Influence of Measuring Systems on Fast Transient Modeling of Zno Surge Arresters

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ABSTRACT

The performance of surge arresters during electromagnetic transients on power system can be simulated with Electromagnetic Transient Program (EMTP)-type computer programs. The surge arrester model can show an important behavior in overvoltage calculation. Arrester model is dependent on V-I characteristics of ZnO arrester. The aim of this paper is to present the influence of measuring systems on V-I characteristics during fast current test, that will affect the fast transient modeling of arrester. In order to find this influence on arrester response under fast current transients, a test program was conducted by using opto-electronic measuring system and results are compared with other papers results.

KEYWORDS

Surge arrester, V-I characteristics, Model, Measuring systems.

1. INTRODUCTION

ZnO surge arresters are extensively used in power systems due to their good performance in over-voltage protection. Appropriate modeling of their dynamic characteristics is very important for arrester location and insulation coordination studies [1]-[8].

Under normal conditions ZnO arrester behaves like an insulator with mainly the capacitive current flowing through it at an order of several hundreds of microamperes, while the resistive current at an order of several decades of microamperes only occupying 5 to 20 percentages of the sum leakage current [3].

For switching surge studies, the ZnO arresters can be represented simply with their nonlinear V-I characteristics [5]. However, such a practice will not be appropriate for lightning surge studies because the ZnO arrester exhibits dynamic characteristics such that the voltage across the arrester increases as the time –to-crest of arrester current decreases and the arrester voltage reaches a peak before the arrester current peaks [5].

Studies of fast fronted impulse response of ZnO varistor have been made despite its practical importance [9]. Pulse studies made by Eda [10], Yokomizo et al [11] and Philipp et al [12] have disclosed that, the voltage over shoots its steady-state value. Researches in this field have been done by Miller et al [13], Breilumann [14], Bargigia [15], Schmidt et al [16] and Fan et al [17]. In testing ZnO varistor by fast fronted impulses all of above mentioned researchers found an overshoot on voltage waveforms. According to their measurement, they introduced equivalent circuit for arrester. The protection behavior of ZnO surge arresters against fast fronted impulses depends on the response of the resistor material to rising impulses. Therefore, a voltage spike (or overshoot) during measurement of the residual voltage affect the arrester modeling. This means their model was influenced by their measurement systems. They used different methods for measurement and got different values for overshoots. The overshoot on voltage waveform was due to interference between measuring circuit and main circuit of test.

2. OTHERS METHODS

Miller et al [13] used a circuit same as Figure 1 for fast transient test on arrester. A system like Figure 1 can provide short rise time pulse. For peaking circuit, they used high voltage cable as it is indicated in Figure 1. The energy storage action of the peaking cables is obtained by discharging the impulse generator into the peaking cable, when peaking cables are charged to a certain voltage the peaking gap fires. By putting different number of cables in parallel produces the results that the out put voltage and current can be easily and effectively controlled. A considerable spike appear on the residual voltage of arrester during their measurement.

Dang et al [18] used a circuit same as Figure 2 for fast transient test on arrester. A system like Figure 2 can provide short rise time pulse. An exploding wire and isolating gap can be connected the points X, Y and Z indicated in Figure 2. The arrangement works as follows: when the generator gap G fires, current flows into the wire W. Initially the voltage across W is small and the gap g isolates the test object so that no current flows in it. After some microseconds, the current in the wire reaches several

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kiloamperes. The resistance of the wire now rises sharply and the voltage across it rises to a level where the gap g breaks down, switching a current of several kiloamperes into the test circuit. According to Dang et al work [18], they mesasured a considerable spike on their measurement.

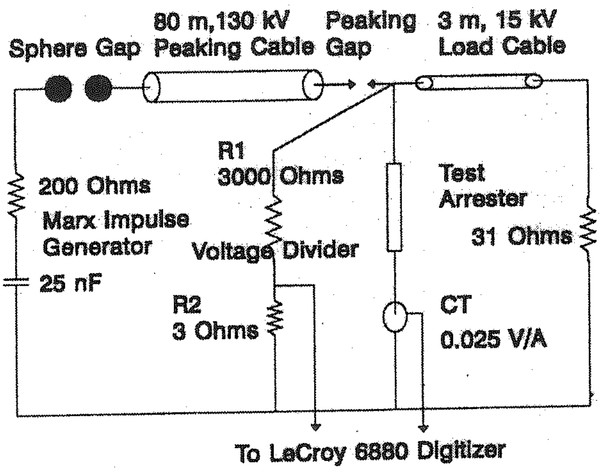

Figure 1: Miller et al circuit for fast front wave test on arrester.

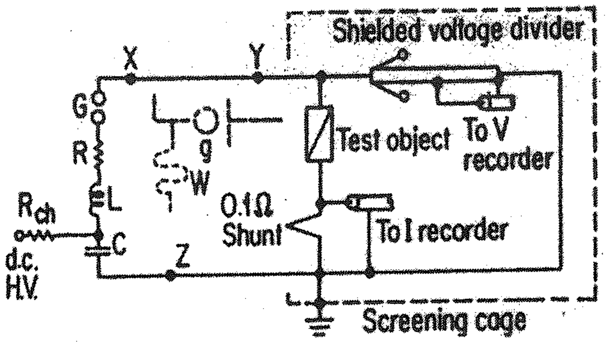

Figure 2: Dang et al circuit for fast front wave test on arrester.

Schmidt et al [16] measurements confirmed that spike on voltage waveform is due to coupling between arrester and voltage measuring loop. Schmidt etal [16] introduced following model for arrester.

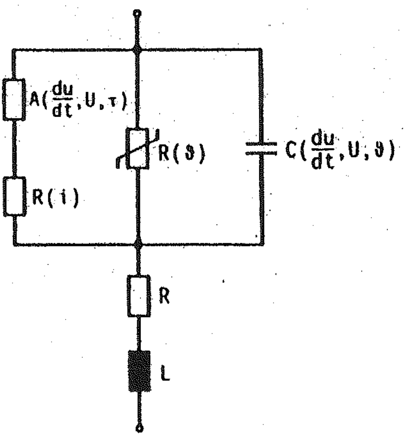

Figure 3: Schmidt et al fast transient model for arrester.

As we mentioned, these researchers measured spike on the voltage waveforms that was due to interference between voltage measuring loop and main test circuit, and the arrester models that they introduced are based on these results. Therefore, the models do not exactly show the behavior of arrester under fast transient.

3. FIBRE OPTIC LINK FOR FAST-FRONTED CURRENT AND VOLTAGE MEASUREMENT

In order to enable measurements of fast pulses in high voltage laboratory, measuring systems are necessary which meet the following conditions.

- Low sensivity to electromagnetic interference if exposed to electrical and magnetical fields of high intensity.
- Fast response time.
- Safety for the people working with it and for the instruments involved.

Opto-electronic transmission systems appear to be ideally suited for this purpose since all three conditions are easily met.

The transmitter and receiver circuits were constructed on one sided copper boards and circuit component layout was as tight as possible [19]. The transmitter and receiver circuits were boxed in aluminum alloy die-cast boxes (Figures 4 and 5). The fibre cable employed in our optical transmission system is a single plastic-coated silica fibre with 50 μm core diameter. Two transmitters and two receivers were constructed for measuring current and voltage at the same time.

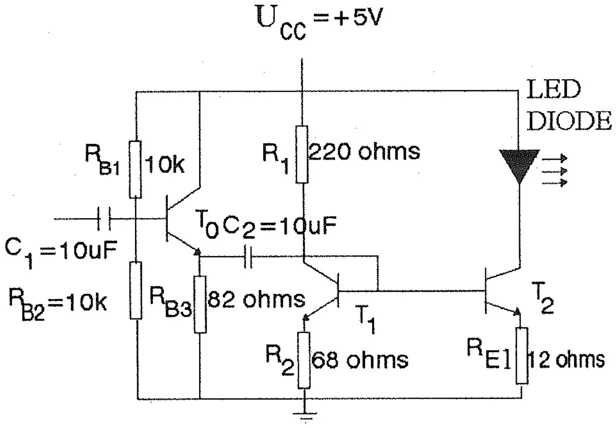

Figure 4: Opto emitter (T_0 = 2N4001, T_1 = 2N441, T_2 = BFR96).

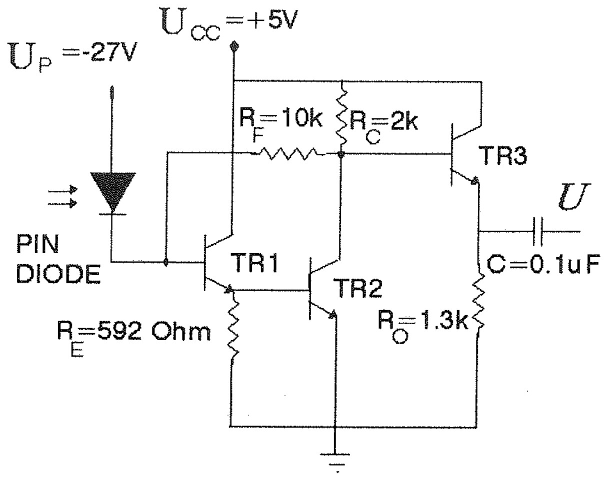

Figure 5: Opto receiver (TR1 = TR2 = TR3 = BC107).

4. COMPACT IMPULSE CURRENT TEST SYSTEM

In order to find the behavior of arresters under fast current transients a test program was conducted. In similar studies Haddad et al [20]-[22] and Naylor [23] even by using a high pressure SF6 spark gap, could only produce impulse currents with front time of about 1.5 μsec. Consequently, as we are interested in faster current front time, in order to produce a fast-fronted current impulse for testing an arrester a compact impulse generator was made. Four low inductance capacitors (0.1 μF, 20 kV) were available. A compact impulse test system (Figure 6) with C_s = 0.1 μF and voltage rating of 40 kV was made and a 10 kA, 3 kV ZnO arrester was chosen for test.

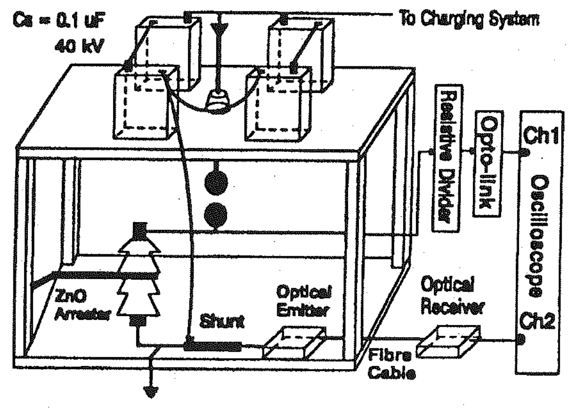

Figure 6: The compact arrester testing system.

5. TEST AND SIMULATION RESULTS

Figure 7 shows the test results of 10 kA, 3 kV arrester. From this figure, we can conclude that rise time of current is around 800 nsec.

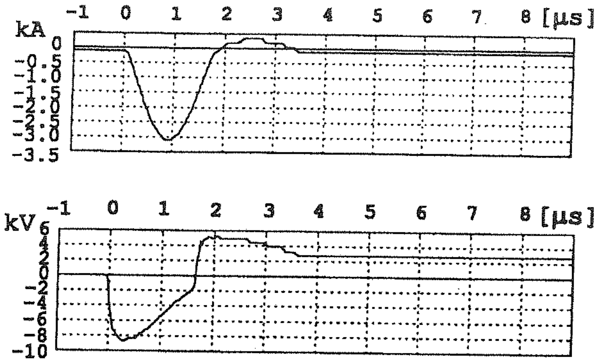

Figure 7: Current (upper trace), voltage (lower trace) of ZnO arrester (10 kA, 3 kV), test result.

According to our fast-fronted test results, the following model was chosen for arrester (Figure 8).

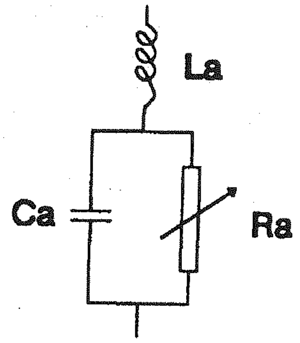

Figure 8: Arrester fast transient model.

In this model the value of *La* is chosen 0.2 μH, value of *Ca* is computed from test results as follow.

$$\frac{1}{Ca}\int i(t)dt = v(t) \qquad (1)$$

or

$$\frac{1}{Ca}\int_{t_1}^{t_2} i(t)dt = v \qquad (2)$$

where:

t_1 is instant that capacitive current is started and t_2 is time of peak value. With regard to results of Figure 9 and equation 2, capacitance of 10 kA, 3 kV arrester is equal to 80 pF.

Ra is a nonlinear resistor that is determined from V-I characteristics of arrester under fast-fronted current. In order to model the nonlinear part of the arrester on Pspice software a voltage-controlled current source (i = G(v)) was used. For specifying the relationship between i and v, a polynomial transfer function method is used in Pspice. Consider a voltage-controlled current source with voltage v. Then the coefficients are associated with the polynomial following this convention:

$$i = C(1)v^{n} + C(2)v^{n-1} + \dots\dots + C(n+1) \qquad (3)$$

In the present paper case, nonlinear resistor of arrester was modeled as current source, that current through this source has been controlled by terminal voltage of this source. Before simulation, a curve fit routine in MATLAB software is used for finding coefficients of polynomial and best result is obtained for n = 5.

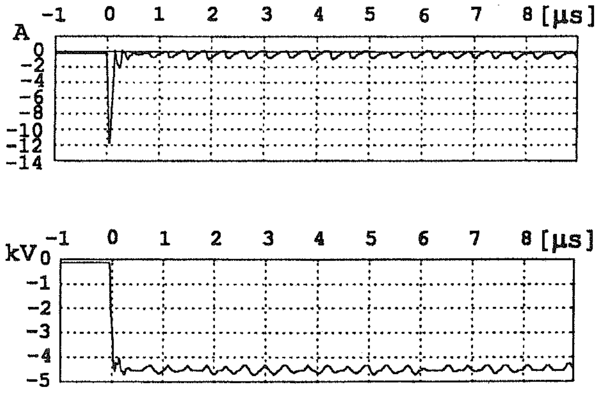

Figure 9: Capacitive current (upper trace), voltage (lower trace) of ZnO arrester (10 kA, 3 kV), test result.

In order to check the arrester model a series of simulation were carried out at 10 kA, 3 kV surge arrester by using Pspice software according to Figure 10.

In this simulation, the total inductance of the circuit (source capacitance + connection wires), Lt was chosen as 2 μH, total resistance of circuit Rt = 0.7 Ω. Figure 11 shows test result and Figure 12 shows the result of simulation. Comparison between theoretical and experimental simulations (Figures 11 and 12) shows good agreement. Good agreement between test and simulation results means the model which extracted from our test measurement is accurate.

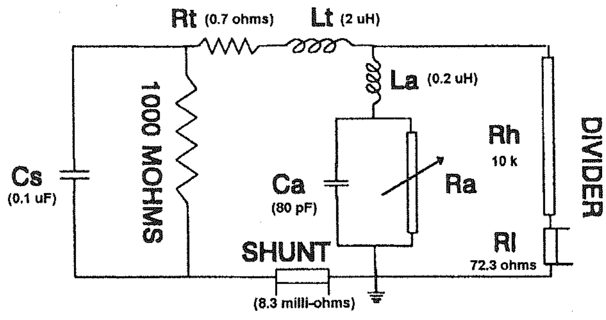

Figure 10: The simulated test circuit in Pspice.

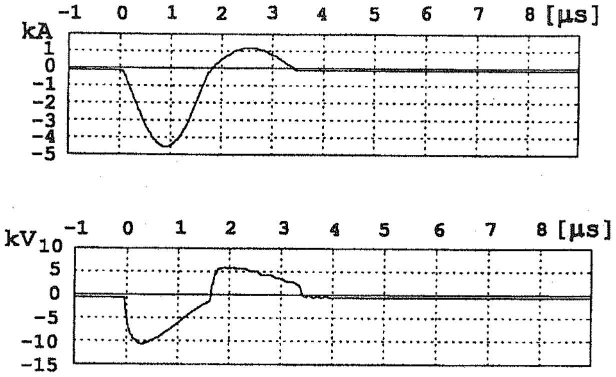

Figure 11: Current (upper trace), voltage (lower trace) of ZnO arrester (10 kA, 3 kV), test result.

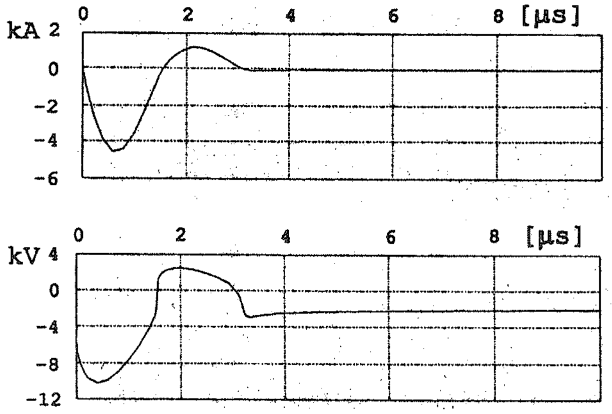

Figure 12. Current (upper trace), voltage (lower trace) of ZnO arrester (10 kA, 3 kV), simulation results.

6. CONCLUSION

Present paper test results are different from others. Miller et al, Breilumann, Bargigia, Schmidt et al and Fan et al recorded an overshoot up to 32% on voltage waveform during their measurement. The overshoot was due to interference between measuring circuit and main circuit of the test. They mentioned that a part of this overshoot is due to behavior of arrester under fast current waveform. They introduced arrester model according to their tests results that were not accurate.

In Haddad et al and Naylor results overshoots were not seen on voltage wave forms (the same as present paper results).

In present paper, by using opto-electronic measuring system, interference between main test circuit and measuring circuit is reduced and overshoots were not seen on voltage waveforms during fast current testing (faster than above mentioned papers). This results show that the high amplitude overshoot on residual voltage is not due to the behavior of arrester, it is due to measuring circuit.

7. LIST OF SYMBOLS

La	Arrester inductance
Lt	Total inductance of circuit
Cs	Source capacitance of impulse generator
Ca	Arrester capacitance
Ra	Nonlinear resistance of arrester
Rt	Total resistance of circuit
Rh	High voltage arm of divider
Rl	Low voltage arm of divider
v(t)	Residual voltage of arrester
i(t)	Arrester current

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