

LEAKAGE CURRENT MEASUREMENT AND HEALTH MONITORING OF SURGE ARRESTERS

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Abstract- This gadget gives visual or remote indication of fault on the electric power framework. called as Leakage current meter, the gadget is utilized as a part of electric power distribution which organizes as a methods for recognizing damage of arresters and transformer placed at substation. Surge arresters are installed on transmission and distribution line in substations between phase and earth in order to improve lightning performance and reduce failure rates. High energy stresses and housing deterioration are the main factors of degradation and damage of surge arresters. Thus, there is need for testing and monitoring the Arresters, in order to verify their good condition and their ability to effectively protect the distribution line. There are number of methods are available to measure the arresters leakage current like point wave method, compensation method, harmonic analysis method. In this project the harmonic analysis method is use. The first purpose of this project is to continuous monitoring of surge arrester. The second purpose is to real time monitoring of substation. This project calculates the resistive leakage current which will effect on the damage of arresters. Also calculate the RMS and the total leakage current from the arresters and store the results. Finally these proposed and developed systems were installed at high voltage substation for testing.

Keywords – Harmonic analysis, Resistive leakage current, Surge arrester

I. INTRODUCTION

In the last few years the new type of high voltage surge arresters of metal oxide type became more importance in high voltage installations. The reason is that, compared with the classic SiC surge arrester, it has very important advantages such as, for instance, significant reduction in size, quick response for steep discharge current and superior protective performance. Several ways of monitoring the state of a ZnO surge arrester in service have been presented in the past. Most of the methods are based on measuring the leakage current in the ground connection of the arrester [1,2] since it is well known that the resistive component of the continuous leakage current is a good indicator of the surge arrester condition. A considerable increase in the continuous resistive current may be caused either by moisture ingress due to sealing problems, or by premature ageing of the ZnO arresters, in contrast to a transient rise in the resistive leakage current caused by a temporary increase in arrester temperature. The construction of ZnO surge arresters consist of a very simple structure. They basically Consist of an insulating housing which is made of porcelain or polymeric material, and the inner active column, composed of the ZnO arresters. The ZnO arrester block elements are the main component of the ZnO surge arrester. They provide the desired non-linear characteristics and present a strong relation with the temperature (low current range). The non-linear resistivity is an inherent bulk property of the composite ceramic resistor, which consists of mainly ZnO with relatively small amount of several additives of other metal oxides such as Bi₂ O₃, CoO₂, MnO₃, and Sb₂O₃ [3] These additives essentially determine the electric properties of the block arresters element.

Zinc oxide surge arresters should behave as an insulator at normal line to earth voltage. They have very high impedance resulting in leakage current with peak value of only a few mille amperes. During over voltage events the metal oxide surge arrester limits the voltage to an almost constant value, even if the discharge current increases extremely. This capability has been found to remain unchanged during its full life, but the insulation performance at operation voltage may subject to change [4]. However, under extreme condition this might lead to an increase of the leakage current. This change called degradation of metal oxide surge arrester. The third harmonic of the resistive leakage current is responsible to the degradation of ZnO surge arrester.

II. LEAKAGE CURRENT IN ARRESTERS

The performance of surge arresters depends on the insulating property of metal- oxide (ZnO) used in arresters. The deterioration of the insulating property increases leakage current in the arrester. This leakage current depends on applied voltage and temperature at the time of measurement. The nonlinear characteristics of ZnO blocks used in arresters, clamps the over voltage generated due to surges and lightning, to normal level and ultimately protects the equipment in the switchyard. In

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the normal application of arrester, at one end of the arrester, voltage is applied and the other end (base) is earthed. The leakage current in the arrester flows to the earth. The electrical equivalent circuit of the ZnO arresters is shown below [5]

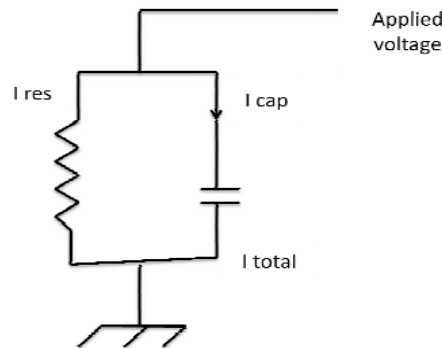


Figure 1: Electrical equivalent circuit of ZnO surge arrester

The arrester, as shown in its electrical circuit, consists of parallel combination of resistor and capacitor. Thus the total leakage current is combination of resistive leakage current and capacitive leakage current. In normal life of an arrester, there is very little change in the capacitive current; whereas marginal change in resistive current is observed due to change in insulation property of arresters. The increase in resistive leakage current causes either by entering moisture in ZnO blocks or by premature ageing of the ZnO blocks. This resistive current is in phase with the applied voltage. So it generates power loss in the form of heat generation. Thus, the leakage current in arresters is divided between capacitive and resistive component. The capacitive current component is predominant and resistive component is significantly smaller. Typically under normal service conditions, the peak capacitive leakage current is in the range of 0.2mA to 3 mA. Generally, this value does not change due to change in characteristics of ZnO blocks.[6] At given voltage and temperature, the resistive leakage current component in arrester is very good indicator of changes in property of ZnO blocks. This component can be used as a diagnostic tool for condition monitoring of metal-oxide arresters. The resistive leakage current of a non-linear metal-oxide resistor is in the order of 5% to 20% of the capacitive current, corresponding to about 10 μ A to 600 μ A peak current. The resistive component under AC voltage is defined as the current level at the instant of voltage maximum ($dv/dt = 0$). The leakage current depends on applied voltage and temperature. The resistive current calculated is normalized to rating of arrester and 200 C temperatures.

III. MEASUREMENT PRINCIPLE (THIRD HARMONICS)

Harmonics are created in the leakage current by the non-linear voltage current characteristics of the arresters. The harmonic content depends on the magnitude of the resistive current and on the degree of non-linearity of the voltage – current characteristics of metal oxide. This instrument reads the leakage current flowing through the Earthing conductor of arrester and calculates third order harmonics current from it. This current is shown as resistive current. A specially designed CT is used to read total leakage current flowing through the Earthing conductor of arrester. This CT should be placed in earthing conductor before the counter (i.e. between arrester base and counter). During the test, instrument takes several samples of current measured by CT. These samples are stored in memory. From the sampled CT current, the peak value is calculated and displayed as total current. [7] The frequency analysis is done using fast Fourier transformation on sampled CT current and amplitude of third harmonics is calculated. Similarly peak current and amplitude of third harmonics current in Field probe current is calculated. The percentage of third harmonics with respect to peak current, present in Field probe current is calculated. The third harmonic current calculated from CT current is compensated with this percentage. Thus the effect of harmonics present in system voltage is nullified and final result is displayed as resistive current.

The total current and resistive current calculated by instrument are peak current values. As the third harmonics is the largest harmonic component of the resistive current, it is most commonly used for diagnostic measurement. Please note, instrument calculates third harmonic current and shows as resistive current. For conversion from harmonics to resistive current, the third harmonic current needs to be multiplied by a constant factor. This depends on the information supplied by arrester manufacturer or from measurement in the laboratory. Instrument provides the facility of programming this factor. By default the factor is set to 1.

IV. CALCULATION OF CORRECTED RESISTIVE CURRENT

The resistive current depends on system voltage (voltage applied to the arrester) and temperature at the time of measurement. To do the correct analysis of arrester, the value of resistive current at standard voltage and standard temperature has to be calculated.

The measured value of resistive current is converted to standard operating voltage of arrester. The correction factor is calculated as per the “typical information for conversion to standard operating voltage conditions” given in the below table.

The correction factor according to the ratio of system voltage and arrester rated voltage is calculated as follows. User is asked to enter phase to phase system voltage and arrester rating (rated voltage of arrester). Arrester rated voltage is phase to earth. [8]

The ratio of voltage is calculated as follows.

$$\text{Voltage ratio} = \frac{\text{system voltage phase to phase} / \sqrt{3}}{\text{Arrester rated voltage (Phase to earth)}}$$

Following formula is used to calculate IR corrected.

$$IR_{\text{corrected}} = I(\text{TH}) \times (\text{voltage multiplication factor}) \times (\text{Temperature multiplication factor})$$

Correction factor table for Rated Voltage									
Vol Ratio = System voltage (U) / LA rated voltage (Ur)									
Here System voltage U = System VPh-Ph / √3									
Vol. Ratio U/Ur	Multipli cation Factor	Vol. Ratio U/Ur	Multipli cation Factor	Vol. Ratio U/Ur	Multipli cation Factor	Vol. Ratio U/Ur	Multipli cation Factor	Vol. Ratio U/Ur	Multipli cation Factor
0.4	3.4	0.5	2.5	0.6	1.7	0.7	1	0.8	0.5
0.41	3.3	0.51	2.4	0.61	1.6	0.71	0.9	0.81	0.5
0.42	3.2	0.52	2.3	0.62	1.5	0.72	0.8	0.82	0.5
0.43	3.1	0.53	2.2	0.63	1.4	0.73	0.8	0.83	0.4
0.44	3	0.54	2.1	0.64	1.4	0.74	0.7	0.84	0.4
0.45	2.9	0.55	2.1	0.65	1.3	0.75	0.7	0.85	0.4
0.46	2.8	0.56	2	0.66	1.2	0.76	0.7	0.86	0.4
0.47	2.7	0.57	1.9	0.67	1.1	0.77	0.6	0.87	0.3
0.48	2.7	0.58	1.8	0.68	1.1	0.78	0.6	0.88	0.3
0.49	2.6	0.59	1.7	0.69	1	0.79	0.6	0.89	0.3
								0.9	0.3
Correction factor table for Rated Temperature									
Temp. T⁰ C.	Multipli cation Factor	Temp. T⁰ C.	Multipli cation Factor	Temp. T⁰ C.	Multipli cation Factor	Temp. T⁰ C.	Multipli cation Factor	Temp. T⁰ C.	Multipli cation Factor
-10	1.76	1	1.37	11	1.17	21	0.98	31	0.81
-9	1.72	2	1.35	12	1.15	22	0.96	32	0.79
-8	1.67	3	1.33	13	1.13	23	0.94	33	0.78
-7	1.63	4	1.33	14	1.12	24	0.92	34	0.77
-6	1.6	5	1.3	15	1.1	25	0.9	35	0.75
-5	1.57	6	1.28	16	1.08	26	0.88	36	0.74
-4	1.54	7	1.26	17	1.06	27	0.87	37	0.73
-3	1.51	8	1.24	18	1.04	28	0.85	38	0.71
-2	1.48	9	1.22	19	1.02	29	0.83	39	0.7
-1	1.42	10	1.2	20	1	30	0.82	40	0.69
0	1.4							41	0.69
								42	0.68
								43	0.67
								44	0.66
								45	0.65
								46	0.65
								47	0.65
								48	0.65
								49	0.64
								50	0.64

Table 1: correction factor table

V. PROPOSED SYSTEM

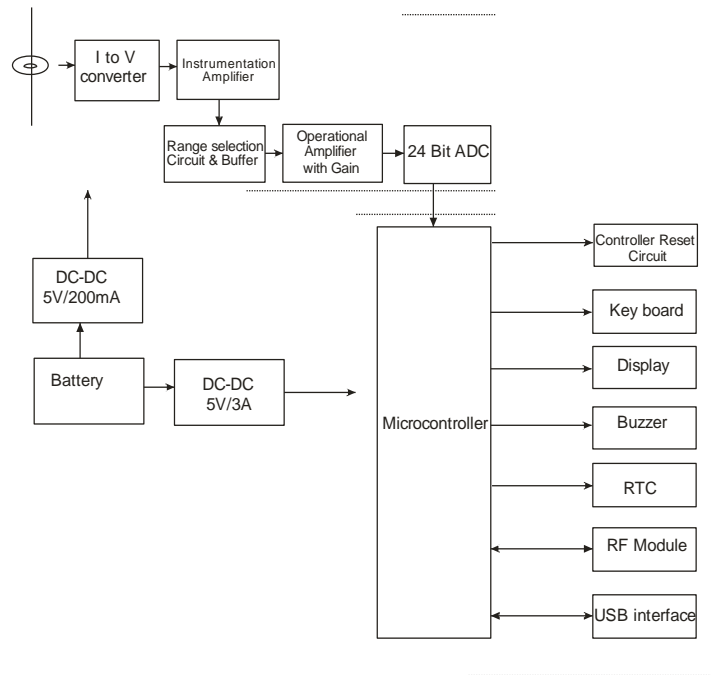


Figure 2: block diagram of proposed system

VI. CIRCUIT DIAGRAM OF PROPOSED SYSTEM

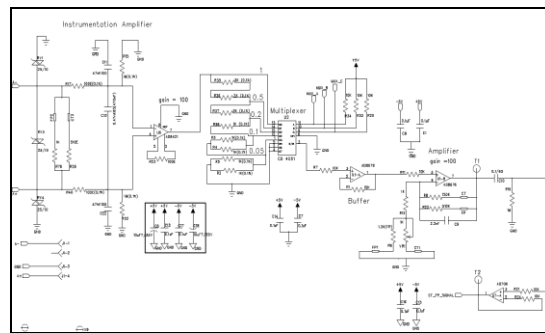


Figure 3: circuit diagram analog section

Leakage current from the arresters can measure from the CT and the leakage current is given to the instruments as the input. The 510 ohm resistor connected across the input current and it is converted in to the voltage. Further that the instrumentation amplifier is use. The CT having the ratio 1:2000 .the ladder circuit is used with the multiplexer. From 0 μ Amp to 40 μ Amp 5 groups are made and according to the fix the output 5V the multiplication stages and used. This is handling by the software. Further circuit is used for purification of the signal.

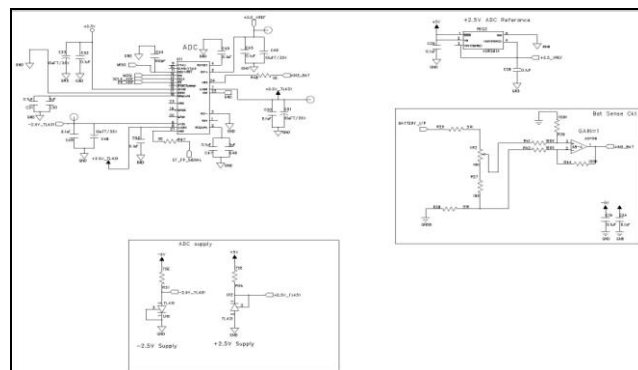


Figure 4: circuit diagram ADC section

The output of the analog section is read by the ADC and the digital output is given to the controller. ADC having +2.5 and -2.5 ref supply which is generated by using ADR 391 ref generator IC. Battery percentage is also calculated for the safety purpose. Instrument shows the battery percentage which is shown by the programming according with the following table.

ADC count	ADC i/p Voltage	Battery voltage	charging %
2703	2.178	12.1	100
2680	2.16	12	95
2658	2.142	11.9	89
2636	2.124	11.8	84
2613	2.106	11.7	79
2591	2.088	11.6	74
2569	2.07	11.5	68
2546	2.052	11.4	63
2524	2.034	11.3	58
2502	2.016	11.2	53
2479	1.998	11.1	47
2457	1.98	11	42
2435	1.962	10.9	37
2412	1.944	10.8	32
2390	1.926	10.7	26
2368	1.908	10.6	21
2345	1.89	10.5	16
2323	1.872	10.4	11
2301	1.854	10.3	5
2278	1.836	10.2	0

Table 2: battery percentage

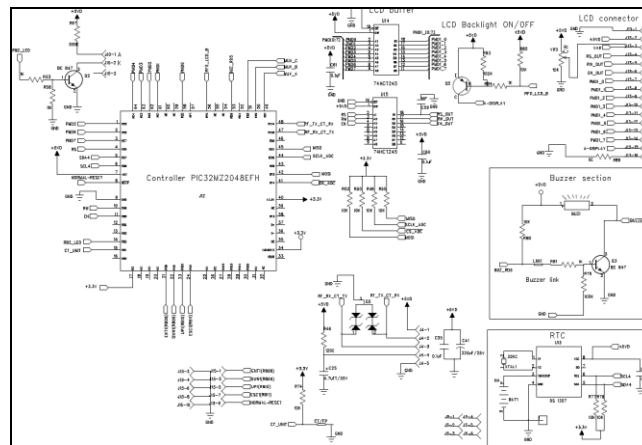


Figure 5: circuit diagram of controller & display connection

The PIC32MZ2048EFH064 pic controller is used. It has the 2GB of storage memory. So we store approximately 1000 of results in the controller. 20 X 4 LCD display is used for the instrument. Having 4 rows and 20 columns. RTC section is also there by using the real term software we see the all result in the PC.

Third order harmonics in the leakage current

When voltage is applied to the arrester, due to non-linear voltage current characteristics of a metal-oxide used in arresters, harmonics in the leakage current is generated. This harmonic component depends on resistive component of arrester. The resistive component depends on applied voltage and temperature. Thus, due to this resistive component, major increase in third order harmonic component is observed. The magnitude of third order harmonics in the leakage current can be used as indicator of resistive current.

VII. SYSTEM HARMONICS

The characteristics of metal-oxide and resistive current generates harmonics in leakage current. Apart from this, the harmonic contents in the system voltage (voltage applied to arrester) also generate harmonics in leakage current. The measurement of

harmonics in leakage current of arrester may considerably be influenced due to these system voltage harmonics. To get correct results, we need to compensate the effect of these system harmonic contents.

Measurement of total leakage current

The total leakage current (I_{total}) in arresters consists of capacitive and resistive current. As the resistive current is only a fraction of capacitive current, the total current mainly depends on capacitive current. The total leakage current is sensitive to the installation of arrester, as this depends on the stray capacitances. Large change in resistive current is needed to observe significant change in total leakage current.

On-line measurement of total leakage current is done using mA-meters built in surge arresters. These meters show R.M.S. values of total leakage current. As the resistive current is very small compared to total leakage current, change in resistive current is not noticeable using these meters. True analysis of diagnosis of arrester health is not possible by measurement of only total leakage current.

Measurement of resistive leakage current

The increase in resistive component of arrester increases resistive leakage current. This current is in phase with applied voltage. Increase in this current increases power loss in arrester. Monitoring and analyses of the resistive current gives true picture of power loss in arrester. Thus, the measurement of resistive leakage current in metal oxide arrester is good indicator of health of arresters. [9]

The resistive component under AC voltage is defined as the current level at the instant of voltage maximum. [10]

- I_c is generally – 0.2 – 3 mA for a typical arrester.
- I_r ranges from – 10 to 600 μ Amp.
 - New: around 25 μ Amp
 - More than 5 years old: around 150 μ Amp

VIII. CONCLUSION

From the above discussion it can be concluded that the accuracy of the leakage current of the harmonics method of measurement is better than any of the other methods. This instrument gives accuracy up to $\pm 5\%$.

It also shows the third harmonic value i.e. the resistive leakage current, which is the main factor to degradation of the arrester. This instrument also calculates the V_{rms} value and the V_{peak} value. The V_{rms} is varying voltage which is equivalent to steady DC value which gives the same effect at output. And V_{peak} is voltage at maximum peak point, which is equal to the total leakage current. Its value is varying from 10 to 600 μ Amp. But above the 600 μ Amp the arrester is considered as faulty. Continuous monitoring of surge arresters is possible from this system. It also stores the results up to 400 tests, which is very important.

IX. REFERENCES

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