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A New Modified Shifted Current Technique To Diagnose The Surge Arrester Condition

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***Abstract*— Over voltages in power system may occur due to lightning, fault or switching operation. To protect the system, electrical equipment and to guarantee an economic and reliable operation, surge arresters are applied in almost all types of electrical power network. Gapless zinc oxide (ZnO) surge arresters are widely used. Arrester leakage current which comprises of capacitive and resistive components is such an important parameter to be analyzed because its third harmonic resistive component is known to be directly related to the ageing or the degradation of the metal-oxide arrester itself. Various methods nowadays can be applied to monitor the condition of the surge arresters. A new resistive component extraction method called the Modified Shifted Current Method (MSCM) is described in this work.**

***Keywords*— arresters, degradation, modified shifted current method, resistive leakage current, and zinc oxide.**

I. INTRODUCTION:

The arrester’s ability to dissipate switching surges can be quantified to a large degree in terms of energy. The unit used in quantifying the energy capability of metal-oxide arresters is kilojoules/kilovolt (kj/kv).If the capability of an arrester is exceeded, the metal-oxide disk(s) may crack or puncture. Such damage will reduce the arrester internal electrical resistance. This condition will limit the arrester’s ability to survive future system conditions; in the unlikely case of complete failure of an arrester, a line-ground arc will develop and pressure will build up inside the housing. This pressure will be safely vented to the outside and an external arc will be established provided the fault current is within the pressure relief fault current capability of the arrester. This low-voltage arc maintains equipment protection. Once an arrester has safely vented, it no longer possesses its pressure relief/fault current capability and should be replaced immediately. During a surge, the arrester provides a safe path for the surge to flow to the grounding system but at the same time the surge causes the non-linear varistor to suffer degradation or ageing. The corresponding leakage current that flows due to its gapless configuration can be used for the purpose of monitoring the condition of the surge arrester. A high leakage current magnitude, in particular, the third harmonic resistive current component, indicates a severely degraded arrester which then has to be immediately replaced. Various methods have been proposed and applied in order to measure the arrester leakage current when the arrester is on-line (on-site) or off-line (off-site) [1-12]. The on-line measurement method can give a fast assessment on the condition of the arrester and therefore can be used for the predictive maintenance. A suitable leakage current measurement device should not only able to measure the total leakage current but also able to accurately determine the resistive current component including its higher harmonics. A technique to extract the resistive component from the total leakage current without the need of any other measured signals is known as the Modified Shifted Current Method (MSCM) [12]. Basically, using waveform manipulations, the MSCM is able to accurately determine the resistive component of a given total leakage current. Hence from the resistive leakage current component, the third harmonic of the resistive current can be obtained and thereafter the arrester degradation can be determined. This paper describes the usage of the MSCM for surge arrester degradation study. The algorithm to extract the resistive component was implemented using the LabVIEW software.

II. MODIFIED SHIFTED CURRENT METHOD

The ZnO surge arrester is modeled as a non-linear resistor with a linear capacitive element in parallel as shown in Figure 2 (Haddad, et al. 1990).

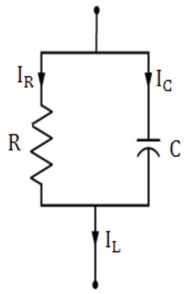

Fig.1: Simplified equivalent model of a typical ZnO arrester

The total leakage current (I_L) of the arrester is given by a vector sum of capacitivecomponent (I_C) which does not vary with degradation of the arrester, and the resistiveleakage current component (I_R) which varies with the degradation of the surge arrester.

Figure 2 shows the typical phasor relationship of all these currents.

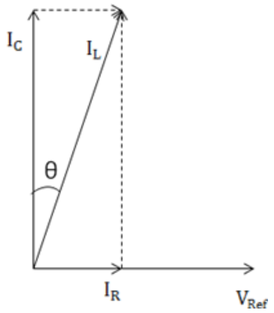

Fig.2: phasor relationship of I_L, I_R and I_C

All currents are time dependent, so I_L, I_C and I_R can be written as:

$$I_L(t) = I_R(t) + I_C(t) \text{------- (1)}$$

The resistive current component can be obtained simply by subtracting the capacitive current component from the total leakage current as shown below:

$$I_R(t) = I_L(t) - I_C(t) \text{------- (2)}$$

The subtraction in (2) can be implemented as described below. Equation (1) can be rewritten as

$$I_L(t) = [I_R] + I_C \cos\omega t \text{------- (3)}$$

Where $[I_R]$ is the resistive current component includes all harmonics. The resistive current component can be simply obtained by adding another capacitive current Ic(t) with a shifted phase angle π to (3), so

$$I_R(t) = I_C \cos\omega t + [I_R] + I_C \cos(\omega t - \pi) \text{ -- (4)}$$

$$I_R(t) = I_C(\cos\omega t + \cos(\omega t - \pi)) + [I_R] \text{-- (5)}$$

$$I_R(t) = 2I_C \cos\frac{\pi}{2} . \cos\left(\omega t - \frac{\pi}{2}\right) + [I_R] \text{-- (6)}$$

While $2I_C \cos\frac{\pi}{2} . \cos\left(\omega t - \frac{\pi}{2}\right) = 0$

Based on the above proposed technique, the algorithm to separate the resistive leakage current from the total leakage current was built. The algorithm for the shifted current method could be summarized as follows. Firstly, the arrester total leakage current is measured, and then a new waveform is introduced by shifting the measured arrester total Leakage Current by a quarter period of its operating frequency. Next, both the two total leakage currents are summed together and their peak time determined. The amplitude of summed total leakage currents at time T_p, where T_p is the time corresponding to the peak value of the summation waveform, is the peak value of the resistive current. The peak time obtained is used to determine the peak time of the capacitive current component which is equal to a quarter of period before or after the peak time of the resistive component. The peak value of the capacitive component is also determined from the original leakage current waveform. The capacitive leakage current is then generated based on the peak time, the peak value and the frequency detected. Finally, the resistive leakage current is obtained by subtracting the capacitive leakage current from the total leakage current. The block diagram of the algorithm for calculating the resistive leakage current using the shifted current method is shown in Figure 3.

III. METHODOLOGY

The MSCM was implemented in LabView complete with a suitable data acquisition system. The algorithm is programmed using block functional diagrams. LabView front panel was also programmed to be user friendly and ready for portable implementation.

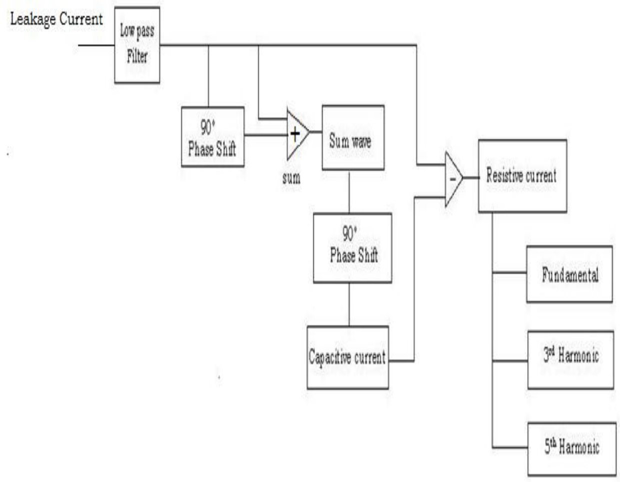

Fig.3 Block diagram of the MSCM algorithm

Experiments were also carried out to determine the resistive component of the leakage current using conventional compensation [2, 3] as well as the MSCM method. The leakage currents of different 9 kV rated, 5 kA ZnO surge arrester was measured. Both total leakage current and the voltage across the arrester were measured. The voltage measurement is required for the conventional compensation method of resistive component extraction. The total leakage current was measured using a 2kΩ resistive shunt (power resistor) and the voltage using a capacitive divider with a ratio 680:1. Both leakage current and voltage signals were captured by a Tektronix TDS3025digital oscilloscope. The laboratory set up is as shown in Fig.4.

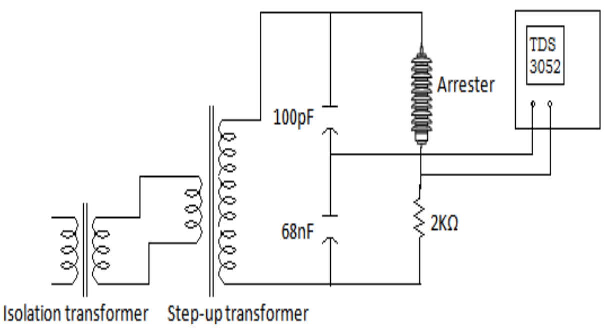

Fig.4. Experimental set up for the leakage current and voltage

For current measurement at the substations, the current probe was clamped on the grounding wire of the surge arresters. Important data such as the rms total current, peak total current, and the rms third harmonic resistive current, as well as oscillograms of the leakage current were captured.

IV. RESULTS AND DISCUSSION

Figure.1-5 shows the resistive leakage current obtained using MSCM technique in LabVIEW for different 9kV rated, 5kA surge arresters, and Table.1 shows the comparison between the results obtained using the MSCM and the conventional compensation method. Both values almost equal each other showing a good comparison. A slight difference, with a maximum of about 5%, is observed. This may be due to measurement errors and harmonic effects [6].

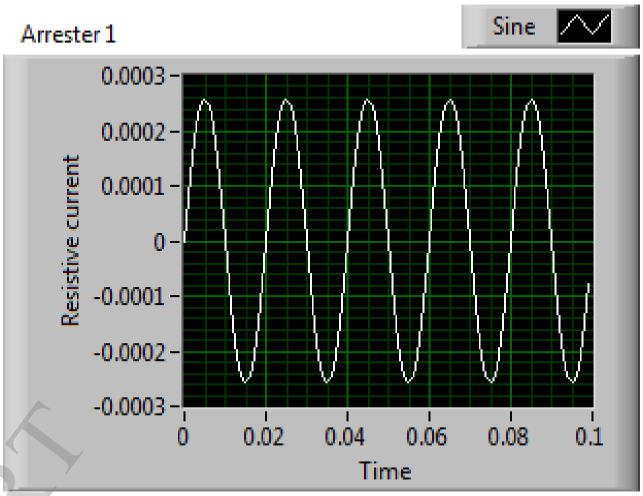

Fig.1: Resistive leakage current obtained using LabVIEW for Arrester 1

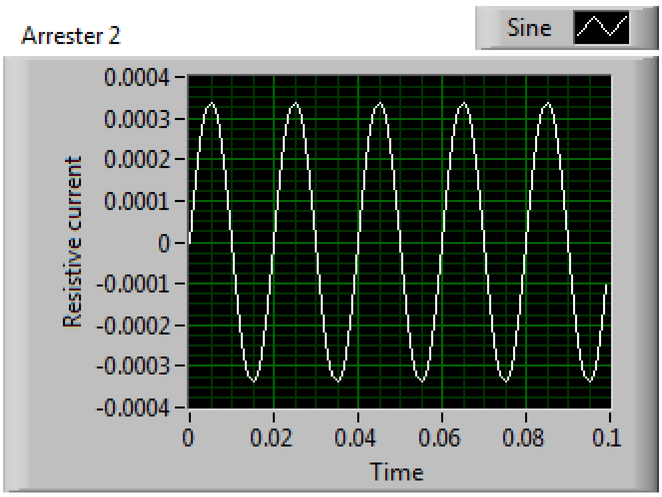

Fig.2: Resistive leakage current obtained using LabVIEW for Arrester 2

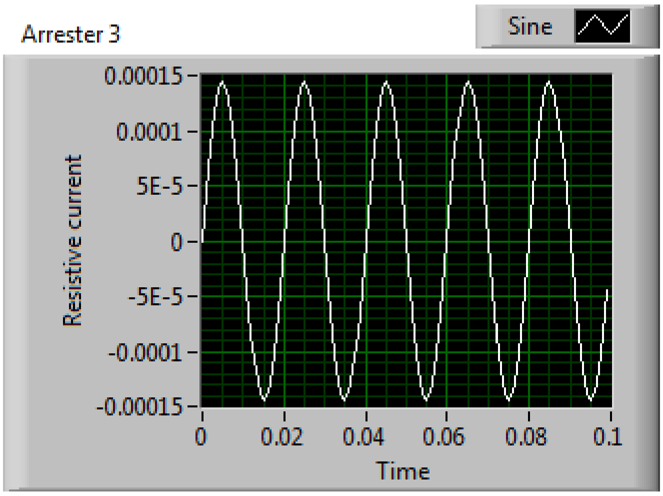

Fig.3: Resistive leakage current obtained using LabVIEW for Arrester 3

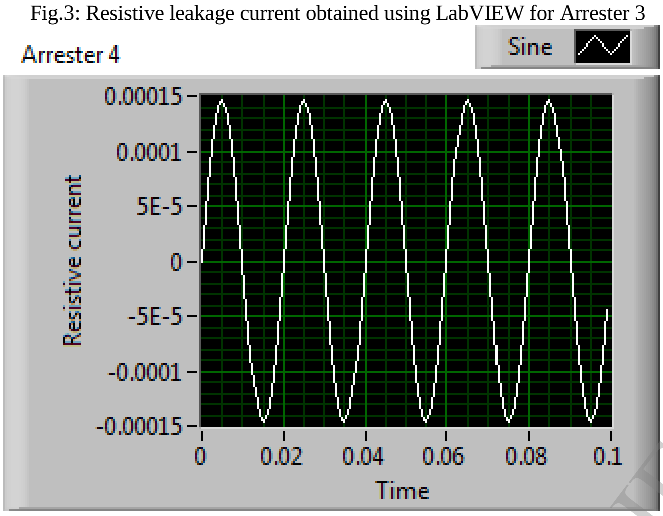

Fig.4: Resistive leakage current obtained using LabVIEW for Arrester 4

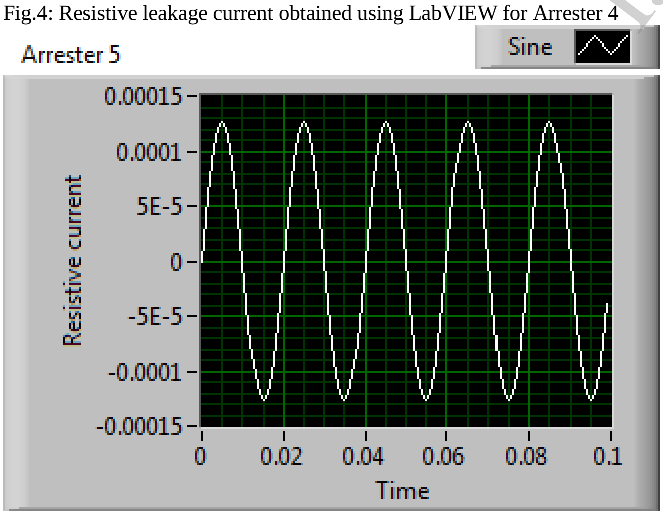

Fig.5: Resistive leakage current obtained using LabVIEW for Arrester 5

Table.1: Comparison of results

Arrester no	I_{R1} (µA) Conventional method	I_{R1} (µA) MSCM
1	184	182
2	236	239
3	100	102
4	104	104
5	86	90

V. CONCLUSION:

The modified shifted current method technique to determine ZnO ageing was successfully implemented in LabVIEW software and proven that the results were obtained from conventional compensation method are nearly same. So that MSCM is a useful for on-site measurement purpose. The developed program provides not only convenience in system management but also provides a user-friendly interface.

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