SENSITIVITY ANALYSIS OF FAULT LOCATOR PERFORMANCE

M.K. Burdi * Abdul Sattar Memon ** and Saeed Ahmed Shaikh **

ABSTRACT

Fault locators are very important for quick detection and rectifying of fault in electric power system. Its construction depends upon precise valued L, C, R components. In their previous papers the authors have described designed details and performance of the fault locator where as this paper describes analysis of its working ability during unsuitable working conditions of temperature, humidity etc.

Due to the delicate construction of the fault locator components and high selectivity requirement for blocking of the resonant frequency together with the narrow band of frequencies around it by the trap circuit and filtration of these by the stack tuner, the fault locator needs (i) accurate designing of its parameters (ii) simulation of its performance (iii) precise manufacturing and (iv) field testing before offering it to its practical commercial use. All these steps are necessary to ensure its reliable performance. Usually all these precautionary steps are enough for successful launching of the product, performance of the fault locator during rough climatic conditions can not be guaranteed due to distributed capacitance of stack tuner. To reduce chances of failure, the fault locator needs careful analysis to make it withstand the rough and tough hostile conditions of cold, hot and humid nature of outdoor installation.

In this paper, authors describe a simple procedure to analyse performance of the fault locator under harsh conditions of the temperature. The result of the test analysis will be discussed and concluded for determination of its usefulness. The analytical test procedure provides clue of stability of the fault locator in changing atmospheric temperature.

INTRODUCTION

A fault locator is usually installed outdoor on poles of 11 kV distribution lines. Variation in temperature is very large in hot summer day-night cycle and between seasons. Surely the temperature variation causes changes in dimension of components and its dielectric strength. This is very often true in case of a stray capacitor formed by insulator gap of two adjacent components. In the case of a sensitive capacitor, not only size of metal, which acts as capacitor plate changes, but also the gap between the plates changes, which surely results in change of parametric value C of the capacitor. The stack tuner capacitor C, in the experimental fault locator (Fig. 1 & Fig. 2), which is improved form of commercially failed fault locator12, is surely such temperature dependent component. Before selling the final improved and tested product of the fault locator, manufacture should ensure usefulness of the product in varying temperature of the outdoor conditions, first by analytical means and then by experimental method by exposing the equipment in varying temperature. In this paper, an analytical method is described to investigate usefulness of the fault locator under extreme conditions of temperature variation.

The analytical method contains selection of above stated well designed and tested fault locator, for retesting of its stack tuner capacitance C, by varying the value by 0.2%, 0.7% and 1.4% representing temperature venerable change in the fault locator of this particular component, as discussed above. These changes in capacitance of the capacitor correspond to reasonable temperature variations. Thus the fault locator is checked numerically for usefulness of its performance against any partial chance of component failure.

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Fig. 1. a
Fig. 1b.

Fig. 2.
2. PROCEDURE FOR ANALYSIS

Figure 1. Shows the single line representation of 11 kV network for testing of the fault locator. The components of parallel resonant circuit (C<sub>e</sub>, L<sub>e</sub>, R<sub>e</sub>) (Fig. 1.b) of the stack tuner take small current and develop small output voltage up to 100 volts during average lighting strokes. The parallel circuit of the stack tuner C<sub>e</sub>, L<sub>e</sub>, R<sub>e</sub> is manufactured from small units in lumped component. Similarly, the series inductor of the stack tuner L is a lumped parameter purchasable from market or designed and fabricated in a factory or workshop. Thus the series inductor of the stack tuner L is lumped parameter and could be small in size as the current is low. The lumped parameters can be manufactured precisely as well. The only three components which bear a lot of current and voltage of 11kV system are the power coil L<sub>e</sub>, power capacitor C<sub>e</sub> and the series stack tuner capacitor C<sub>e</sub> as shown in Fig.1.b. Location of capacitance C<sub>e</sub> of the series stack tuner capacitor and its distributed nature makes it more vulnerable than any other component of the fault locator.

Present investigation and testing is numerical analysis, of the improved designed of the actual product, shown in Fig.2<sup>1</sup> which when tried in commercial use had failed to perform successfully. However, this new design as shown in Figure 1.b was analytically tested<sup>1</sup> to be the best and is being further tested for unpredictable conditions of temperature variation. The research was aimed to improve performance of the product, first analytically. The value of C<sub>e</sub> was measured on the available unit using latest methods and equipment in the department of Electrical Engineering<sup>2</sup>. Then fabrication of the fault location is suggested to be carried out and finally factory testing of manufactured item is suggested to be carried out according to the improved latest design described there. Figure 2 shows the original manufactured product, which at that time of the research<sup>2</sup> was waiting for improvement and investigation.

The capacitance of the series stack tuner capacitor C<sub>e</sub> is formed from a metallic coating and central metallic tube separated by an insulating plastic tube. The metallic tube holds the 11kV distribution conductor and the tube forms one side of the capacitor while the other side is metallic coating. A terminal is brought out from the metallic coating to connect it with the series inductor L and the parallel resonant circuit of the stack tuner (L<sub>e</sub>, R<sub>e</sub>, & C<sub>e</sub>) as shown in Fig 1.b. It is likely that the capacitance C<sub>e</sub> of the series stack tuner capacitor may change due to one or other reason. These reasons for C<sub>e</sub> variation include (i) change in dimension caused by temperature variation (ii) change in dimension due to change in size of diameter of the distribution conductor inserted inside the metallic tube (iii) changes in metallic coating due to aging, bending or breaking and (iv) manufacturing defect etc. To ensure satisfactory performance of the design and manufacturing of the fault locator, it must be thoroughly measured for its components at the center frequency f<sub>c</sub>. For any change in measured value of any one or more components, performance of the fault locator must be examined before putting it into service.

In this paper, the effect of variation in capacitance value of the series stack tuner capacitor C<sub>e</sub> on the performance of the fault locator is studied. This research assumes that the only component which changes from its design value is this capacitor.

3. CIRCUIT ARRANGEMENT

The circuit arrangement of Figure 1.a shows application of the fault locator for test arrangement. This arrangement is similar to the circuit arrangement already described in another paper<sup>1</sup>. The trap circuit of this fault locator uses 0.05mH inductance of the power inductor, capacitance of power coil is neglected. Tables 1,2 show the design details of the fault locator components in Figs 1.a & 1.b<sup>1</sup>.

<table>
<thead>
<tr>
<th>R&lt;sub&gt;e&lt;/sub&gt; (Ω)</th>
<th>F&lt;sub&gt;e&lt;/sub&gt; (kHz)</th>
<th>L&lt;sub&gt;e&lt;/sub&gt; (mH)</th>
<th>C&lt;sub&gt;e&lt;/sub&gt; (μF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0005</td>
<td>10</td>
<td>0.05</td>
<td>5.06605918</td>
</tr>
</tbody>
</table>

Table-1 Design Details of Trap Circuit

<table>
<thead>
<tr>
<th>C&lt;sub&gt;e&lt;/sub&gt; (μF)</th>
<th>F&lt;sub&gt;e&lt;/sub&gt; (kHz)</th>
<th>L&lt;sub&gt;e&lt;/sub&gt; (mH)</th>
<th>L&lt;sub&gt;s&lt;/sub&gt; (mH)</th>
<th>C&lt;sub&gt;s&lt;/sub&gt; (μF)</th>
<th>R&lt;sub&gt;s&lt;/sub&gt; (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>10</td>
<td>3618.613</td>
<td>0.005</td>
<td>50.66059</td>
<td>2.467401E-4</td>
</tr>
</tbody>
</table>

Table-2 Design Details of Stack Tuner


4. **PROCEDURE FOR SIMULATION AND STUDY**

Using the designed parameters as shown in above table, it is first found out that if or not these parameters of the fault locator are capable to locate a fault. If confirmation of such successful results is obtained, further simulation for different values of $C_t$ are carried out to examine the effect of variation of capacitance corresponding to variation to temperature on performance of the fault locator. The procedure for numerical analysis is described in previous paper.

With the design parameters shown in given table, performance of the fault locator for simulation at 10 kHz is shown in Fig.3. It shows the output of the fault locator from various stack tuners. These output puts show that this design of the fault locator works very well and the fault locator is capable of locating the fault at YARB between Loc2, Loc3 & Loc5. This performance of the fault locator has been obtained with the capacitance of $C_t = 70$ pF of the stack tuner and solid earth fault at YARB.

5. **DETAILS OF TESTS**

5.1 **Method Of Operation:**

Fault is created by closing a switch between phase B and earth at point YARB. As soon as the fault occurs, transient frequencies are generated at the point of fault and propagated in all directions along all lines away from the fault point. The transient frequencies at different points along the lines at selected frequency are called signals. Signal fault voltages of different magnitude start appearing in all stack tuners. These signal voltages travel away from point of fault towards each end of line in all possible directions.

Each fault locator unit is made of two stack tuners and a trap circuit between the two tuners in the shape of Greek Letter Pi. All stack tuners & trap circuits are tuned at same single frequency: Trap circuits are nothing but band stop or band reject passive filters. When ever signal voltage passes a trap circuit of a fault locator the signal frequency is absorbed or stopped by it in the line. Thus after the first trap circuit (and consequently the first fault locator) the signal voltage disappears from rest of the transient-frequencies, every where all along particular line(s).

Stack tuner is another type filter circuit, across which a signal voltage is collectable, provided it is available in the transient strike a stack tuner, the stack tuner extracts the signal voltage. Signal voltages are available before first trap along each line after the fault as explained above and hence signal voltages appear in all such stack tuners. If there is no signal output, then it would mean that the filter circuit (hence the fault locator) is not the first stack tuner after the fault.

This principle underlines the working procedure of the fault locator. Fault signals appear only in fault sides of the first fault locator in each power lines meeting at the near fault point.

Thus all fault locators automatically identifies the fault point and the fault is said to be between these fault locators. Once identified by automatic means at the signal station, a repairing team of electricians is sent to reach the point of fault location. Thus the fault is removed with little labour efficiently without loss of time.

5.2. **Method Of Tests:**

EMPT is used as a source of simulation test, with each different value of $C_t$, one value at a time in all the fault locators. One test is carried out at the designed value of $C_t$ where as remaining simulation tests are performed at values other than the designed one as explained at other sections of this paper. The above method of operation is carried out from the beginning exactly in the same way. The test signal output from each stack tuner is obtained. This test is repeated for all values of $C_t$. Quality of test signal is compared mutually for the same test and with previous tests values at the same stack tuner. If the signals become similar at all stack tuners, for the same test (i.e. loose sensitivity), or become too small at each stack tuner, (loose selectivity), fault location is unrecognisable (i.e. the system becomes corrupted or obsolete), then the value of $C_t$ at that value is unsatisfactory and the fault locator is said to be defective, un-operational and unsuitable as a fault locator.

6. **TEST RESULTS**

The fault locator is now tested for four differ-
Figure 3.
(a) signal output MR2 from Loc2

(b) signal output ML3 from Loc3

(c) signal output ML5 from Loc5

(d) signal output from fault locators (MR1) away from fault

Figure 4.
ent values of series stack tuner capacitance $C_r$. The values are 70 pF, 70.2 pF, 70.5 pF & 71 pF. This provided simulation of four different output voltages from each fault locator. The fault performance in all these cases is achieved under same conditions of the circuit arrangements and fault simulations. Each time the fault is created by short circuiting switch at YARB with ground. The output is collected from across the paralleled branch of the stack tuner (Fig. 1.b).

Figure 4 compares output voltages from 3 stack tuners of Loc2, Loc3 & Loc5 close to the fault. The fault was created between fault locators Loc2, Loc3, & Loc5 at location YARB with earth. The results shows there is very wide variation in output voltages for small changes in the capacitance. At capacitance value of 71 pF the fault locator output voltages shows that each stack tuner output is low and almost same in magnitude from all places. This fault locator loses its property of discrimination for fault location at $C_r=71$ pF. Thus figure also shows that the fault locator is capable of locating fault within the variation of + 0.5 pF. This variation forms only +0.7% variation. This shows that for successful operation of the fault locator, attention must be given to the required accuracy of parameter even with good weather conditions.

7. CONCLUSION

- Performance of the fault locator with change from 70 pF capacitance value to 70.2 pF shows that it is still capable of fault location.

- The fault location property is reduced when the capacitance value is increased to 70.5 pF or beyond. Nevertheless the fault locator is still capable of discrimination up to the capacitance value 70.5 pF.

- Difference in output voltages from four different simulations using small change each time in the series stack tuner capacitance $C_r$ shows that the fault locator requires attention for any variation in parameter values. It is capable of operating successfully, if the series stack tuner capacitance changes are within + 0.7%.

- However for the capacitance changes greater then 0.7%, performance of the fault locator becomes unreliable. It shows that for successful performance, the fault locator needs (i) high quality design of circuit components (ii) high quality manufacturing and (iii) necessary safeguard from the damage in the outdoor installation, so that is installation in the outdoor performance does not change any component value of any or all rough uses.

- The successful performance of the fault locator with simple two branch trap circuit proves that (i) the present fault locator and its stack tuner are efficient (ii) the fault locator can work on low values of inductance of the power coil (equal to or less than 0.05mH) (iii) the trap circuit is very simple in arrangement.

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REFERENCES


