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Detection of Asymmetrical Faults in De-Energized Distribution Feeders

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***Abstract*: -- To ensure a safe re-energizing of an overhead distribution feeder after it is de-energized for an extended period, a fault detection technique by controlling a thyristor-based device is proposed in this paper. A controllable signal is a feed into de-energized distribution feeder using a thyristor-based device to generate the electrical response. The proposed method involves injecting a thyristor-generated controllable signal into the de¬ energized feeder. By using this technique we also check the false response due to capacitance present in the line. For that purpose, we constructed a simulation diagram in MATLAB. In this paper, we detecting the fault by observing the waveforms of current and voltages. From this current and voltage waveforms we identify the type of fault on this distribution line.**

***Keywords*— De-energized distribution line, fault detection, power electronics, safe re-closer.**

I. INTRODUCTION

After a feeder is de-energized for an extended period due to events, such as repair, maintenance, or storms, there is always the possibility that humans or animals may be in contact with feeder conductors unknowingly. A reclosing action in such a situation can easily lead to harmful effects on them. Therefore, to avoid this and to detect the different asymmetrical faults on distribution system, we are proposing a new technique which will be helpful for analysing the faults before reclosing the feeder by sending the controllable signals to the downstream line. This controllable signal is generated by the thyristor based device. Fault detection in an energized system is easier than fault detection in de-energized system because it needs the voltage signal production and executed it to the downstream line. We can take energy from upstream line to generate the signal which overcomes the need of additional power source. Inrush current is injected into the downstream line before inserting the series impedance because of auto re-closer. Main drawback of all above devices is that they cannot detect all faults in only one device. Recently, to minimize the inrush current a pulse re-closer technique is elaborated, but after the use we have to change an existing breaker or re-closer by new one. This can be costly. We can generate the signal by using the capacitor by charging and discharging and by connecting it into the circuit but it is not able to reach to the very high voltage. so we are proposing the thyristor based device for detecting the faults in a de-energized distribution feeder. The parallel connection of the device is made with a re-closer to inject the adjusted signal by changing the firing angle of thyristor when the system is de-energized.

The proposed idea has another important feature, which is the ability to detect different kinds of faults by using a single device (in parallel with a re-closer). A fault could be asymmetrical or symmetrical and it may occur between phase to ground or phase to phase. The fault-type detection ability of the proposed technique can greatly facilitate the utility to make proper action.

II. POWER-ELECTRONICS-AIDED FAULT DETECTION

The proposed technique is able to generate this kind of signal by adjusting the thyristor's firing angle. The single line representation of the proposed method is shown in Fig. 1. A thyristor is connected in parallel to a circuit breaker or re-closer by a switch. The switch is off in the normal system operation. When maintenance or repair at downstream is completed and the de-energized feeder needs to be restored, the line operator can turn on the switch and control the thyristor to trigger at several degrees before the voltage crosses zero. The energized upstream line is thus momentarily connected to the de-energized side so that a detection pulse is created in the downstream. The thyristor automatically shut off when its current drops to zero. A step-down transformer is used to decrease the voltage of the distribution line to a low level for thyristor operation and then a step-up transformer is used to restore the signal back to the system voltage level. Point X in Fig. 1 is the location for measuring the stimulated voltage and current signals. The typical thyristor voltage, current and the measured waveforms at point X are shown in Fig. 2. A low strength signal is acts as an alarm to the human or animals in contact with the feeder conductors so that they can get away from the live conductor to avoid the injury.We are increasing the strength of signal in the feeder for the high impedance fault detection by decreasing the firing angle of the thyristor.

III. CONTROL STRATEGY

In a three-phase four-line system, a fault could be symmetrical or asymmetrical and it may occur between phases or be-tween phase and ground. Therefore, the detection and classification of all kinds of faults is highly desired. To do this, a three-phase thyristor bridge-based scheme is proposed. As shown in Fig. 3, a three-phase thyristor bridge circuit is connected in parallel to the circuit breaker. The upper thyristors are connected to one phase of the energized upstream and the bottom thyristors are connected to the neutral line. As mentioned earlier, to minimize the size and reduce the cost of power-electronics de-vices, transformers are used to let the thyristors operate at a lower voltage level. Even considering the added cost on trans-formers, the overall cost of this configuration will be lower.

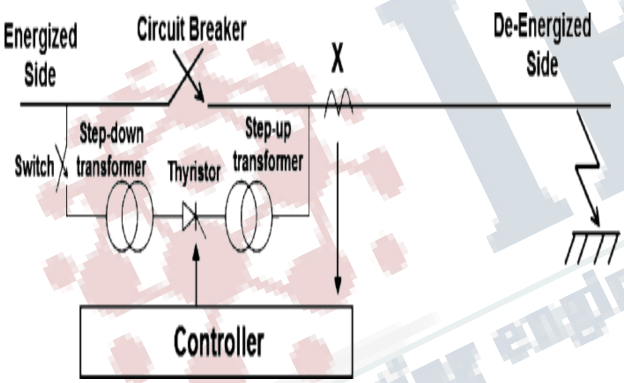

Fig. 1. Single-line representation of the proposed fault detection method.

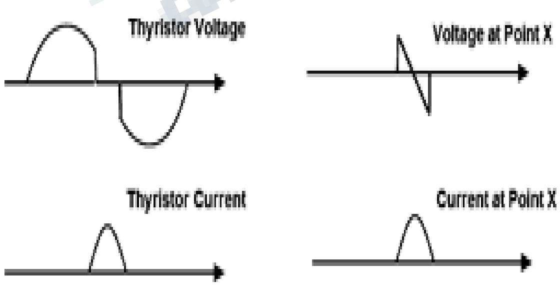

Fig. 2. Waveforms of
(a) thyristor voltage and current
(b) measured voltage and current at the point X.

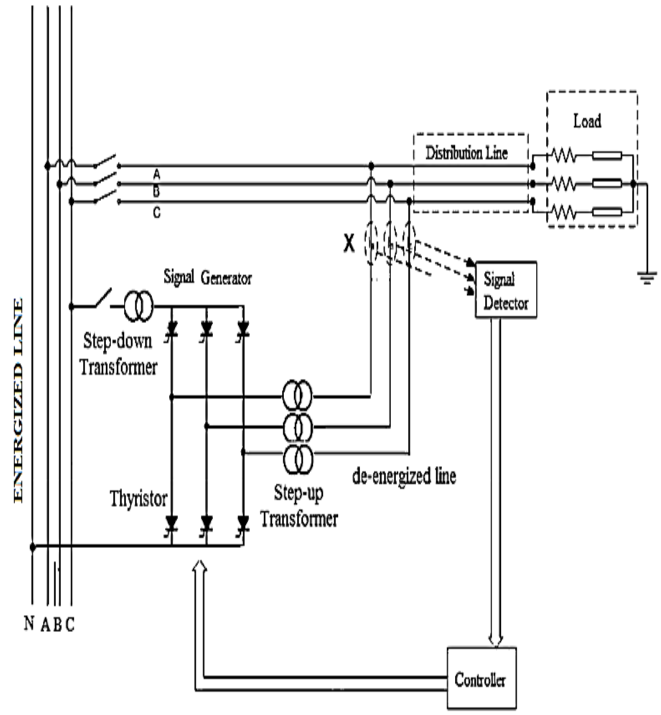

Fig. 3. Three-phase thyristor bridge-based fault detection scheme.

Once the detection signals are injected, voltage and current at point X are measured and analyzed in the signal detector to determine if there is a fault. The detection for different kinds of faults depends on the gating signals arrangement for the thyristor bridge. In the first mode, for detecting the phase to ground fault, only upper three thyristors are to be triggered and all bottom thyristors are off. As the firing angles of the upper thyristors are reduced, the strength of the detection pulse injected in the de-energized distribution feeder is increased to detect the high impedance fault. If the fault is exist between any phase and ground then it will reflect in the magnitude of the current. In the second mode, for phase to phase fault detection there are two steps: first one is that one thyristor from upper group (phase A) and two from bottom group (phase B & C) are to be triggered for phase A-B & phase A-C fault detection and in second step one thyristor from upper group (phase B) and one from bottom group (phase C) are triggered to identify the phase B-C fault. This control logic is also explained from the following table 1 which detects all types of faults including three steps.

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TABLE I:- OVERALL CONTROL LOGIC AND DETECTED FAULT TYPES

Step No.	Control Logic	Fault Types
Step I	T1, T3, T5 On, T2, T4, T6 Off	Single phase-to-ground fault Double phase-to-ground fault Three phase-to-ground fault
Step II	T1, T4, T6 On, Others Off	Phase A to Phase B fault Phase A to Phase C fault
Step III	T3, T6 On, Others Off	Phase B to Phase C fault

IV. FAULT ANALYSIS

4. 1. Phase-to-Ground Faults Detection

The phase to ground fault is most frequently occurred fault in power system. The frequency of occurance of this fault is near about 75% to 80 % than the other types of fault-Due to this reason The Unbalanced Phase-to-Ground fault can be detected as per the following criteria: -

Step I- (T1, T3, T5 Thyristors are ON)

As the three thyristors are ON, the signal is send to the three phases and the Magnitude of current is measured in all three phases. After measurement of current in all three phases, if the magnitude of current in each phase is identical then there is NO fault present in the system. Which means there is no presence of any type of asymmetrical fault in the system but there may be a chance of Symmetrical fault (LLL – G) present in the system . If magnitude of current in all three phases is not identical which means there is presence of asymmetrical fault in the system.

1) If the magnitude of current in one of the phases is greater than other two current magnitudes in other two phases, (e.g. $I_a > I_b$ and I_c , where $I_b = I_c$) then it indicates that there is a presence of single phase-to-Ground fault in the system and the faulted line is identified by just observing the current magnitude in all the three phases. (e.g. If { $I_a > I_b$ and I_c } then in this case Phase A to Ground Fault occurs in the system).

2) If two current magnitudes in phases are equal and greater than the remaining third phase current magnitude (e.g. $I_a = I_b$ & $I_b > I_c$), then it indicates that there is a presence of double-phase to ground fault in the system. Then again by just observing current magnitude the two faulted lines are identified . (e.g. If { $I_a = I_b$ & $I_b > I_c$ } then in this case Phase A - Phase B to Ground Fault present in the system).

4 .2 Phase-to-Phase fault Detection

Similarly, the Phase to Phase fault can be detected as per the following criteria: -

Step II- (T1, T4, T6 Tyristors are ON)

In order to find out phase to phase fault measure the phase B and phase C currents magnitude. If the magnitude of current in phase B i.e. ($I_b < 0$), then fault is present between phase A and phase B. If the magnitude of current in phase C i.e. ($I_c < 0$), then fault is present between phase A and phase C. If all this two conditions are not satisfied, then there is no phase to phase fault present in the system. i.e. fault between phase A and other is not present.

Step III- (T3, T6 Thyristors are ON)

For finding out the phase to phase fault in between lines B and C, the upper thyristor T3 and the lower thyristor T6 are triggered. If the magnitude of current in Phase C i.e.; (IC < 0), then fault present between phase B and phase C. If this condition is not present, then there is no fault present between phase B and phase C. In Step II and Step III all types of phase to phase faults are identified.

V. COMPUTER SIMULATION

The simulation is done by using MATLAB to perform and verify the analysis mentioned in section 4. The distribution line rated voltage is 400V. The parameters considered for constructing the device are as follows:

i) Utility: L-L RMS 400 V, Star-ground connected.

o Transformers:

Step-down Transformer: - Single phase, 230V/12V,

Step-up Transformer: - Single phase, 12V/230V.

o Feeder:

Both feeder Line 1 and Line 2 are of 1-5 km long, the positive sequence

R_1= 0.2138Ω/km,

X_1= 0.3928Ω/km,

B_1= 4.2315μS/km;

the zero sequence

R_0= 0.3875Ω/km,

X_0=1.8801Ω/km,

B_1= 1.6058μS/km.

1. Signal generator: Three phase Thyristor Bridge.

o Fault resistance:0-25Ω the default resistance 0.001Ω.

o Load: Lamp Load

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According to the FIG.4 the thyristor controlled device is connected in parallel with the re-closer through a switch and step down transformer. The bridge is connected to downstream line by step-up transformers. We have connected three separate single phase transformers instead of one three phase transformer because current pulses are not balanced and also to reduce interference between two phases. The firings of thyristors are carried out according to the control logic given in section 3. In each step thyristors are fired at an angle near to 160°-170° and reduced after until the faults are identified.

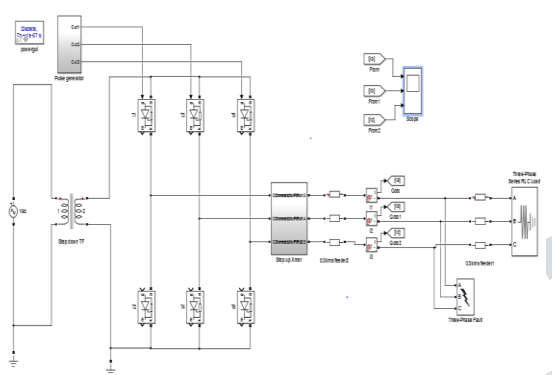

Fig 4. Computer simulation by using thyristor- bridge in MATLAB

5.1 During no fault condition.

During no fault condition when the upper three thyristors T1, T3 and T5 are on and the other three lower thyristors of thyristor bridge is off. We take the power from energized line and the signal is injected in the three phases A, B and C. If magnitude of current in all three phases are same then there is no fault exist in all the three phases. From fig .5 it is shown that when the signal is injected then the current magnitude in all the phases is same, which means there is no fault present in the de-energized line. After performing this condition in MATLAB the waveforms across all three phases are shown in fig .6

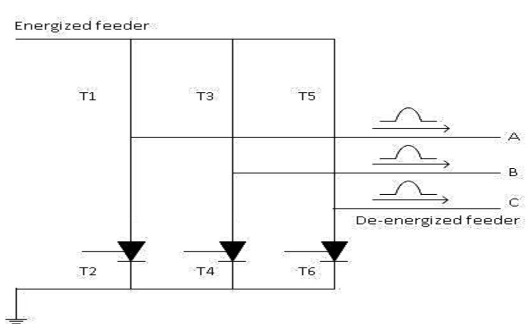

Fig 5. Current waveforms during no fault.

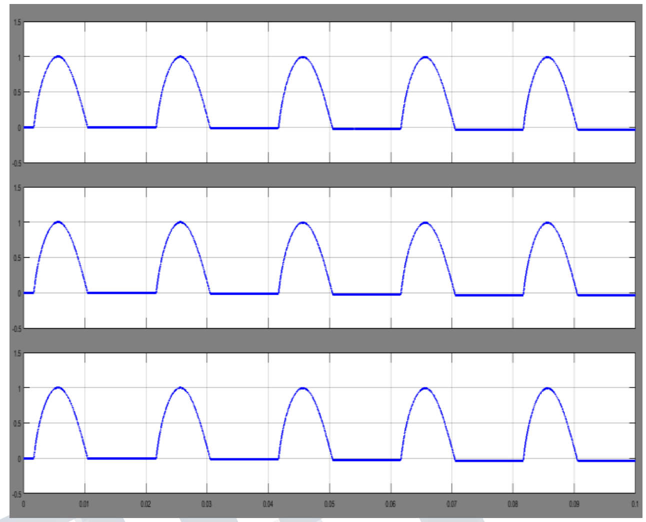

Fig 6. Current waveform during no fault.

5. 2 Phase-to-Ground Fault

In step I, if the phase-to-ground fault exists in the system between phase A to Ground then the current will changes accordingly as shown in FIG.7 and it is greater than the other two phase currents. The phase A to ground fault does not affect the phase B and phase C. But the fault current magnitude is depending upon the fault resistance. If the fault resistance is small then the fault current magnitude is more and if the fault resistance increases then the fault current will be having less
Magnitude.

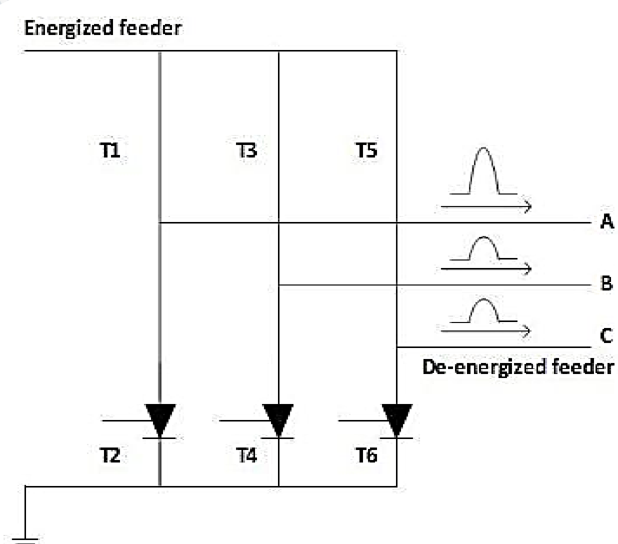

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Fig 7. Current waveform during L-G fault condition

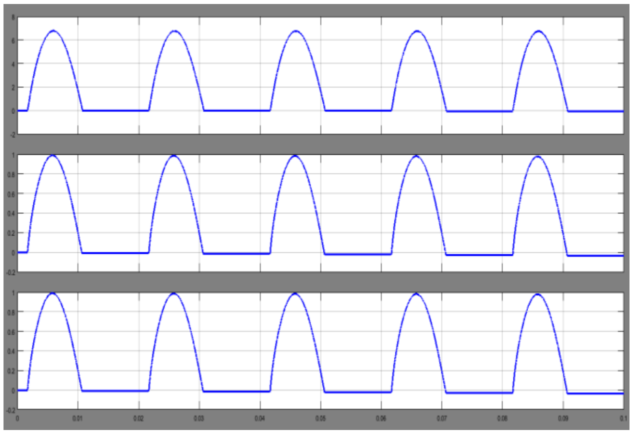

Fig 8. Current waveform during L-G fault condition

5. 3 Phase-to-Phase Fault

If a fault occurs between phase A to phase B as shown in FIG.9 then the current waveforms are as shown in FIG.10. The reverse signal in phase B shows that there is presence of phase-to-phase fault. According to the asymmetrical fault calculations for the line-to-line fault the current in faulted phases are exactly opposite in magnitude. As also the signal is injected from phase A, therefore it shows reverse signal in the phase B as fault occurs in between these two phases. To verify it, if we inject signal from phase A then it shows reverse signal in phase B. The fault current in the phase-to-phase fault is depending upon the three parameters such as the fault resistance, load and fault location (line impedance) i.e. the length from fault detection point.

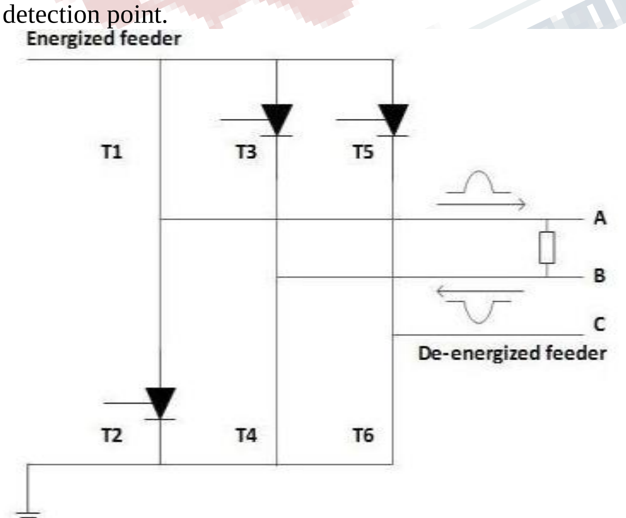

Fig 9. Current waveform during L-L fault condition.

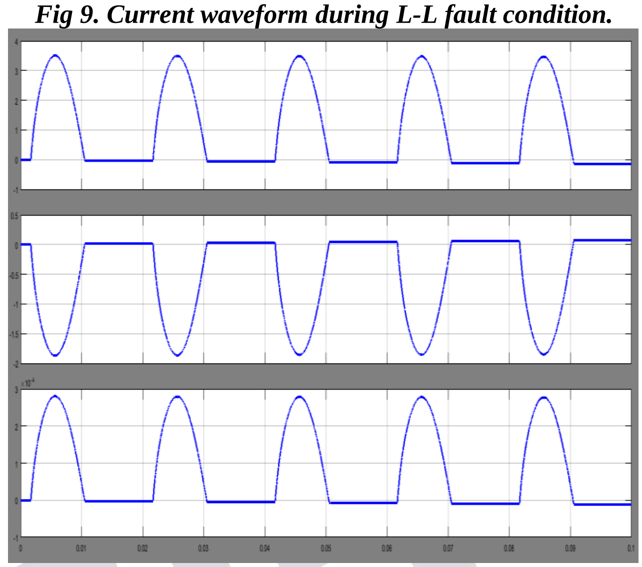

Fig 10. Current waveform during L-L fault condition.

VI. CONCLUSION

In this paper a thyristor bridge is used to detect the fault. Fault detection is carried out in De-energized downstream system to ensure a smooth and reclosing without causing a hazard to the downstream devices and personnel. The thyristor bridge is connected in parallel to the re-closer can generate a controllable signal and giving signal to the downstream line to detect fault by analysing the voltage and current waveform. The fault is detected in three steps. In step I all phase to ground fault will be detected. In steps II and III phase to phase faults are detected. We studied the asymmetrical faults and computer simulation is developed a model in MATLAB to analyse the working of proposed scheme.

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