ISSN No:-2456-2165

Power System Protection

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Abstract:- The reliability and security are major aspects of a power system. However, the fast development in electrical systems makes the protection more complicated and difficult to achieve the desired objective. These relays have many advantages such as fast operation. The use of relay protection enhances the reliability and security of the electrical systems. In this paper, an overcurrent relay is modeled using MATLAB/SIMULINK. The overcurrent relay was chosen as it is widely used in fault detection and clearance of power systems and grids. A relay by definition is an electromechanical switch which is used to sense faults in transmission lines and once the fault is detected, sends a signal to trip the circuit breaker. The overcurrent relay in specific operates when the load current goes beyond the pick-up current value. This paper discusses two important types of protections for overcurrent in the power system, i.e., primary protection and backup protection. For primary protection, every line is provided with an overcurrent relay that trips the circuit breaker when the fault occurs as opposed to backup protection where one relay is given for multiple lines which operates with a definite time delay in absence of the primary protection.

Keywords:- *Overcurrent Relay, Circuit Breaker, Trip, Fault, Primary, Backup.*

I. INTRODUCTION

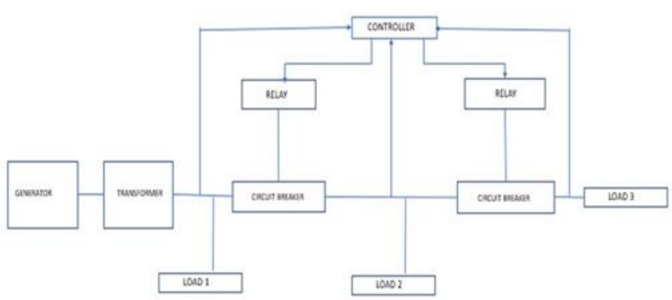

Fig. 1. Block diagram of the four-bus distribution system

Microgrid consists of DGs, loads and control systems operating in grid tied or islanded mode. It is a self-sufficient energy system. Microgrid technology aims at attaining a reliable, sustainable, optimal, economical and modern power distribution system. In primary protection, the fault clearance action is fast, but is limited to defined boundaries or a certain zone of the power system. It is also known as the first line of defense and is very sensitive with a current setting value lesser than the backup protection. However, despite its low fault clearance time, there are incidents when the primary protection fails. These situations include voltage or current supply to the relay, failure of tripping circuit or circuit breaker, absence of DC tripping voltage, insufficient contact to trip circuit and malfunctioning of relays. This is when the second line of defense comes into picture, i.e., the backup protection. The backup protection is cost effective and is mainly implemented to protect the power system against short circuits. This type of protection is implemented with a delay, specifically when the primary relay fails to operate or is out of service. Normally, when a fault occurs, the relaying operation of both primary and backup relays starts simultaneously but primary relay trips first while the latter resets itself before completing the relay operation. When a backup relay is given for a set of lines, the delay is determined by the slowest primary relaying of those lines. Discussed below is the method of implementation of primary and backup protection of relays in microgrids.

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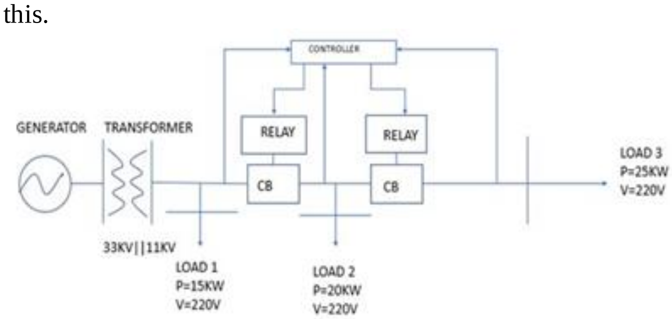

Fig. 2. Single line diagram of four- bus system

II. MATERIALS AND METHODS

Overcurrent protection is a critical safety measure taken toavoid numerous hazardous situations that may arise due to the improper overload protection or short circuit protection. The overcurrent relays protect the grid from dangerous occurrences like ignition of materials or an electric shock to a person due to short circuit or overload current. So, it is very important to install an overcurrent protection on the lines of the transmission line.

The two types of relay operations discussed here are the instantaneous overcurrent relay and the definite time overcurrent relay. The relays are further distinguished as primary and the backup overcurrent relays. Every line in a microgrid has a monitoring system which records the line current values. The monitoring system in the microgrid then updates the values to the controller.

When the overcurrent fault occurs, the controller prompts the circuit breaker to trip the circuit. lts in the circuit, the controller has reacted to it and has prompted the circuit breaker to trip the circuit. The tripping of the circuit can be instantaneous or delayed based on the application required. The design of the controller for these two methods of relaying and circuit breaker operation is discussed below.

A. Flowchart

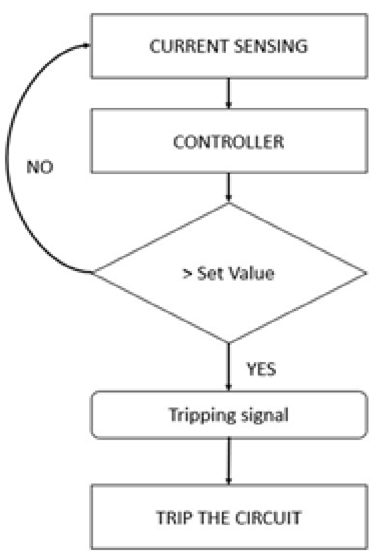

Fig. 3. Flow Chart

B. Definite time relay controller

The definite time relay controller works based on the relational and logical operators. The monitoring circuit gives inputs about the line currents to the controller, the controller continuously compares it with the set value for the normal working of the grid. If the input value crosses the set value on any line of the microgrid then the controller signals the circuit breaker to trip. During simulation, SR flip flops have been used for triggering action of circuit breaker with R input logic fixed to zero and the output of the comparator of the measured current and the set value of the current is the input to S. Based on the truth table of the SR flip flop, the output is set when S is high and the R is low. So, when current crosses the set value the S goes high and as a result, output of the controller also goes high leading the controller to trigger the communication port of the circuit breaker to trip the circuit. As mentioned earlier, there may arise situations where the primary circuit breaker fails to trip the circuit mainly because of manufacturing defects, lightning surges or overloaded circuits. To avoid the damage in the circuit due to the failure of the primary relay, a secondary relay should also be installed as the backup protection.

This relay works giving some time allowance for the circuitto regain its synchronism by itself if any fault occurs in the circuit. This feature is not optimal in the instantaneous relay.

C. Instantaneous relay controller

```
function [c,d] = fcn(x,y,z)
if x>55
    u=x;
elseif y>55
    u=y;
elseif z>55
    u=z;
else
    u=0;
end
if u~=0
    TSM=0.6;
    CS=1.5;
    pickup_current=u*1.5;
    fault_current=55;
    PSM=fault_current/pickup_current;
    PSM_o=round(PSM);
    PSM1=[1.8,2,4,6,8,10,12,14,16,18,20];
    TSM1=[11.5,9,5.6,4.4,3.5,3,2.6,2.4,2.3,2.2,2.1];
    t=0;
    for i=1:length(PSM1)
        if PSM1(i)==PSM_o
            t=TSM(i);
        end
    end
    %operating_time=TSM*t;
    operating_time=(0.14*t)/(((fault_current/(CS*PSM_o))^0.02)-1);
    if operating_time>2
        d=1;
    else
        c=1;
    end
end
c=x;
d=z;
```

Fig. 4. Function for instantaneous controller

This circuit breaker trips the circuit without any tolerances at the instant when fault occurs. Here, the line current valueis compared with the preset value, if the line current valuegoes higher than the preset value, the circuit is trippedby the circuit breaker. This controller can be coded on a microcontroller.

The backup relay waits for some time for the primary circuit breaker to work. After the toleration time of the backup relay, it is assumed that the primary circuit breaker has failed and does the work of the primary circuit breaker.

ISSN No:-2456-2165

The plug setting multiplier is the ratio of the actual fault current to the pickup current. Pickup current is the current above which the circuit breaker starts to operate. The below equation is used to specify the operating time between the two circuit breakers defined by the IEC and BS standards for overcurrent relays.

In operating time relation, TMS is time multiplier setting second the system operates normally. At time = 1 second it is observed that the fault has occurred and the fault is a single line to ground fault on phase A. The circuit breaker waits for 0.05 seconds for the system to regain synchronism by itself and if the system fails to regain synchronism, trips the circuit. The representation in the Fig.8 shows that the fault has CTR is current transformation ratio PMS is plug multiplier setting.

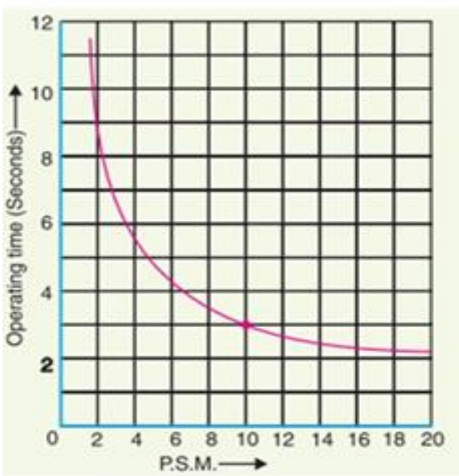

Fig. 5. Operating time vs plug setting multiplier (Pic courtesy: Principles ofPower System, V K Mehta)

$$Operating\ time = \frac{0.14 \times TMS}{\left(\frac{fault\ current}{CTR \times PMS}\right)^{0.02} - 1}$$

Fig. 6. Operating time relation

These type of overcurrent relays are used in long transmission lines as there exists time lag between the fault occurance and the measurement of the fault. The further delay may cause the damage to the circuit. Hence, the circuit needs to be tripped instantly.

III. RESULTS AND DISCUSSIONS

A. Definite time relay

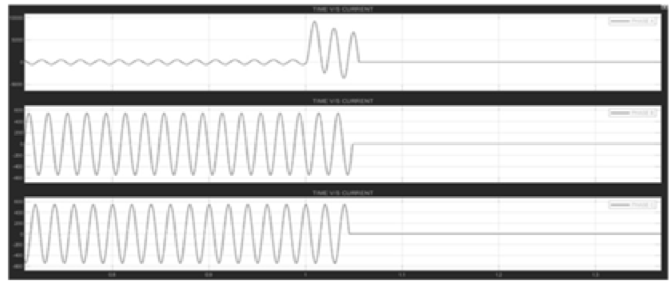

Fig. 7. Phase current vs time, Primary relaying

The representation in the Fig.7 is the characteristics of the current vs time on the lines of the microgrid .Until time =1 occurred at 1 second at the phase A and ground, since even after 0.05 seconds, tripping hasn't occurred, the secondary controller waits for 0.03 seconds and then trips the circuit.

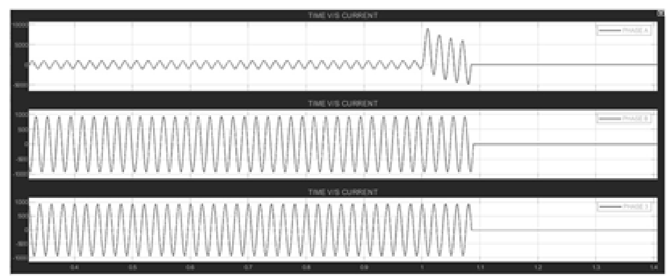

Fig. 8. Phase current vs time, Backup relaying

B. Instantaneous time relay

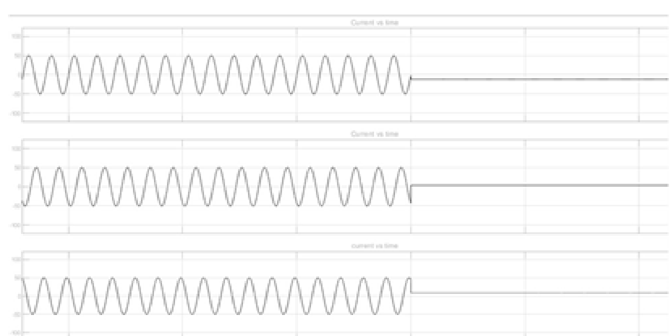

Fig. 9. Phase current vs time, Primary relaying

The above is a representation of the current in the three lines of the microgrid.Until time =1 second the system operates normally, but from the characteristics it can be observed that the fault has occurred at time = 1 second and the fault is triple line to ground fault. When the fault has occurred the relay trips the circuit instantly without any delay. Therefore, no current flows in the circuit after time=1 second.

ISSN No:-2456-2165

IV. CONCLUSIONS

When fault occurs there is a significant rise in current observed just before the circuit breaker trips. These relays can be designed and adapted in power system to protect them from overcurrent problems. There can also be a backup protection in case the primary protection fails.

ACKNOWLEDGEMENTS

Editors of this paper are obliged and thankful to international board members and reviewers for their valuable contribution to the journal.

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