High-Voltage Vacuum Capacitors for Vacuum Voltage Transformers

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Abstract

The Voltage Transformer (VT) is a device used for voltage measurement. It comes in different types such as the winding type, the capacitor type, as well as others. These types, however, have some technical challenges such as "failure of insulation" and "low temperature characteristics." Consequently, either type is not deemed very high in quality.

In order to solve such challenges, we developed high-voltage Vacuum Capacitors (VC) with featuring high accuracy from "favorable temperature characteristics," high reliability from "freedom from aging deterioration," and compactness from "high withstand voltage." As a result, we developed the world's first VC Series for high voltages which are applicable to vacuum VTs.

1 Preface

The Voltage Transformer (VT) is a device that serves as an input source for instruments such as voltmeters, protective relays. It converts a high voltage into a safe low voltage through a shunt circuit. It comes in several types such as winding type, capacitor type, and resistance type. The winding type VT has a risk of producing a ground fault due to mold deterioration. The oil-immersed capacitor type VT has a poor temperature feature. Due to these quality challenges, the industry calls for overall improvements.

We have developed a Vacuum Capacitor (VC) for the vacuum VT to be applicable as the capacitor type of VT. This paper introduces the effects of this product and possible applications to the vacuum VTs.

2 Introduction of Vacuum VT

2.1 Advantages of Vacuum

The target features of the vacuum VT are: compact design, high accuracy, and high reliability. The most cited key feature of the vacuum device is a high dielectric strength. Due to this feature, it allows for the compact design of the device and the light mass. Since vacuum dielectric constant is not influenced by temperatures, the temperature features are good which leads to high accuracy. Because of the structure of VCs, there is no occurrence of a burnout failure, and this ensures high reliability. Despite the aforementioned, since the vacuum dielectric constant is low, it has a smaller capacitance compared with other capacitors. If static capacitance level is increased, the internal design will become complicated and the size will be bigger.

2.2 Vacuum VT Prototype

For the prototype, we conducted the design and verification based on 33 kV voltage specification, according to our original plan for application to the product. Fig. 1 shows a conceptual drawing of the prototype.

For a capacitor type VT, the bigger the static capacitance of the primary-side capacitor becomes, the voltage characteristics improve respectively. We therefore would like to design for large static capacitance. For this purpose, it is preferable that the gap between electrodes be reduced as much as possible; however, the power device has to undergo the withstand voltage test. For a VT specified for a 33kV class, it is necessary to withstand the lightning impulse withstand voltage. To clear this withstand voltage test, the gap between electrodes is required to be larger. In order to meet such contradictory requirements, we analyzed the results from basic research tests, verifications of alpha design model prior to the prototype, and from the calculations of electric field. Based on the obtained research

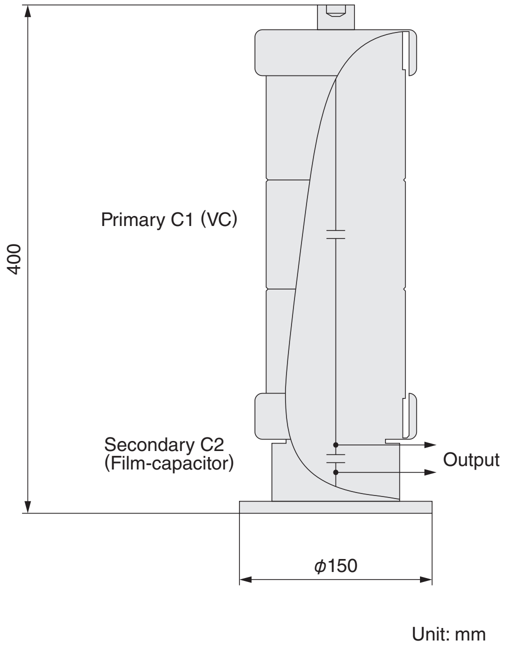

Fig. 1 **Conceptual Drawing of the Prototype**

A vacuum capacitor is used and applied to the high-voltage side.

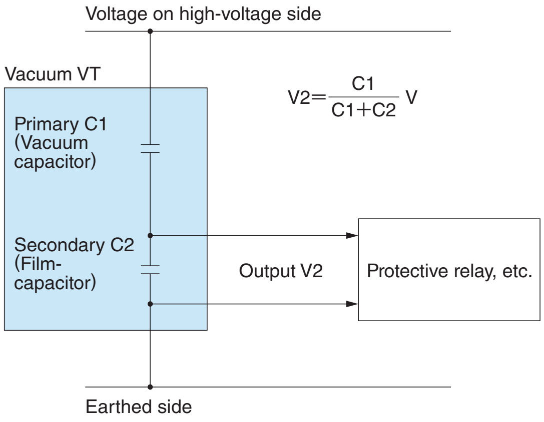

Fig. 2 **Measuring Circuit Diagram**

The capacitor type VT measures the voltage through voltage division with two capacitors.

data, we determined the electrode gap length. Since raw materials of electrodes can greatly affect the withstand voltage, selection of raw materials was determined based on the verification data obtained from joint research project with Saitama University, Japan.

Fig. 2 shows the measuring circuit diagram. In order to set the secondary output (Output V2) of the capacitor type VT around 100V, the secondary-side capacitor is required to have a substantial amount of static capacitance. The required value of this secondary-side capacitor is attributable to the capacitance range greater than that of vacuum capacitors.

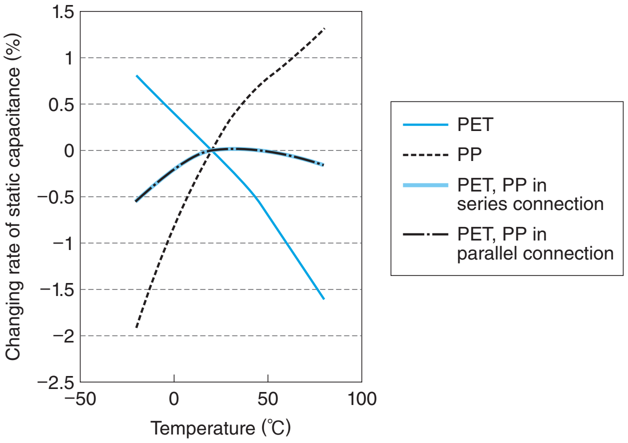

Fig. 3 **Measures against the Film-Capacitor Temperature Feature**

Capacitors with different temperature features are combined to obtain improved temperature features.

We therefore decided to adopt film-capacitors.

Fig. 3 shows the measures against the film-capacitor temperature feature. The film-capacitor has the static capacitance that changes greatly with changes in temperature. Even though a vacuum capacitor with a good temperature feature is used for the primary-side capacitor, its features become obsolete. As such, we adopted a combination of capacitors: a capacitor whose capacitance gets greater as temperature becomes higher and another whose capacitance gets smaller as temperature rises. In this way, we took measures to minimize the difference in static capacitance caused by temperature variations.

As a result of factoring the aforementioned in capacitor design, our prototype achieved a lightning impulse withstand voltage of 200kV. In addition, other characteristics of voltage such as temperature, frequency, etc., produced the positive result data. Meanwhile, we also found other design challenges such as the static capacitance of the primary-side vacuum capacitor is slightly affected by environmental conditions and that performance of lightning impulse withstand voltage is unstable.

2.3 Next-Generation Model

According to the prototype’s verification test results, we decided to adopt a next-generation model to be a plug-in type with its external surface as fully grounded. The fully grounded configuration can eliminate the effect of environmental conditions and the adoption of plug-in type can improve the ease of maintenance.

3 Postscript

According to the verification test results of the vacuum VT prototype, we verified that it has a possibility of commercialization. There are many requests to solve the issues of the conventional types of VTs in the market. Since there is a strong need for the improved VTs, we would like to commercialize this product as soon as possible. We will make the design review so that our high-voltage VCs could be a de facto standard of choice for vacuum VTs.

We would like to express our sincere gratitude to the joint research project members at Saitama University and TC-TANIC, Incorporated for their useful advice regarding the development of this product.