



# *Study of Lightning Protection for Hydrogen Station*

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**Abstract**—By global warming, air pollution of environmental issues, and the seriousness of the energy problem, fuel cell vehicles that do not generate CO<sub>2</sub> on the time of traveling is being sold. Thereby, hydrogen stations are beginning to be built in various places. Now, because there is no lightning protection guidelines in the hydrogen station, we examined the lightning protection of the human body and equipment in the hydrogen station. We conducted an experiment of applying the impulse voltage to the hydrogen station. The results of the experiment, erroneous operation and failure of the equipment occurred. In addition, the potential difference is generated between the equipment and the earth. Experimental results revealed the damage to the equipment due to nearby lightning strikes. In the case of direct strikes, there is a possibility that the high voltage is applied to the operator.

**Keywords**-component; Hydrogen Station, Lightning Protection

## I. INTRODUCTION

Due to global warming, air pollution, environmental issues, and the seriousness of the energy problem, fuel cell vehicles that do not generate CO<sub>2</sub> are now being sold. Consequently, hydrogen refuelling stations are beginning to be built in various places.

Because there are no lightning protection guidelines for hydrogen stations, we examined lightning protection for the equipment in hydrogen stations and for the human body.

In a hydrogen station, the vent stack is most likely to be struck by lightning, and the grounding line is the most probable incoming route for a lightning surge.

We use an impulse generator to simulate lightning, apply a lightning surge through the vent stack and grounding line, and evaluate the effects on the human body and equipment.

## II. TARGET HYDROGEN STATION

On the left-hand side of the container is the dispenser unit, used to charge the hydrogen gas directly to fuel cell vehicles, and the hydrogen station operator panel. The electrical, communication, and signal systems are contained in the operator panel, and the Class C and Class D grounding electrodes are individually buried. In the past, five units of safety barrier contained in the hydrogen station operator panel were damaged and a false alarm from the sensor system was raised.

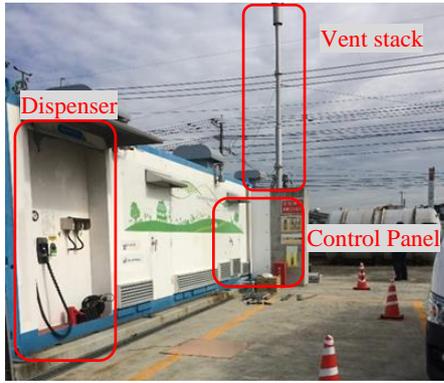
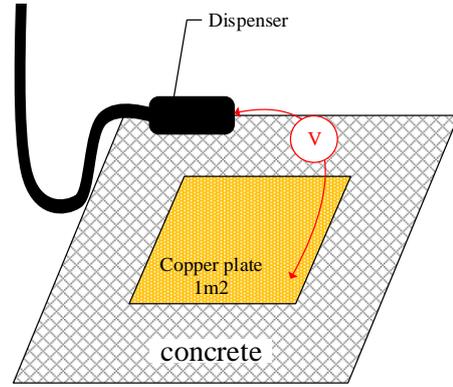


Figure 1. Hydrogen station



(a) Measurement image

### III. TEST METHOD

#### A. Impulse test system

Figure 2 shows the test system. The auxiliary current electrode (electrode C) is the grounding electrode for the impulse generator. The auxiliary voltage electrode (electrode P) is the grounding electrode that obtains the reference potential. Figure 3 shows how to measure the potential between the dispenser and ground, and Tables 1 and 2 show the parameters of the impulse generator.

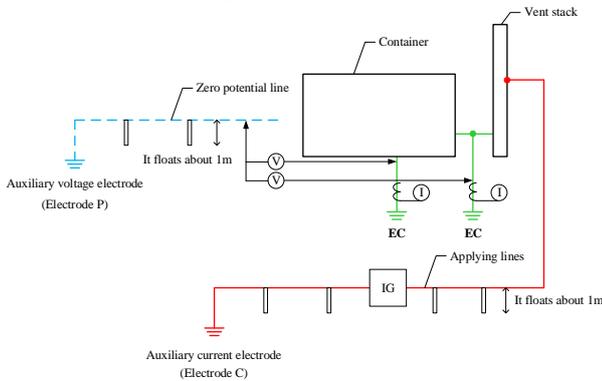
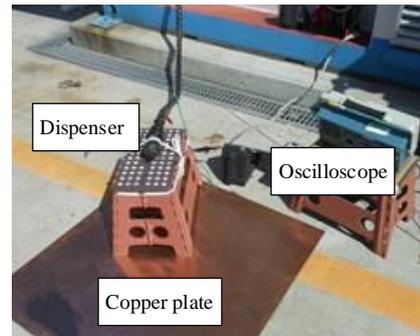


Figure 2. Impulse test system



(b) Measurement situation

Figure 3. Measuring method between dispenser and ground

TABLE I. IMPULSE GENERATOR (IG)

Item	Specification
Maximum voltage	40 kV
Main capacitor capacity	0.5 $\mu$ F
Output waveform (opened)	1.2/50 $\mu$ s

TABLE II. PULSE GENERATOR (PG)

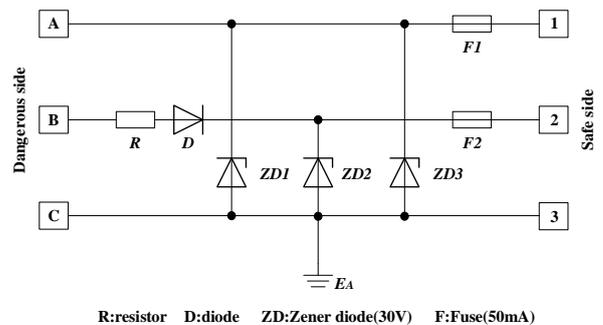
Item	Specification
Applied voltage	1 kV
Continuous application frequency	10 times/s

#### Safety barrier imitation circuit

The safety barrier is a device with an anti-explosion structure that limits the electrical energy inside the equipment exposed to an explosive atmosphere as well as within the interconnected wires to below a level that may cause ignition due to a spark or heat.

We removed the five units of safety barrier that had previously failed and established a jig that simply imitates the safety barrier with a single line.

Figure 4 shows the circuit diagram of this imitation jig.



R:resistor D:diode ZD:Zener diode(30V) F:Fuse(50mA)

Figure 4. Safty barrier imitation circuit

#### IV. TEST RESULTS

We conducted multiple tests by changing the voltage application location in order to see the influence of a direct lightning strike and the consequent rise in ground potential. The following summarizes the test results:

##### A. Application to vent stack

To simulate a direct lightning strike, we applied a voltage to the vent stack and checked the voltage and current states at each location. Figure 5 shows the voltage and current states.

The current flowing into the vent stack branched into the Class D ground electrode and the container rack. The current flowing into the container passed from PIT and PLC through the safety barrier and to the Class C grounding electrode; most of it was discharged to the ground from the rack through the base. Part of the current flowing into the container flowed to the outside through a power supply line.

The potential difference between electrode P and the Class C grounding electrode was 17.0 V, the potential difference between the electrode P and the Class D grounding electrode was 28.3 V, and the potential difference between the Class C and Class D grounding electrodes was 13.9 V.

The potential difference between the dispenser and the ground was 14.8 V, and the potential difference between the container and the ground was 15.2 V.

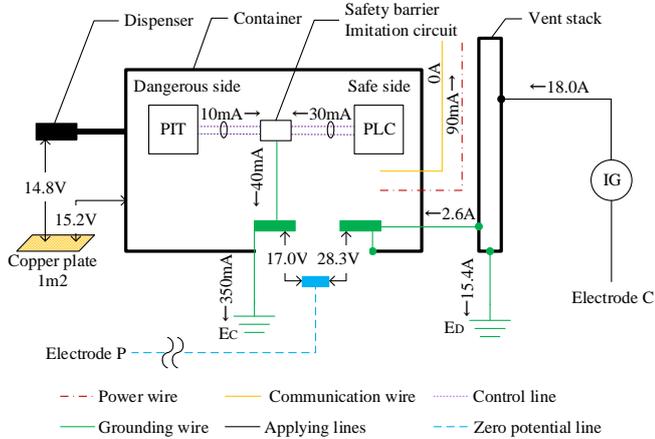


Figure 5. Voltage and current states for application to vent stack

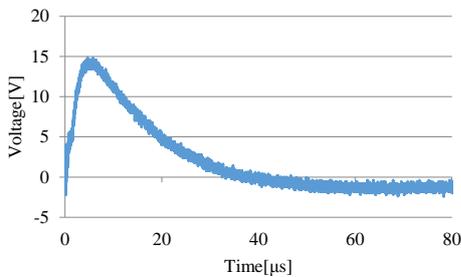


Figure 6. Dispenser voltage

##### B. Application between grounds

To simulate a rise in ground potential due to a nearby lightning strike, we used the impulse generator directly between the Class C and Class D grounding electrodes to conduct tests with both positive and negative polarities. Figures 6 and 7 show the voltage and current states.

When the voltage was applied with the Class C grounding electrode as the positive pole, a current of 18.0 A flowed from the grounding line to the safety barrier and then branched to PLC (11.0 A) and PIT (7.5 A). The potential difference was 385.6 V between safety barrier A and C, and 353.4 V between B and C. A Zener diode with an operating voltage of 30 V was used with the imitation jig, and it is considered that the fuse was blown by the current passing through the Zener diode.

When the voltage was applied with the Class D grounding electrode as the positive pole, a current of 11.5 A flowed from PLC, connected with the Class D grounding electrode to the safety barrier, and branched from PIT into the safety barrier (7.7 A) and the Class C grounding electrode (18.7 A). The potential difference was 368.2 V between the safety barrier A and C, and 356.7 V between B and C. A Zener diode with an operating voltage of 30 V was used with the imitation jig and it is considered that the fuse was blown by the current passing through the Zener diode.

Actual lightning, especially in summer, rarely strikes only once but usually strikes multiple times. We used the pulse generator to continually apply voltages (10 times/s) with positive and negative polarities.

During continual application with the output voltage at 1 kV, the over-range alarm of the sensor was triggered for both the positive and negative polarities. It is considered that the current flowing from the grounding line into the safety barrier branched into the control lines and the lightning impulse overlapped with the port link timing of PLC, resulting in the alarm.

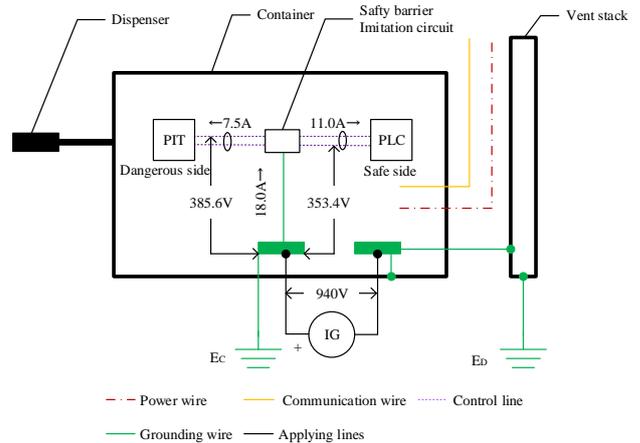


Figure 7. Voltage and current states for application between grounds

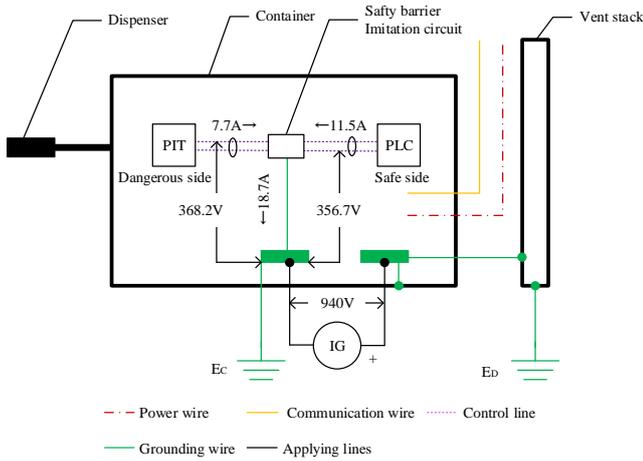


Figure 8. Voltage and current states for application between grounds

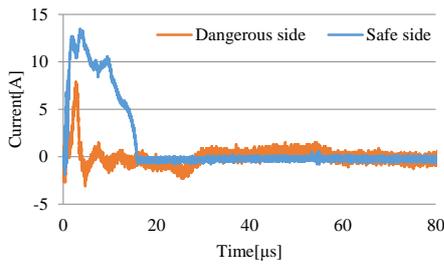


Figure 9. Current waveform with continuity (Class C grounding electrode is positive)

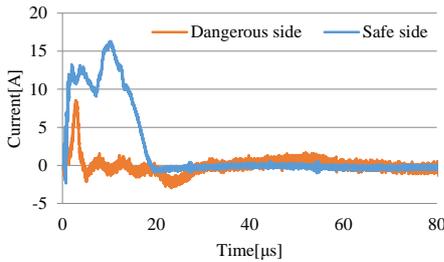


Figure 10. Current waveform with continuity (Class D grounding electrode is positive)

### C. Simulation of a nearby lightning strike

To simulate a nearby lightning strike, we buried a ground bar at a point 3.5 m south of the hydrogen station, where a lightning strike had been observed in the past, and used the pulse generator to conduct the test. Figure 11 shows the voltage and current states.

The potential difference between the Class D grounding electrode and the electrode P was 53.1 V, and the potential difference between the Class C grounding electrode and the electrode P was 2.0 V, resulting in a voltage rise of approximately 51.1 V between the Class D and Class C

grounding electrodes. While the potential difference between the Class D and Class C grounding electrodes was below the operating voltage of the Zener diode, the current could not be measured due to the low energy of the generator. However, when a lightning strike occurs nearby, the potential difference between the Class D and Class C grounding electrodes at the strike point becomes large, a false alarm occurs, and the safety barrier fuse is blown.

The potential difference between the dispenser and the ground was 1.24 V.

According to 2014 lightning data, there was a strike of 17 kA at a point approximately 700 m from the Tosu Hydrogen Station. The potential difference that occurred at that time between the Class D and Class C grounding electrodes can be calculated as follows.

$$51.1 \text{ V} \times (17 \text{ kA} / 1.6 \text{ A}) \times (3.5 \text{ m} / 700 \text{ m}) \approx 2.7 \text{ kV} \quad (1)$$

However, since the error of the strike location is 500 m, a larger potential difference may have occurred.

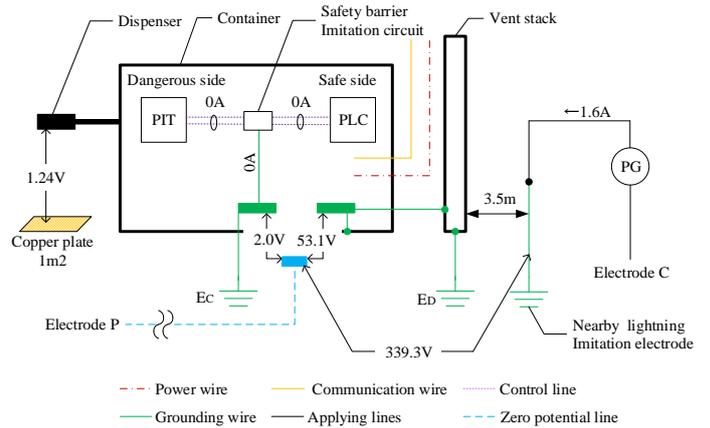


Figure 11. Voltage and current states for simulation of strike of lightning in the proximity

## V. CONSIDERATIONS

Under the current situation at the facility, when a potential difference occurred between the Class C and Class D grounding electrodes, the safety barrier was triggered and the lightning surge rushed into the connected equipments such as PLC and PIT, resulting in an alarm. Also, when the surge current passed through the safety barrier, it blown a fuse with a low rated current.

When the voltage was applied to the vent stack, it was confirmed that the current branched into the power supply line. It is considered that a potential difference from the power supply facilities, apart from the station itself, occurred and that an incoming route for the lightning surge was created. There was a potential difference between the dispenser and the ground. If the vent stack is directly struck by lightning while hydrogen charging is taking place, it can be assumed that a high voltage will be transferred to the human body.

The risks found from this test are listed below.

- When a potential difference occurs between the Class D and Class C grounding electrodes due to a nearby lightning strike, the safety barrier can be broken. The lightning surge can be applied to various equipments, resulting in an operational error or damage to them.
- When a large rise in potential occurs with an actual lightning strike, a potential difference can be applied to any connected remote equipment via the power supply and communication lines, resulting in an operational error or damage to the equipment.
- When a hydrogen station is directly struck by lightning, a potential difference occurs between the dispenser and the ground, and a high voltage can be passed through the human body.
- When a PLC port link and lightning surge occur simultaneously, the sensor may trigger a false alarm.

#### ACKNOWLEDGMENTS

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