

Field sensor for linearity measurement of high voltage capacitor

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Abstract — High voltage capacitors are used in high voltage measurements as a part of a measuring system. According to IEC 60060-2 calibration of voltage measuring system is sufficient with 20 % of nominal voltage. Few methods are presented in the standard how linearity test could be performed for AC measuring system. This paper describes a simple method how to use field sensor to measure capacitance dependency up to nominal voltage. Some linearity test results are presented.

Index Terms — High voltage capacitor, voltage linearity, measurement techniques, measurement uncertainty.

I. INTRODUCTION

Gas insulated (SF₆) capacitors are widely used for high AC voltage measurements. These capacitors have often good voltage linearity characteristics. Direct comparison of two capacitors with capacitance bridge is the simplest way to investigate voltage nonlinearity if we have a reference capacitor with known voltage dependency. Lack of reference capacitor might be problem. Dimensions and weight of high voltage capacitor could also make transportation impractical.

II. THEORETICAL STUDIES OF VOLTAGE DEPENDENCY OF HIGH VOLTAGE CAPACITOR

Very nice overview of methods how to investigate capacitance voltage dependency is presented [2]:

- direct comparison,
- voltage transformer method
- voltage-doubling method
- double frequency method
- direct voltage method

All these methods are very useful. Measuring setup or other arrangements may take a lot of time. There should be much simple method to investigate voltage dependency.

III. FIELD SENSOR FOR LINEARITY MEASUREMENTS

A. Basic principle

Method is based on the stray capacitance between high voltage circuit and field sensor. Field sensor is a capacitor such as “double sided copper plate” or small-sized high voltage capacitor. It is assumed that the stray capacitance between high voltage circuit and field sensor is inherently constant. Weak spot of the assumption is that stray capacitance is affected by changes in ambient conditions and corona discharges.

B. Voltage ratio measurement

Investigated capacitor is modified to a capacitive divider. Capacitance of low voltage arm should be selected carefully to have negligible voltage dependency. Typical value could be some μF . Field sensor should also act as a divider, but this divider is not connected directly to high voltage circuit. Distance between field sensor (divider) and high voltage circuit is typically several meters. While the ratio of the output voltages of both dividers is measured, we can easily investigate capacitance voltage dependency. Voltage stability of high voltage supply is not typically good. Simultaneous triggering of both voltage meters is almost obligatory. Widely used setup for power measurement (2x3458A) could be one choice for voltage ratio measurement.

C. Capacitance bridge

Direct comparison of high voltage capacitors is usually performed with capacitance bridge. High voltage capacitor under investigation is connected to one branch of bridge. Field sensor capacitance and stray capacitance in series forms other branch of the bridge. Depending on the distance the effective capacitance might be only few pF. Sensitive of the bridge is increasing with voltage.

IV. LINEARITY MEASUREMENTS

First measurements were performed in a small high voltage laboratory. Voltage dependency of investigated capacitors were known.

Measurements were continued at Tampere University. Two capacitors were compared with a capacitance bridge directly and they were also compared against a capacitor with known voltage dependency (about 10 ppm) up to 180 kV. Above 180 kV voltage dependency was estimated according to these measurements. After direct comparisons linearity measurements were performed with field sensors.

A. Voltage ratio method below 200 kV

Two high voltage capacitors were investigated, 100 kV (37 pF) and 200 kV (100 pF). We can see from Figure 1 that measurement results and expected curve fits excellently. In Figure 2 results are good. It is expected that corona discharges started about 170 kV voltage level.

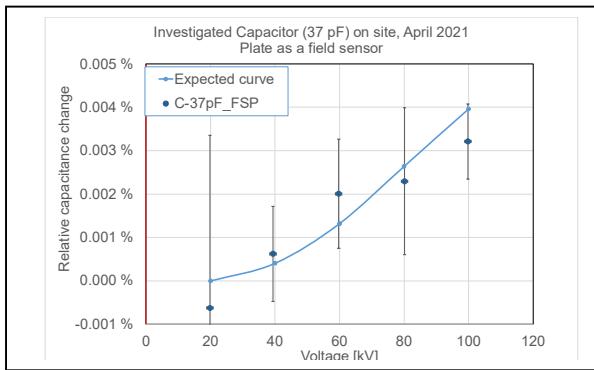


Fig. 1. Capacitance (37 pF) voltage dependency, voltage ratio measurement, plate as a field sensor. Error bars shows standard deviation of measured ratio.

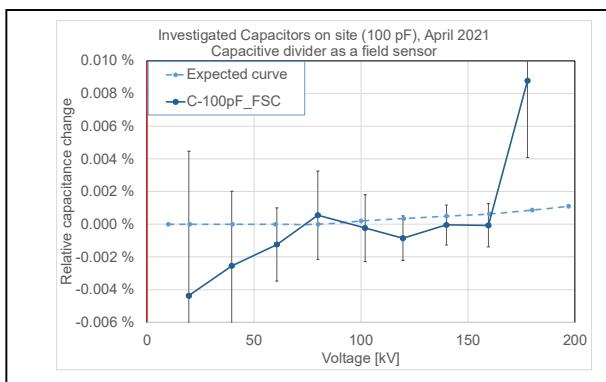


Fig. 2. Capacitance (100 pF) voltage dependency, voltage ratio measurement, capacitive divider as a field sensor. Error bars shows standard deviation of measured ratio.

A. Voltage ratio and bridge methods up to 280 kV.

At Tampere university two high voltage capacitors (75 pF and 100 pF) were investigated up to 280 kV voltage. Arrangement is shown in Figure 3. Results with capacitance bridge and voltage ratio methods are presented in Fig. 4 and 5.

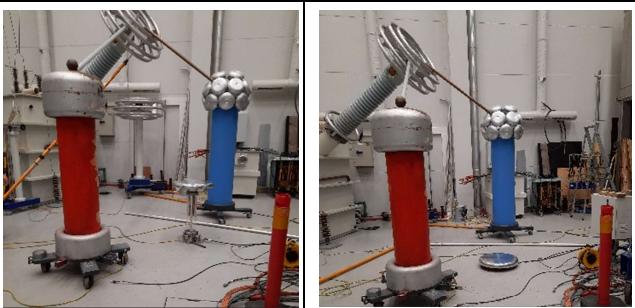


Fig. 3. Arrangement for voltage dependency measurement, high voltage capacitor (left) and plate (right) as a field sensor.

The results are good in first part of voltage range. Above 180 kV we can see (Fig. 4 and 5) something not expected. We assume that diameter of high voltage tubes connecting capacitors is too small (Fig. 3) and we probably have some corona discharges.

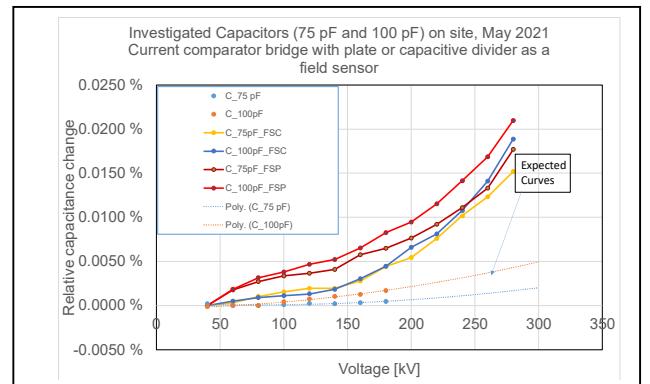


Fig. 4. Capacitance voltage dependency, capacitance bridge measurement, capacitive divider and plate as a field sensor.

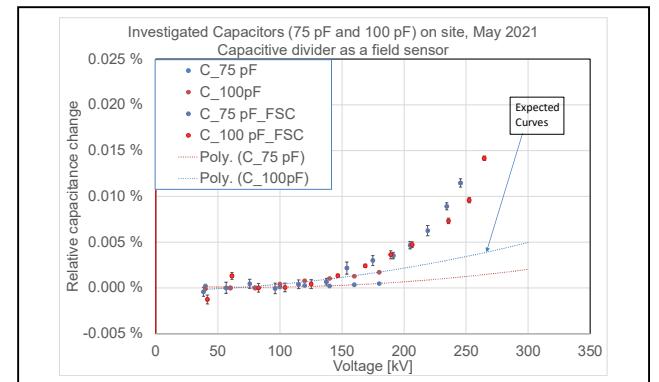


Fig. 5. Capacitance voltage dependency, voltage ratio measurement, capacitive divider and plate as a field sensor. Error bars shows standard deviation of measured ratio.

VI. CONCLUSION

Field sensor is sensitive to corona discharges and the measuring setup must be carefully constructed. Corona discharges causes nonlinearity in measurement results while using field probe. Some linearity test results are presented.

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