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Protection of Microgrid by Using Adaptive Relaying Scheme

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Abstract— Recently, different ideas are developed and implemented towards the interest of getting more effective low carbon energy sources and Microgrids. A microgrid has two modes of operations, Grid connected mode of operation and stand alone mode of operation . When the mode of operation is changed from grid connected mode to stand alone mode there is a drastic reduction in the magnitude of the fault current , so this mannerism and shows the problem with the protection .In order to overcome this sort of problem we develop this scheme. In this scheme the relays are made quite intelligent to decide the mode of operation of the system and to sense the expected faults on time. Relay shows a flexible behavior to the magnitude of the fault and change its setting according to the fault magnitude. Here is the demonstration of how to develop the hardware for the adaptive relays for the purpose of protection of microgrids, certain cases are also developed to validate its operation too. Relays adopts itself to the fault to adjust its setting and time of operation.

Keywords— Low Carbon energy, Microgrid, Quite intelligent, Drastic, Adaptive relay.

I. INTRODUCTION

It is near to impossible to design such a system having no problem of facing faults and failures. As it is understandable to have a system having minimum faults and an easy access to fault clearance, hence a development is needed to develop system like having multiple power source in a junction in which each and every system or part is easily be replaced by an alternative grid in order not to affect the reliability and continuity of supply. This needs a skill to make the systems properly intelligent enough to perform in such a way to inter its input, output, fault, fault location, fault automatic clearance and alternative supply in a short period of time as much as possible.

Microgrid: It is a small-scale power grid which run independently or in conjunction with the area's main electrical grid. Any small-scale sectarian station with its own power resources, generation and loads and apparent boundaries enables as a microgrid[1].

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Microgrid and load sharing: The microgrids are of much importance in effect that these are the electricity distribution systems. That can be operated in junction with the main grid or main power network. Microgrids are considered to be effective in reduction of the greenhouse gas emission and global warming because these grids are capable to handle the load overall of a small area and can also be used to share a load during the peak hours [3].

MODES OF OPERATION: There are two types Modes of operation of a micro-grid named as grid connected mode and stand alone mode. In grid connected mode it is in contact with the other utility or some type of central grid by a point known as point of common coupling (PCC), through certain isolation device in order to connect and disconnect on demand[2,3]. While in stand-alone mode the micro-grid provides the supply to the past of a specified load to which it is connected, it is not connected to any other power generating unit or central grid.

Protection as One of the Primary Objective: Continuity and reliability of a system is one of the major factor's to deal with. The absence of power can led to serious issues so the protection seems to be the primary objective. As avoiding consequences of natural events like equipment damage, human or systematic faults (mal-operation) is near to impossible but still the system should to be much intelligent to handle these types of conditions and faults.

II. PROBLEM STATEMENT

The main challenge that engineers face while implementing the adaptive relaying is changing the relay setting to suit the load, generation level and topology changes. Overcoming this challenge is what makes this type of relaying more effective.

There are usually three different methods to reach coordination of relays. These methods are

- Trial and error method
- Topological analysis method
- Optimization method

In optimization method the parameters of relay are set in a manner to optimize the protection of grid[6].

Power system quantities are dependent of the systems fault and its nature. When the insulation of a cable is damaged by certain factors their parameters and quantities changes in accordance to its fault being occurred on the system. The changing parameters may be like,

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- Temperature
- Power factor
- Contamination of the insulation
    - Over current
    - Over voltage
    - Under voltage
- Weather conditions like Snow, Rain
- Chemical effects etc.

Usually shunt fault can occur which can interrupt the supply over voltage can occur of two reasons it may be because of internal (by switching) or external (by lightening)

Breakdown of insulation can cause the fault and this type of fault is temporary like the faults that is being occurred on transmission lines because of insulators which results in the production of arc. The production of arc is undesirables and it's ale ionizing is alone by the disconnecting the supply for a short time after disconnecting the arc will disappear. This is an unintentional tripping and this process of interruption is called as reclosure. There reclosure attempts are allowed in low supply network which only one is allowed in high voltage system for sake of the reliability of the system.

We term this kind of effect as metallic fault when the fault is occur due to the passage of itself. The enter load consent through itself. The resistance of the arc is nonlinear in nature. The arc resistance can be modeled as,

$$\text{Rarc} = \frac{8750(S+3ut)}{(I^{1.4})} \qquad (1)$$

In equation (1), the S stand for distance (ft), *U* nominate the air's velocity, T is the time and I is the fault current measured **(**Amps).

III. TYPES OF FAULTS

The main types of faults are,

- Symmetrical type fault
- Series type fault
- Unsymmetrical type fault

Symmetrical Type Faults: In case of symmetrical fault the system does not imbalance because the fault current is distruibted symmetricaly in all the three line, but the equipments of the system is demage. The ocreance of this type of fault is (2-5) %. This type of faults are intense and very severe. One of the type is line to line to ground fault. Fig.1 show two cases of the symmetrical fault.

Series Type Fault: This type of fault occur due to the breakage of the current's continuity .These occurs due to broken part i-e line or current carrying conductors touches some sort of another conductor or any grounded part . These open circuit faults are often very dangerous and can lead to dangerous and hazardous circumstances or consequences.

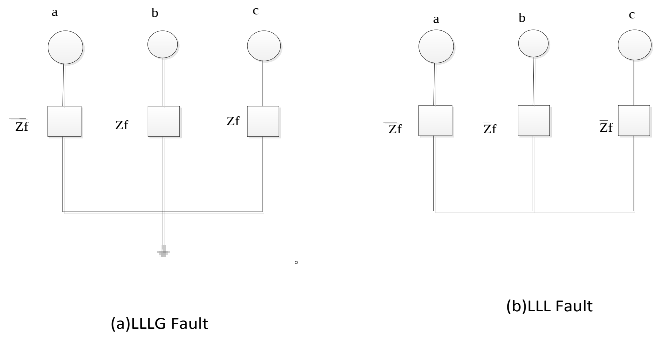


Fig 1. Symmetrical Type Faults

Fig shows the symmetrical types of faults in which the system is balanced during the fault because the fault current is equally distributed in all the lines.

Unsymmetrical Type Faults: These types of faults are very common and is less severs as compare to the symmetrical faults. In case of unsymmetrical faults the fault current is distrubited unsymmetrically in all the three line.

The very common types of this fault are;

i. L-G **line to** ground fault.
ii. L-L line to line fault.
iii. L-L-G Double line to ground fault.

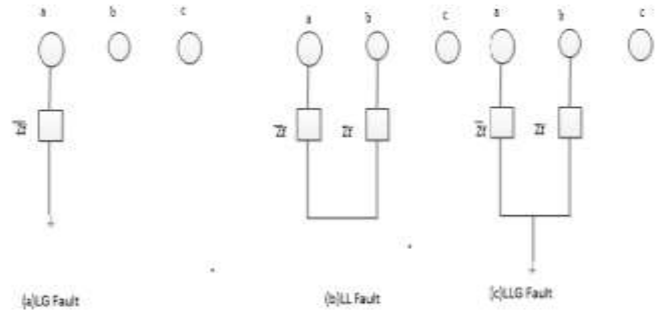


Fig 2. Unsymmetrical Type Faults

Fig shows unsymmetrical type faults, the most common faults are line to ground faults .It is occurred due to the contact of the line conductor with the ground or earth. About 65-70% of the faults are line to ground faults. L-L fault are when 02 of the conductors are in contact with one another**,** these faults are rare and about 5-10% [10].

When there is contact in between two of the conductors and the ground or earth then these type of faults are called as double line to ground fault. These types of faults are about 15-20%.

IV. RESULTS

Two cases from test have been carried out to check and validate the performance of adaptive relaying scheme as described below.

These cases are design in E-Tab,

CASE #1 Fault on Microgrid (DG1) side while in stand-alone mode:

Consider Fig 3 the static switch is open so the system is running in the stand-alone mode. Now if 3 phase fault occurs at t DG 1 then the relay R1 and R2 sees the fault current feeds through DG2 as DG2 is also connected through the bus 3. Thee fault current magnitude and it's the operating time of the relay is s also measured. The coordination between the relay R1 and R2 is such so they have some difference in their operating time. The fault current at point A is measured to be 2400 Amperes for which the operating time of R1 and R2 is 0.3 and 0.35 seconds respectively.

A Mimic is shown below which has one central generatingg system and two micrgrids named Distributed generator 1 and d Distributed generator 2 and loads which are shown by three g green panel lights respectively. The equipment's used in the s Mimic are of very low ratings so we graded the results according g to the simulation results. After the occurrence of the fault as s shown in figure our system sense the load of the DG2 and if the e supply of DG2 can handle the load of DG1 then this load is s shifted to DG2 as shown in the figure 18. Relay R1 operates and gives signal to the circuit breaker CB1 and hence the load of DG1 now shifted to DG2.

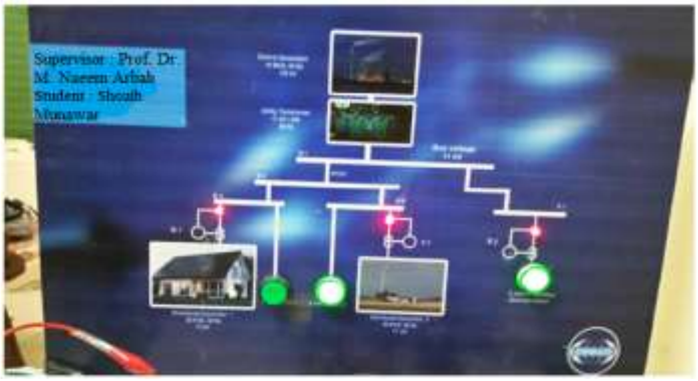


Fig 3. Fault at DG 1 while in stand-alone mode

Fig 4. Load of DG1 shifted to DG2 in stand-alone mode

CASE # 2 Fault on Microgrid DG1 side while in grid-connected mode:

The static switch is closed and the system is running in interconnected mode. The loads are shared by all the three generation units. Now if a 3-phase fault occur at point A as shown in Fig 4, then Relay R1 sees the fault current feed through DG2 and utility generator and Relay R2 sees the fault current feed through only DG2. The fault current magnitude is 7500A. The operating time for relay R1 is 0.1sec and for relay R2 is 0.15 sec respectively. In grid Connected mode the load is now shifted to main grid as the capacity of utility is generator is more than DG2.

Fig 5. Load of DG1 Shifted to Main grid in grid-connected mode

V. APPLICATIONS

The Microgrid, can't be considered as a replacement for the national grid, but can be really beneficial for the areas which have abundant renewable sources.

- Financial commitments of microgrids are much smaller compared to main grids.
- Because of the renewable resources microgrids are more environmentally friendly with carbon footprints comparatively lower.
- Another benefit of microgrid is that it's operating is fully automatic and require fewer technical skills.
- Microgrids are isolated from any grid disturbance or outage. If running in grid-connected mode can be isolated by proper protection scheme (Adaptive Relaying).
- Microgrids place the consumer out of the grip of large corporations that run the generation networks.

VI. PROPOSED METHDOLOGY

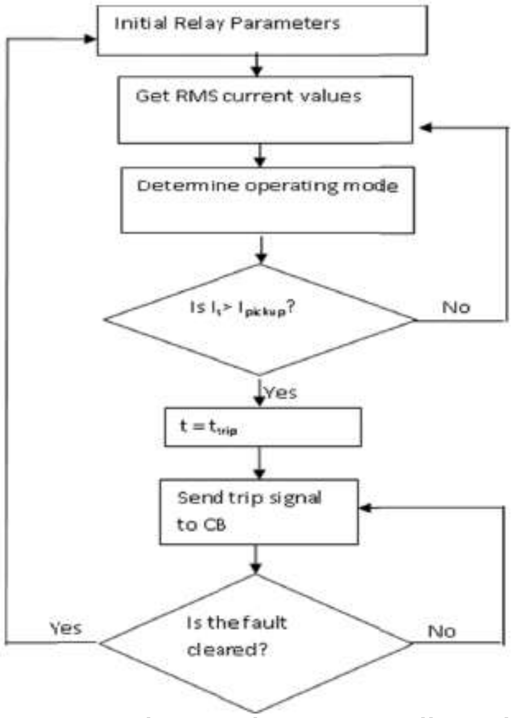


Fig 6. Adaptive Relay Microcontroller Model

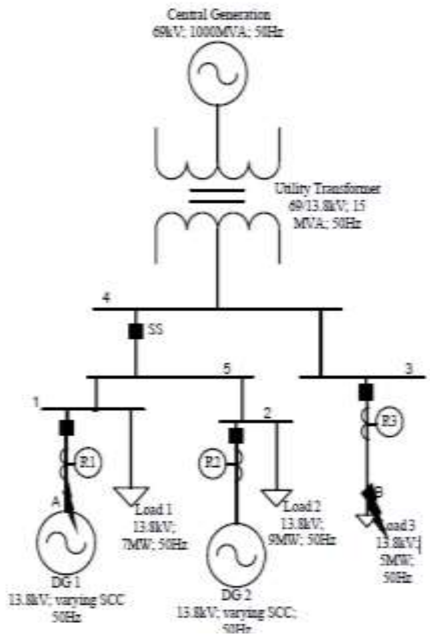


Fig 7. Microgrid Test system and Utility Model

Adaptive relaying is a scheme that have the capability to adopt the system parameters if they are changed. Adaptive relaying refers to the fact that setting of relays will be changed or adopted on-line to suit the status of power system at different times.

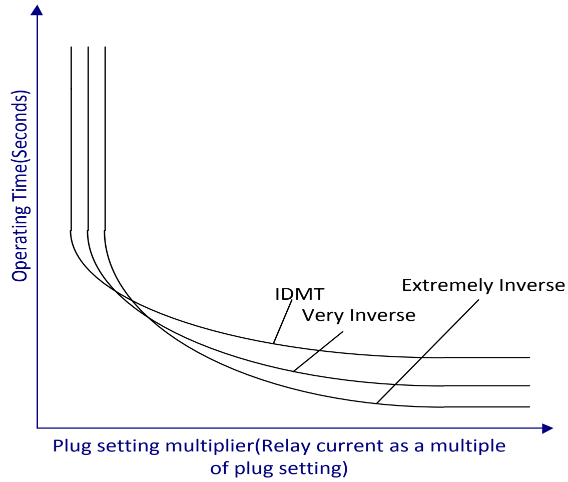
In this type of relaying technique developed to suit the fact that the power system conditions are continuously changing leading to change in fault current levels and distribution in the network [5].

One possible approach to achieve minimum shock to the system due to faults would be to minimize a sum of the operating times of all primary relays [6].

Inverse definite minimum time relay is used for relay modeling in this project. This function also enables the user to approach the coordination problem as linear programming problem [7].

$$t_{op} = \frac{0.14(TMS)}{(PSM^{0.02}-1)} \quad (2)$$

In equation (2), t stan for trip time, TMS for Time Multiplier Setting and PS for Plug Setting.



Graph 1. Show IDMT Characteristic [10]

Relay Operation:

A protective relay receives signal in the form of current and voltage from the CT and PT respectively. When the fault occur relay pickups the current and initiate its operation [9]. Both failure to operate and incorrect operation can result in major system upsets involving increased equipment damage, increased personnel hazards, and possible long interruption of service.

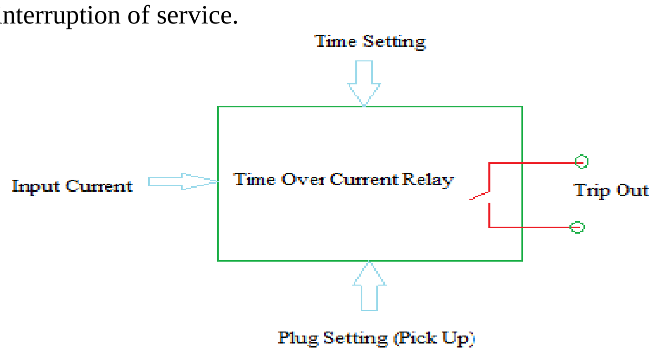


Fig 8. Operation of Over Current Relay

Pick Up Current: The Current at which relay operates is called pick up current of the relay. The current setting of the relay is expressed in percentage ratio of pick up current of the relay to the current transformer rated secondary current. Sometimes it is also called plug setting.

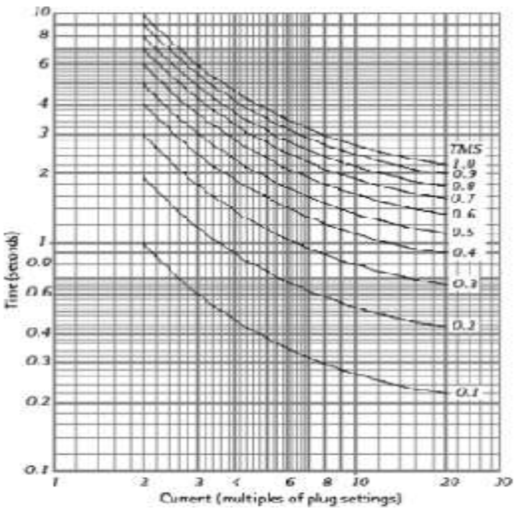
$$\text{Current setting} = \frac{\text{Pick up current}}{\text{CT secondary current}} * 100\ \% \qquad (3)$$

Plug Setting Multiplier: It is the ratio of current in the relay coil to pick up current of the relay.

$$\text{Plug setting multiplier} = \frac{\text{Fault current in the relay coil}}{\text{Pick up current}} \qquad (4)$$

Time Setting Multiplier: The operating time of an electrical relay mainly depends upon two factors. So far adjusting relay operating time, both of the factors to be adjusted. The adjustment of travelling distance of an electromechanical relay is commonly known as time setting. This adjustment is commonly known as **time setting multiplier of relay[10]**. The time setting dial is calibrated from 0 to 1 in steps 0.05 sec.

- How long distance to be traveled by the moving parts of the relay for closing relay contacts [10].
- How fast the moving parts of the relay cover this distance[10].



Graph 2. Show Time/Plug Setting curve of IDMT Relay [11]

Time to clearance = t + relay delay = circuit breaker delay. With the below equation in mind the trip time of the above relay is assumed to be 0.3 secs. The TMS is derived from the following equation.

$$TMS = \frac{(PSM^{0.02} - 1)}{0.14} \qquad (5)$$

The plug setting is chosen using a thumb of ruleas mentionedby Bedekar et al. in [8].
$PS \geq$ 1.25* maximum load current
$PS \leq$ 2/3 * minimum fault current

For stand-alone mode of operation of Relay 1 and Relay 2
Maximum load current= 30A
Minimum fault current= 1950A
Therefore,
$PS \geq 1.25 * (30/200)$
$PS \leq 2/3 * (1950/200)$
$0.19 \leq PS \leq 6.5$

For stand-alone mode of operation of Relay 3
Maximum load current= 230 A
Minimum fault current= 4000A
Therefore,
$PS \geq 1.25 * (280/300)$
$PS \leq 2/3 * (4000/300)$
$0.96 \leq PS \leq 8.88$

For grid-connected mode of operation of Relay 1 and Relay 2
Maximum load current= 280 A
Minimum fault current= 6000A
Therefore,
$PS \geq 1.25 * (280/400)$
$PS \leq 2/3 * (6000/400)$
$0.875 \leq PS \leq 10$

For grid-connected mode of operation of Relay 3
Maximum load current= 450 A
Minimum fault current= 4000A
Therefore,
$PS \geq 1.25 * (450/600)$
$PS \leq 2/3 * (4000/600)$
$0.94 \leq PS \leq 4.44$
From the above calculations we assumed the Plug setting of 1 because it satisfy all modes of operation of all the three relays.

TABLE I. PARAMETERS OF RELAY 1

	Stand Alone Mode	Grid Connected Mode
CT ratio	400:1	200:1
TM	0.1	0.1
PS	1	1

TABLE II. PARAMETERS OF RELAY 2

	Stand Alone Mode	Grid Connected Mode
CT ratio	400:1	200:1
TM	0.11	0.12
PS	1	1

TABLE III. PARAMETERS OF RELAY 3

	Stand Alone Mode	Grid Connected Mode
CT ratio	600:1	300:1
TM	0.1	0.11
PS	1	1

VII. ADVANTAGES

The main advantages of the microgrid protection are as follows

- First is to detect the fault automatically. The detection of fault has been developed for both of the schemes or modes.
- Second is when the fault is detected then it has to isolate the micro-grid that is connected with the main or central unit known as common coupling point (PCC).
- Third is to synchronize the micro-grid with the utility grid to make it functional when fault is cleared.

CONCLUSION

It is observed from the above carried tests numbered as from1 to 6, in micro-grids the fault current varies with the perspective of the mode of operation of a micro-grid. It is being observed that the fault current is quite higher in value during the grid-connected mode as comparative to the fault currents when the grid is operating in a stand-alone mode. The higher fault current value in grid connected mode is just because of the reason that in grid connected mode more of the sources are connected which contributes really its proportion. While developing this adaptive relaying scheme Arduino based digital relays are used in place of the electromagnetic relays because of the reason that digital relays have an option such as Mode of operation. Hence it is concluded that the Adaptive relaying scheme is enough confident and intelligent to sense the operating mode of the system and to adopt itself according to the changes being occurs.

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