal system, level measurement in the tank is required to be measured since safety alarms and set points for system protection are linked to the level signal of the tank in the system. In the case of Liquid Metal Reactor, the large main vessel also requires the level signal to monitor the system[1]. The mutual inductance type level sensor works on the principle of variation of mutual inductance between two windings when they are in the proximity of an electrically conducting fluid such as liquid metal[2].

In this paper, we have provided configurations and design features for power supply and instrumentation circuit to obtain improved level data from mutual inductance type liquid metal level sensor.

2. Preliminaries

In this section, configuration and requirement of mutual inductance type liquid metal level sensor is described.

2.1 Overview of Mutual Inductance Type Liquid Metal Level Sensor

The mutual inductance type liquid metal level sensor has two windings wound in bifilar fashion on a non-magnetic stainless steel core as shown in Fig. 1. The two wounded coils is inserted in a stainless steel sheath and it is installed in a guide tube to protect it from direct contact of liquid metal.

The principle of mutual inductance type liquid metal level sensor is as follows: The primary winding of the sensor is excited with an alternating current (AC) at a constant frequency. The liquid metal is electrically conductive and the electro motive force can be induced by supplying the alternating current[3]. If an electro motive force is induced in liquid metal, then the eddy current flows in it. Then, the magnetic flux due to eddy current oppose the magnetic flux produced by the primary winding. Thus, the net magnetic flux linked with secondary winding decreases and the secondary voltage reduces when the liquid metal level increases. Then, liquid metal level can be obtained by measuring the induced voltage in the secondary winding. Thus, power supply and instrumentation circuits are required to be appropriately designed for obtaining improved data from the level sensor.

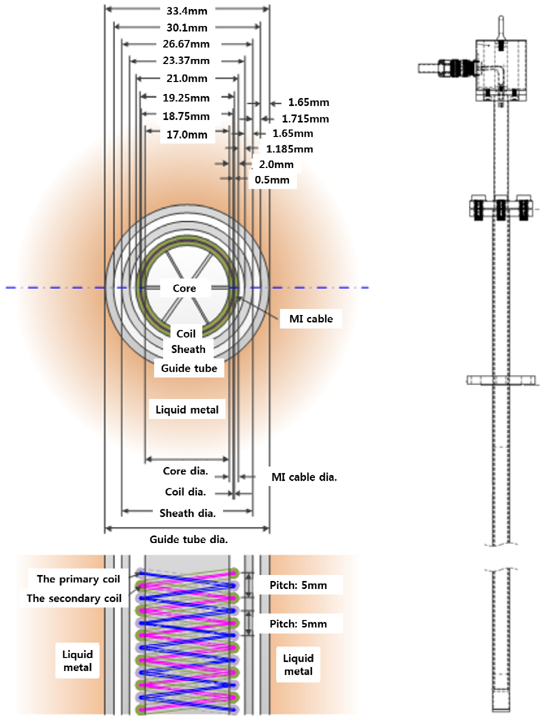

Fig. 1. Configuration of mutual inductance type liquid metal level sensor

When the liquid metal temperature increases, the resistivity of liquid metal increases. Then, the eddy current decreases and the induced voltage in the secondary winding increases. Thus, temperature compensation is required in order to make the output voltage independent of temperature. For temperature compensation in the secondary winding, external resistance could be added in the secondary winding circuit as in [2].

3. Design Features

In this section, configurations and design features of power supply and instrumentation circuit for mutual inductance type liquid metal level sensor are provided.

3.1 Design Features of Power Supply Circuit for the Primary Winding

As previously mentioned, temperature compensation is required for mutual inductance type liquid metal level sensor to obtain improved level data as shown in [2]. For this purpose, constant current can be applied to the primary winding. When alternating constant current is

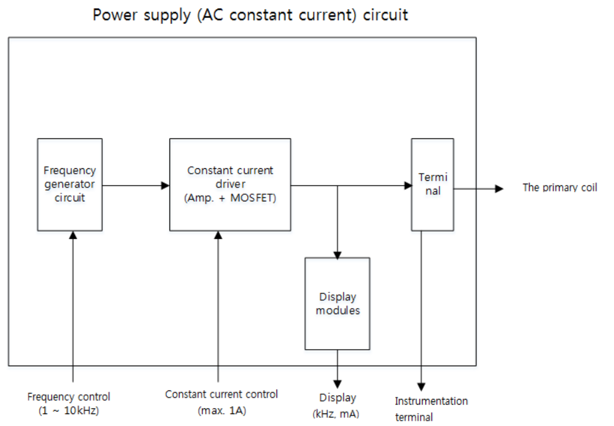

Fig. 2. Configuration of power supply circuit for providing constant current to excite the primary winding

fed into primary winding, electro motive force induced in the secondary winding does not depend on resistances of the coils. Thus, constant current power source is required for reducing effects caused by changes in temperature. Furthermore, for temperature compensation in the secondary winding, external resistance is added in the secondary winding circuit. For specifying value of the resistance, we need to check optimum frequency of operation and value of the resistance. Thus, frequency adjusting is required for power supply circuit.

The power supply circuit to excite the primary winding is shown in Fig. 2. The circuit consists of a frequency generator circuit, a constant current driver, display modules, control knobs, and terminals for instrumentation. The frequency generator circuit controls frequency of input power with 60 Hz to the frequency range from 1 kHz to 10 kHz. Next, constant current driver consists of operational amplifier and MOSFET (Metal Oxide Semiconductor Field Effect Transistor). The operational amplifier operated as comparator between reference voltage and the source voltage of MOSFET. Within the linear operation region of MOSFET, the applied voltage to the primary winding is adjusted by the comparator, so that the applied current to the primary winding remains constant. Display module and control knobs are for monitoring and adjusting the frequency and amplitude of current, respectively. Furthermore, terminal for instrumentation is for measuring frequency (kHz) and amplitude (mA) of current and converted to 4~20mA signals for acquiring the data in data acquisition system.

3.2 Design Features of Instrumentation Circuit for the Secondary Winding

The instrumentation circuit for measuring induced voltage of secondary winding is shown in Fig. 3. The circuit consists of a high-pass filter, an amplifier, a microprocessor, a memory, a digital to analog converter,

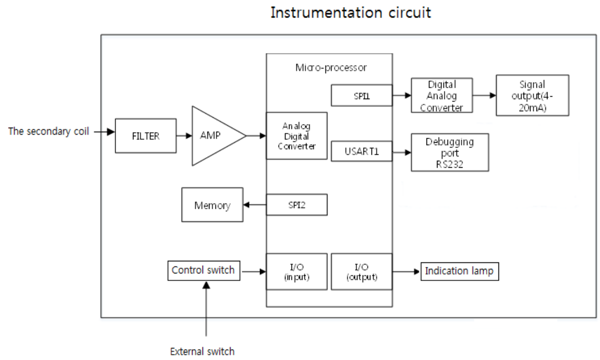

Fig. 3. Configuration of instrumentation circuit for measuring induced voltage of the secondary winding

and a control switch. The high-pass filter which passes signal with a frequency higher than a cutoff frequency is applied for filtering 60 Hz input power noise. After amplifying the low level induced voltage of secondary winding, this analog signal is converted to digital signal by the analog to digital converter in the microprocessor, and it is stored in the memory. The control switch is for zero and span adjustment using stored data in the memory through the microprocessor. Finally, the data is converted to analog signal through the digital to analog converter within the range of 4~20mA for acquiring the data in data acquisition system.

3. Conclusions

In this paper, we have provided configurations and design features of power supply and instrumentation circuit for mutual inductance type liquid metal level sensor. The power supply circuit provides alternating constant current to the primary winding for reducing the effects caused by changes in temperature. The instrument circuit provides measurement of induced voltage without input power noise in the secondary winding and provides temperature compensation. We believe that improved level data can be obtained with the design features, which enable temperature compensation. The power supply and instrumentation circuit is now being implemented, and qualitative or quantitative performance of the mutual inductance type liquid metal level sensor with the circuit will be evaluated through experiment as further works.

4. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

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