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Coordination of Over Current Relays in Distributed Generation

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Abstract*: *The modern power system increases the power by adding Distributed Generation (DG). When distributed energy sources are added to the network, they effect the conventional fault levels and fault current paths and have been proved that the accurate operation of the overcurrent protection is not possible. This paper describes time overcurrent relay protection for radial distribution system (RDS) with DG. These time overcurrent relays is implemented by using IEC-60255 standard. The proposed protection outline is verified on a typical IEEE 13-bus radial distribution system with distributed energy source. The model of the system is replicated by using MATLAB/Simulink.

Index Terms*: *Distributed Generation, Overcurrent protection, Radial Distribution Systems.

I. INTRODUCTION

In present days Distributed Generations (DG) are extensively used in power system and connected in radial distribution network. But, distributed energy resources leads the radial networks change into bidirectional networks [1]. DG is successful in power systems universally, the prominence of DGs in forthcoming intelligent grids increases, seeing the point that DGs will have a key title part in power system safety, consistency, productivity, and superiority [2]. The consideration of the DGs into the current DG connected system can cause a few assurance issues relying upon their category, zone, and fitting and play nature. The greater part of the network circulation frameworks are radial with their protection synchronization intended to work for uni-directional power flow. In any case, the power flow may never again be unidirectional with the heading of DGs coming about in the mal-activity of conventional directional overcurrent relay. The variety in the issue current level may prompt deferred security which, as it were, can be classified "breakdown of protection". The protection framework in an overcurrent relay is the significant factor in its activity, and any adjustment in the system configuration would require an adjustment in the protection settings. The presentation of DGs in the distribution system alters the condition of network in its islanded method of activity which require an adjustment in the protection framework and synchronization of the relays. Thus, relay synchronization turns into a critical concern when power islands are made because of shortcomings or some other unsettling influences in the network. Likewise, with elevated amounts of DG entrance, purposeful islanding has turned out to be progressively obvious and gives multidimensional advantages which requires a correction in the conventional security strategies Be that as it may, the enormous infiltration of DGs into the conveyed networks may prompt bi-directional power movements and the fault commitment from DGs may majorly affect the security of the feeder. To moderate DG's effects on conventional protection structure, a few strategies has been proposed, which can be grouped into: 1) looking for greatest DG limit without legitimately influencing the current insurance framework; 2) changing the protection system dependent on reconfiguration of power system network; 3) restricting the level of fault current utilizing fault current limiters. [1-2]. Aside from the overhead strategies referenced as a few papers have outlined the idea of adaptive overcurrent (OC) relay protection. In this paper an efficient over current protection scheme for distribution lines with DG is proposed. The reset of this paper is precise strategy as pursues: Section II presents detail description of the mathematical modelling of radial distribution system (RDS). Section III discusses the proposed over current relay protection. Section IV explains the detailed Simulink modelling. Section V elucidates the simulation results. Section VI gives conclusion to the paper.

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II. RDS MATHEMATICAL MODELLING

Radial Distribution System:

Distribution System comprises of a radial principle feeder as it were. The one-line outline of such a feeder containing n branches/nodes is shown in Fig. 1.

The Radial Distribution System can be calculated in two sections. 1) Forward Sweep and 2) Backward Sweep [7]

From Fig. 1. Load Voltage can be inscribed as

$$V_i^K = V_{i-1}^K - Z_i I_i^{K-1} \quad (1)$$

Where

V_i^k is the voltage of load i at the k^{th} iteration,

Z_i is the impedance of a branch located between load (i-1) and load i,

I_i^k is the current of a branch located between load (i-1) and load i at k[th] iteration.

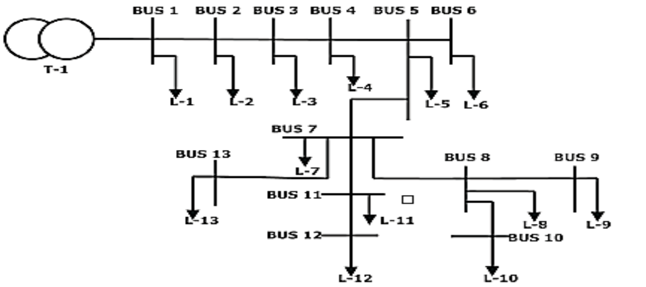

Fig. 1. Single Diagram of IEEE 13 Bus Radial Distribution System [6] In Backward Sweep the load and branch currents must be evaluated. When the load is constant power so that current can be inscribed as

$$I_{Li}^{K} = \frac{S_i *}{V_i^{K} *} \quad (2)$$

When the load is constant impedance so that current can be written as

$$I_{Li}^{K} = \frac{V_i^{K}}{Z_{Li}} \quad (2a)$$

Branch currents from the end of feeder

$$I_i^{K} = I_{Li}^{K} + \ldots\ldots + I_{Ln}^{K} \quad (3)$$

Where S* is the power load at i[th] bus,
I_{Li} is the current of load i[th] at k[th] iteration,
n is the total number of loads.

Further simplification of the above equations (3) leads to [7]

$$V_i^{K} = V_{i-1}^{K} - Z_i(I_i^{K} = I_{Li}^{K} + \ldots\ldots + I_{Ln}^{K}) \quad (4)$$

III. OVER CURRENT RELAY PROTECTION

An overcurrent relay gives assurance against over currents. This relays utilizes current contributions from a current transformer and contrasts the measured values and preset values. Fig. 3. Shows portrayal of the logical overcurrent relay, if the input value surpasses the set value, the relay notices a high current and concerns an outing sign to the breaker further opens its contact to detach the ensured gear. At the point when the relay identifies an issue, the condition is called fault pickup. The relay can direct an outing signal quickly in the wake of getting the fault (on account of momentary overcurrent relays) or it can sit tight for a particular time before delivering an outing signal (on account of time overcurrent relays). This time deferral is otherwise named as operation time of the relay, and is figured by relay protection algorithm [3-6].

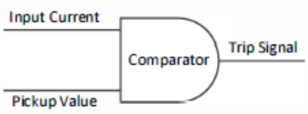

Fig. 2. Representation of the logical overcurrent relay

A. *Categorizing Over-Current Relays*

Overcurrent relays are categorized on the foundation of their time of operation, as:
1) Instantaneous Overcurrent Relay
2) Definite Time Overcurrent Relay
3) Inverse Definite Minimum Time (IDMT) Overcurrent Relay

In correspondence with IEC 60255 the characteristics of IDMT relays are characterized as:

$$\text{Trip time of the breaker } t = \frac{A*TMS}{M^{B} - 1} \quad (5)$$

$$\text{pick-up current } M = \frac{I_f}{I_p} \quad (6)$$

Where
I_f is the fault current,
I_p is the pick-up current,
TMS is the time multiplier setting,
A, B are taken as 0.14 & 0.02 respectively [4].

By utilizing suitable TMS settings, the sorting of a power system protection framework can be accomplished. The scope of TMS is ordinarily 0.1 to 1.0. Various curves can be acquired by fluctuating A and B. Table I underneath gives esteems for A and B relating to each curve.

Table I: Inverse Characteristics

Type of Relay Characteristic	A	B
Standard Inverse	0.02	0.14
Very Inverse	1	13.5
Extremely Inverse	2	80
Long Inverse	1	120

A. *Over current Relay Protection:*

Overcurrent relay is typically used to safeguard the system apparatuses in a distribution network. It is likewise probably the most effortless sort of security. Fig. 3. Speaks to the working of the overcurrent relay.

Operating Principle:
Under normal operation : I' < I_{pickup}
Short Circuit fault : I' > I_{pickup}

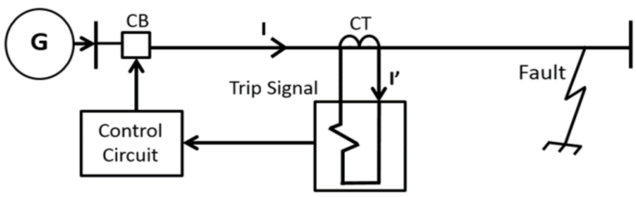

Fig. 3. Representation of overcurrent relay

Under ordinary activity, no trip sign hence, circuit breaker (CB) is shut. At the point when the transformer current is more prominent than the pick-up, there is a trip sign and Circuit Breaker operates and disengages the line. To ensure the protection framework, the pick-up and setting of time in relays need to be appropriately chosen and precisely set dependent on the essential working times and the deficiency current flows.

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The methodology of choosing and setting the protective strategies is called protection coordination. Around two kinds of overcurrent relays. They are immediate overcurrent relay and time-overcurrent relay. Immediate overcurrent relay is prearranged so that there is not at all time deferral in the activity, as soon as it drives past the relay setting. Under time overcurrent relay, three regularly utilized characteristics. As the working time diminishes, the current increments [8]. They are inverse, very inverse, and extremely inverse characteristics as appeared in Fig. 4.

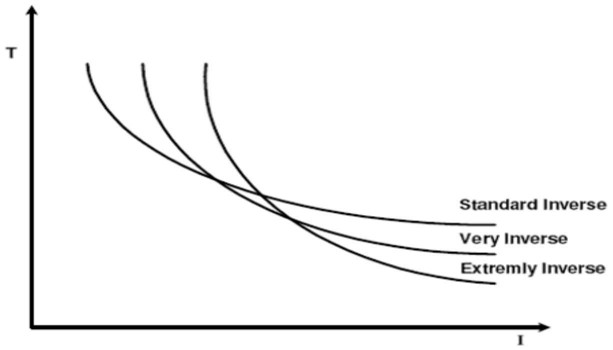

Fig. 4. Tripping characteristics of Inverse time over current relay

IV. OVERCURRENT RELAY SIMULINK MODELING

The over current relay model is developed in MATLAB software as presented in Fig. 5. The over current relay is built by following the IEC-60255 standard. The over current relay has different natures which are encompassed in simulation model like normal inverse, very inverse and extremely inverse.

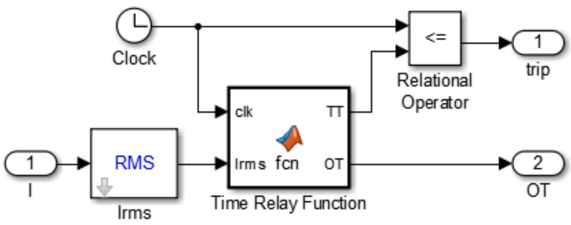

Fig. 5. Simulation of over current relay

In the Simulink model, the input currents are taken from the instrument transformer. These input currents are supplied with the sine wave form of 50 Hz frequency. These input current values are computed to root mean square (RMS) values. The RMS calculation is essential in order to excerpt the necessary section of the current signals. These intended RMS values are supplied in to the Time Relay Function for estimation and choice making of the relay. These values are utilized by relay protection algorithm to determine the relay operating time.The security algorithm for overcurrent relay flow chart is as exposed in Fig. 6. The protection algorithm needs pick-up value, TMS and kind of inverse characteristics to decide the relay operating time. In this simulation model, inverse characteristic of relay type with TMS of 0.1 is used to explore the relay. The considered RMS values are then matched with pick-up value to attain the current ratios. In this given model, the pick-up is set as 300A. If the current ratio is greater than 1, this shows that the RMS input current overdone the pick-up value. Hence, the protection algorithm of the relay begins the process to decide the relay operating time. The relay operating time is calculated based on inverse characteristic of the IEC-60255 standard. The relay operating time obtained is compared with a Relational operator. The relay operating time exceeds the Relational operator and then output tripping signal is generated.

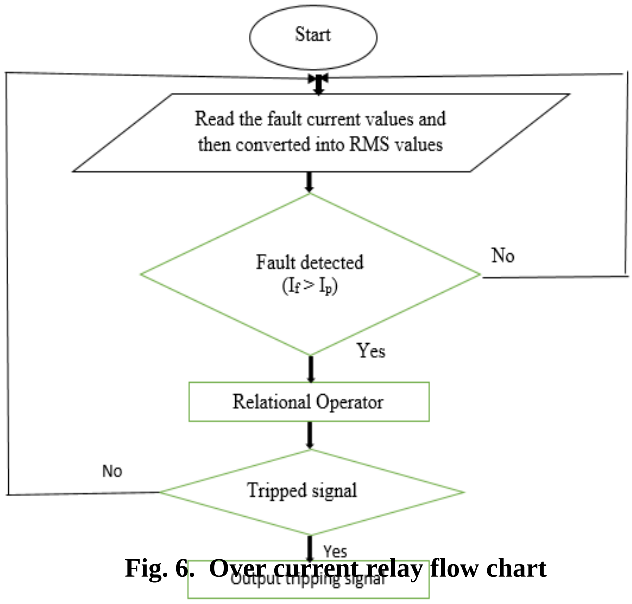

Fig. 6. Over current relay flow chart

V. SIMULATION RESULTS

These results are obtained from MATLAB/Simulink Simulation. These network tested in two cases as follows:

Case-1: Without DG

Case-2: With DG

A. *Without DG*

This case DG is not consider the radial distribution system (RDS). These circuit connected in Simulink environment. When Fault is occurred in RDS before the bus No.9, the time overcurrent relay is placed at bus No. 8. The total simulation time of the system is 3Sec. When fault is occurred in 2.6 Sec of simulation time. When fault is occurred the overcurrent relay is operated, the operation time of the overcurrent relay is 0.2433 Sec.at IEC standard inverse. When fault occurred system voltage and currents varied, at bus no. 9 the system voltage and current goes to the zero position at fault is occurred, as shown in Fig. 7 (a). & Fig. 7 (b). After fault is cleared the system voltage and current back to the primary values because of circuit breaker is tripping. When fault is cleared the system voltage and current back to the primary values in bus no.8 as shown in Fig. 8 (a). & Fig. 8 (b).

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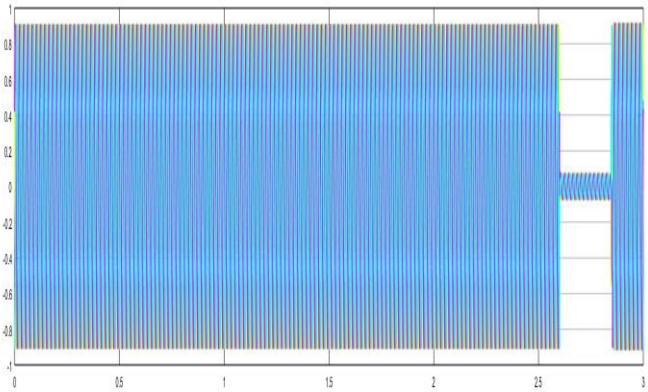

Fig. 7 (a). Voltage wave from at bus no.8

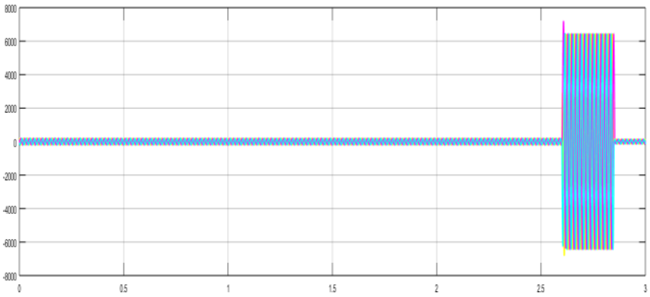

Fig. 7 (b). Current wave form at bus no.8

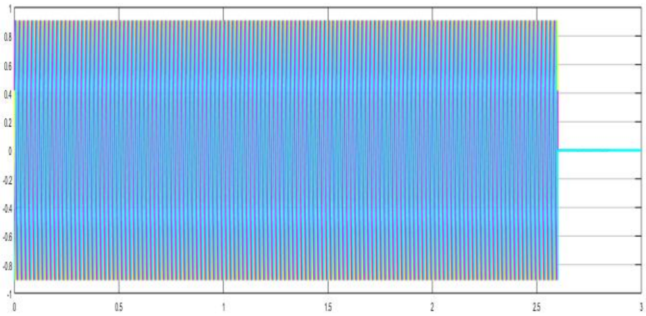

Fig. 8 (a). Voltage wave form at bus no.9

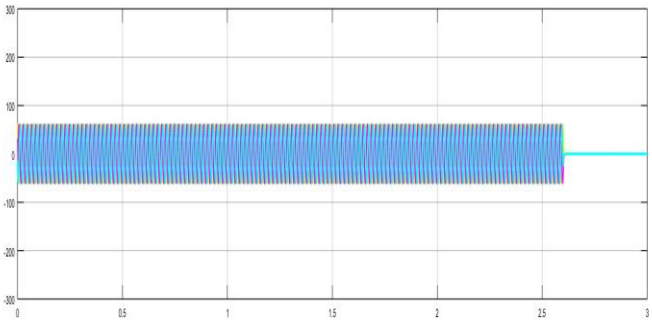

Fig. 8 (b). Current wave form at bus no.9

The inverse overcurrent relays are different characteristics as explain in section III. These inverse time overcurrent relay operation time as shown in table II according to IEC standard. These relays are tested in Radial Distribution System.

Table-II: Relay Operation time A/C IEC Standard

S.No.	Plug Setting (%)	TMS	Operation time		
			Standard Inverse	Very Inverse	Extremely Inverse
1	75	0.1	0.2203	0.06499	0.01691
2	100	0.1	0.2432	0.08769	0.02987
3	125	0.1	0.2648	0.1111	0.04653
4	150	0.1	0.2852	0.1353	0.06694

B. *With DG*

When the RDS is connected to Distributed Generation (DG) then system results is varied because of added the DGs power. The DG is connected to the bus no.9. When fault is occurred before connected point, then results are varied as shown in Fig. 9 (a) and Fig. 9 (b).

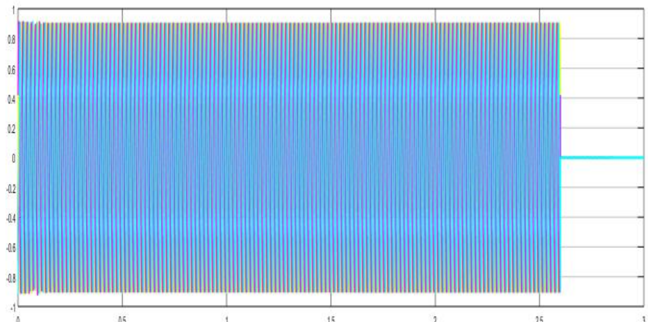

Fig. 9 (a). Voltage wave from at bus no.9

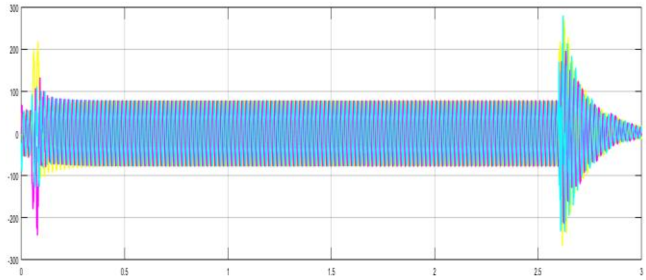

Fig. 9 (b). Current wave from at bus no. 9

VI. CONCLUSION

This paper demonstrates by the protection solution for Distribution lines. When Distributed Generation is connected to the RDS, the entire system is employed by the IEEE-13 bus system. Fault is occurred before the DG connected point, fault is occurred DGs power flow in reverse direction because of faulted point is very low resistance. The DGs Protection purpose directional overcurrent relays will be used.

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