

# PROTECTION OF MICROGRID FROM HIGH IMPEDANCE FAULT USING DIFFERENTIAL RELAY

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## Abstract

As source of traditional energy is vanishes day by day, importance of microgrid increasing very effectively. In traditional generation and transmission of electrical power we have to rely on frequency and generation of power but in case of microgrid we have to depend on whether condition. Managing these systems to change of atmospheric condition becomes challenging. All study going on all over world related to microgrid protection of microgrid is one of them. Micro grids can either operate connected to the grid, or in the case of a grid fault, in an islanded mode. Effect of high impedance fault is studied in this paper, by taking help of Matlab-Simulink's SimPower Systems. We model a microgrid containing mix of renewable DG and one dispatch able source, we then simulate the HIF fault at one of the bus in both grid-connect and island modes and analyze fault currents and voltage levels in order to determine how the protection scheme of the distribution network would need to be changed to facilitate microgrid functionality. We show that standard protection methods are insufficient and propose the use of digital relays which is different from traditional system.

**Keywords:** Fault analysis, Microgrid, Protection

## INTRODUCTION

From the United state report Investigator says "Microgrid has been proposed as way of integrating large number of distributed renewable energy sources with distribution system, one problem with microgrid implementation is designing proper protection scheme". Relay protection of microgrid is different than conventional power distribution grid in following ways (1) Current flow in microgrid in both direction while in conventional grid support single end power supply.(2)Use of large power electronic converters cause another problem.(3)Relay protection should be provided for islanding and normal mode, with high speed, selectivity and reliability Which lead to great challenge for protection of Microgrid.

Domestic and foreign researchers have made extensive studies on the relay protection of MG. N-line operation. Similarly, N. Schaefer et al. [4, 9] describe a scheme and the algorithm of an adaptive protection relay, which comprises a real-time block and a non-real time block, both implemented in software and hardware. Y. Han et al. [13] propose that, comparing the system's impedance and the microgrid's impedance, over current instantaneous protections can be automatically adjusted to the new situation. Then, K. Dang et al. [14] propose to use a way of comparison between the zero-sequence current and a threshold. T. S. Ustun, et al [2] present an adaptive protection system based on an extensive communication system that monitors the microgrid by means of a Central Protection Unit (CPU).

The main objective of this thesis is the modeling of a hybrid microgrid with its protection which will also clear high impedance faults. A development of novel method for modeling high impedance faults is

important to demonstrate to show how the protection scheme can protect against them. This is important in microgrid protection not only because as the percentage of high impedance faults on the distribution system is not insignificant [7], but also because microgrids, in the islanded mode, typically have lower fault currents. Hence modeling and complete protection of microgrid are the main part of this paper. The overall system is simulated using MATLAB environment. In simulation work the renewable sources are modeled using different equations.

## SYSTEM TOPOLOGY AND DG MODELS

### A. SYSTEM DESCRIPTION

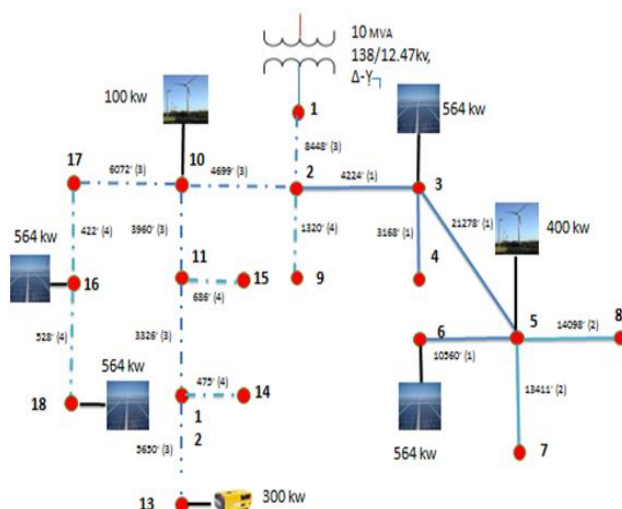
A microgrid is group of controllable interconnected loads and distributed generation (DGs) with clearly defined electrical boundaries that act as single controllable entity with respect to grid. Dynamic structure of microgrid and its versatile operation will lead to alternative protection strategy. The system used in this study is taken from [3] an 18-bus network with a load capacity of 3.03 MVA connected to a 10 MVA transformer. The system with line parameters and feeder source impedance are given. The phase loads of each bus were also given and are shown in Table 1. The system is protected using fuses and reclosers on the overhead lines and breakers on the underground lines. To this system we added four solar arrays, two wind turbines, and one diesel generator. The solar arrays are each connected to three-phase inverters and provide a total of 2,256 kW. The wind generators provide an additional 500 kW to the grid. During islanded operations, additional generation and load following is provided by a 300 kW diesel generator. System is shown with solar arrays, wind turbine, diesel generator is shown in fig 1

**Table 1 bus loads for the microgrid in fig. 1**

BUS	Phase A		Phase B		Phase C	
	P (kW)	Q (kvar)	P (kW)	Q (kvar)	P (kW)	Q (kvar)
3	117	73	121	65	90	98
4	97	33	86	35	91	36
6	46	15	77	23	64	19
7	100	65				
8			85	32		
9					354	180
13	75	34	75	34	75	34
14	111	53				
15					176	34
16	89	63	89	63	89	63
17			314	126		
18	210	99				

### B. DISTRIBUTION SYSTEM WITH DG SOURCE

The given system in [3] is converted to microgrid by adding 4 solar arrays having capacity 564 Kw, 2 wind turbines provides 500Kw to grid and 1 diesel generator which gives additional generation and load following is provided by 300 kW. They are connected to three phase inverters to give total of 2256 kW. Solar array are connected to node no. 3,6,16 and 18 and wind turbine is connected to 5th and 10th node of system. Diesel generator is connected to node no.13



**Fig1:- One line diagram of the microgrid with added DG sources**

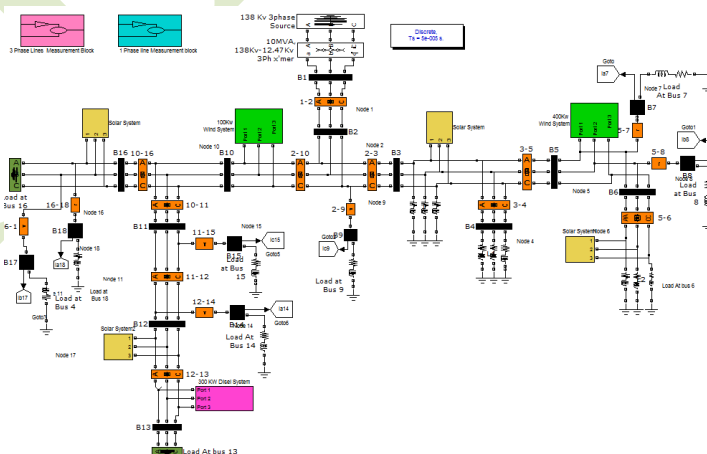
**C. MODELING MICROGRID IN MATLAB SIMULINK**

(i) PV arrays are built up with combined series/parallel combinations of PV solar cells, there are several ways to model a PV cell, module, or array for simulation. A possible model of a photovoltaic array and inverter [17] was researched. According to theory, its features were modeled in Simulink.

(ii)The diesel motor model used in this study is a modified version of matlab-simulink library demo model [5] and is connected to a 300-kW/12.47-kV synchronous generator .The asynchronous motor is rated 150 HP, 12.47 kV and the synchronous machine is rated 375 KVA, 12.47kV.The diesel engine and governor system are modeled by a Simulink block initially, the motor develops mechanical power of 150 HP (300 kW) and the diesel generator is in standby, providing no active power

(iii)Wind turbines are connected to a 100-kW and 400-kW squirrel-cage induction generators. According to Wind turbine characteristics given wind speed is calculated which will give maximum power output. Constant Wind Speed is fed to turbine to give required output.

Figure 2 shows grid connected system with DGs at various nodes; measurements are taken at each node as shown.



**Fig2:- MATLAB model of micro grid with different DG sources**

## SIMULATION OF HIGH IMPEDANCE FAULT

### A. INTRODUCTION

When fault current is below pick up of conventional over current,  $I_f < 100$  Amps on grounded system, which occurs because of Incipient insulator failures, Fallen conductors on concrete, tree, soil, gravel, sand, asphalt, etc. this condition raises the electric potential of tangible objects around us and may result in death by electrocution, severe electrical burns, or fires ignited by arcing and heating of materials. The occurrence of such conditions also constitutes a loss of energy to the power companies as not all of the produced electrical power is delivered to their appointed loads. Power is lost on the way of delivery and dissipated through foreign objects which should not be in contact with the line. Conventional relaying schemes monitor short-circuit conditions where a significant amount of the energy supplied by the power company flows directly into the ground and never reaches its load. In this paper a new technique is proposed to model, locate, and detect high-impedance faults. Patterns and characteristics in the line's current provide for recognition and are investigated to detect such faults. [21]

### B. STATEMENT OF PROBLEM

Conventional detection schemes monitor only low-impedance faults (LIFs that result in instantaneous and large increments of current due to a low-impedance path to ground ).A HIF seems invisible to such detection methods because it presents only a small increment in line current and appears to be a normal load increment. Following figure 6.1 depicts this scenario.

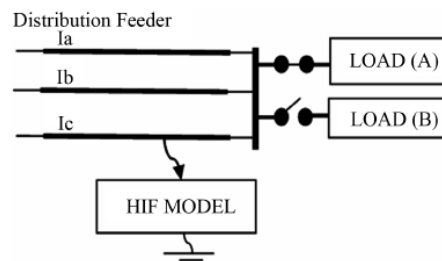


Fig3:- Distribution network with HIF

### C. PURPOSE OF STUDY

HIF can occur in two cases. In one case, a conductor breaks and fall to ground and fallen phase current decreases and protection relays cannot detect fault because current is not more than setting current of relays. In other state conductor isn't break but it touches a high impedance thing such as tree limbs. In this state feeder current increase but it is not enough to detect by conventional protection relay. Therefore this type of fault is very difficult to detect also it is very dangerous for human life and necessary to detect.

### D. STATERGY OF HIF FAULT DETECTION

HIFs detection is very difficult by conventional techniques, various methods are proposed before [23]-[25] but no effective solution. This paper proposed technique based on measurement of current sequence component. One of the advantage is that it can easily incorporated with digital Relays .Based on superposition theorem, cureent can be consist of two component (i) a normal-running component, and (2) a fault-imposed component. The fault-imposed component can be calculated using superimposed networks [26],[27]. Assuming that  $i_n(t)$  is the current of the normal system (normal-running current),  $i_f(t)$  is the current of the faulted system (fault current), and  $i_{fi}(t)$  is the current of the superimposed network (fault-imposed current), one can write:

$$i_f(t) = i_n(t) + i_{fi}(t)$$

Typical HIF currents values of above type for a 12.5-kV distribution feeder are listed in Table 2[10].

**TABLE 2 HIF currents values**

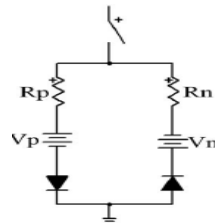
Material	Current(Amps)
Dry Asphalt	0
Concrete(non-reinforced)	0
Dry Sand	0
Wet Sand	15
Dry Sod	20
Dry Grass	25
Wet Sod	40
Wet Grass	50
Concrete Reinforced	75

To evaluate the method of HIF detection, a model based on Emanuel model for HIF is utilized, which is depicted in Figure 4. HIF Current changes between 0 and 80 Amp as shown in above table 2 and it is obtained with change of Emanuel parameters. A list of Emanuel parameter that is result from practical test [18] is brought in Table 3.

**TABLE 3 Value of Emanuel model parameter**

	$R_p$	$R_n$
1	208	212
2	215	223
3	235	225
4	244	227
5	245	245
6	247	271
7	255	280
8	267	286
9	269	289
10	272	290

Data in Table 3 are used to simulate a HIF in a distribution feeder



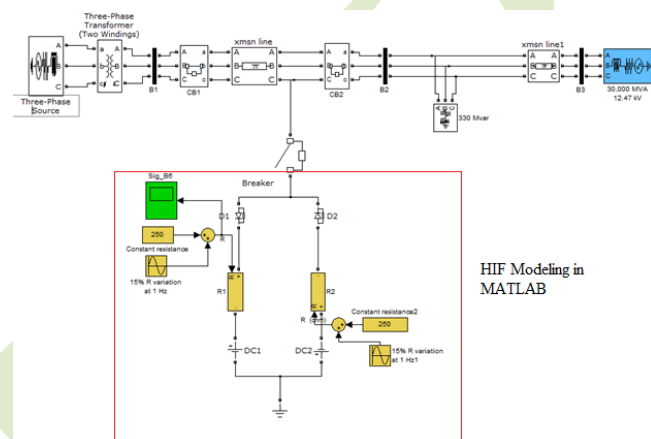
**Fig3:- Emanuel Model of HIF**

## SIMULATION OF HIGH IMPEDANCE FAULT

Emanuel model used to create Matlab Model which includes two DC sources,  $V_p$  and  $V_n$ . These represent the *arcing voltage* of air in soil and/or between trees and the distribution line; two resistances,  $R_p$  and  $R_n$ , between diodes which represent the resistance of trees and/or the *earth resistance*. When the line voltage is greater than the positive DC voltage  $V_p$ , the fault current starts flowing towards the ground. The fault current reverses backward from the ground when the line voltage is less than the negative DC voltage  $V_n$ .

Using above parameters of resistance from table 3 a variable resistance is modeled in matlab with controlled voltage source. Resistance value is taken of 15% of constant resistance of 250ohm. Hence variable resistance is obtained for which min and max values are from a table 3 To study a simulation of HIF, a sample distribution system is considered with 12.47kV three phase source and transmission line with two circuit breakers on both sides. Figure 4 gives High impedance fault created on sample distribution system in matlab.

Model of HIF thus discovered is used to simulate a fault on 18 bus distribution system. This fault is simulated on various buses of Microgrid system.



**Fig4:- HIF Fault on sample distribution System**

## MODELING OF NUMERICAL RELAY FOR COMPLETE PROTECTION OF MICROGRID

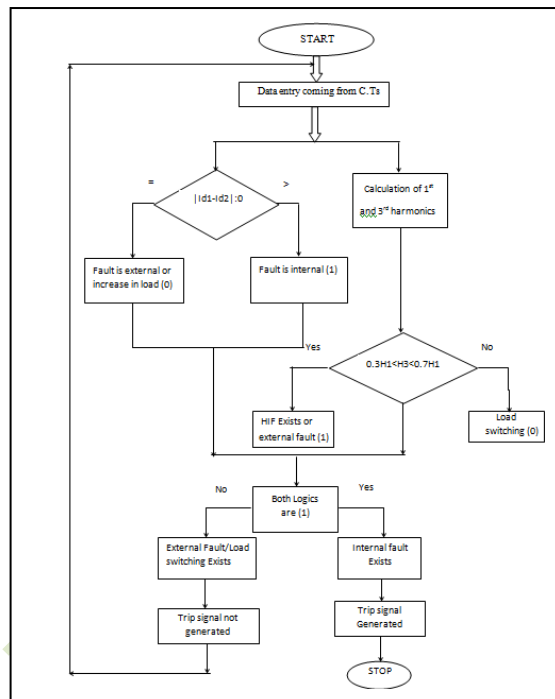
### A. INTRODUCTION

There are different philosophies of protecting islanded microgrids. One is to simply trip the entire microgrid offline once the fault is detected during islanding. For additional reliability, the faulted line will need to be removed from service and the remaining connected loads and sources will operate as two smaller islands. This will only work if the generation and load in each smaller system match. If higher reliability is required, the feeders can be connected as a loop, so the loss of a feeder or a lateral will not result in service disruption to customers. The higher reliability, however, comes at a higher cost.

### B. PROPOSED PROTECTION SCHEME FOR MICROGRID

This proposed protection scheme uses a current differential relay with specified algorithm which considers internal, external and high impedance faults. By using these relays on the end of each line segment, a very robust protection scheme can be developed. During this simulation study, HIF current patterns are evaluated by decomposing the line current into its spectral content and studying its harmonic content. It is observed

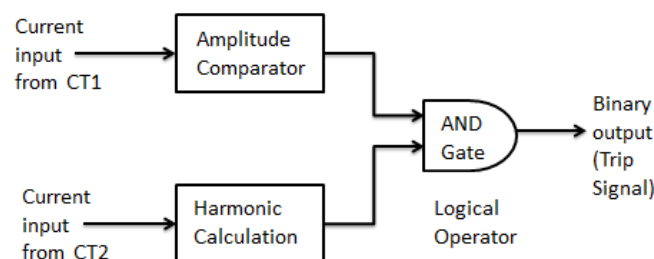
that HIF currents content different patterns than load switching and other system variation condition. Specifically, it is noticed that phase shift for the 3<sup>rd</sup> harmonics current with respect to the fundamental has occurred. This phase shift of 3<sup>rd</sup> harmonics current is used to distinguish the presence of high impedance fault than load switching condition. This differentiating criterion is used to find out the algorithm for numerical relay for HIF protection.



**Fig 5:- algorithm for numerical relay for HIF protection**

### C. IMPLEMENTATION OF THE DIGITAL DIFFERENTIAL PROTECTION USING MATLAB

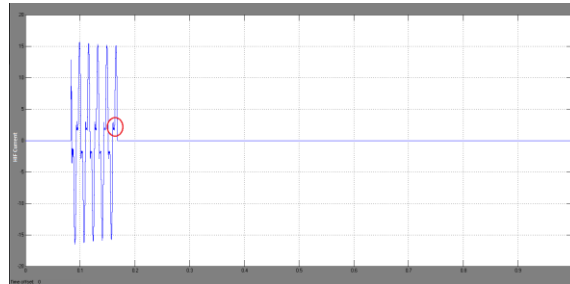
Different protection functions are required to design an appropriate protection scheme for microgrids. “*the amplitude comparator module*”, “*the harmonic comparator module*” inside each comparator block. The amplitude comparator module compares the magnitude of the fault currents at two end of protective device and the output trip signal of the amplitude comparator module is used by the islanded-mode protection module. Harmonic calculation module is generally comes in picture when high impedance faults exists in system. Finally, the tripping module decides whether or not a trip signal should be issued to external controlled circuit breaker.



**Fig 6:- Tripping Module**

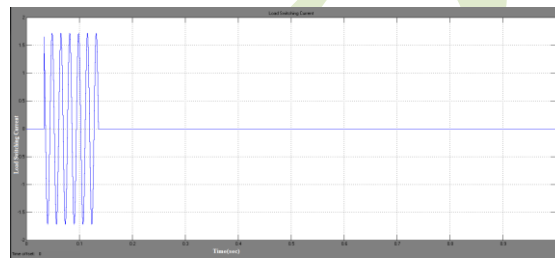
## SIMULATION RESULT

High impedance fault is simulated on sample distribution system. Results obtained for current waveform of HIF is shown in figure 7



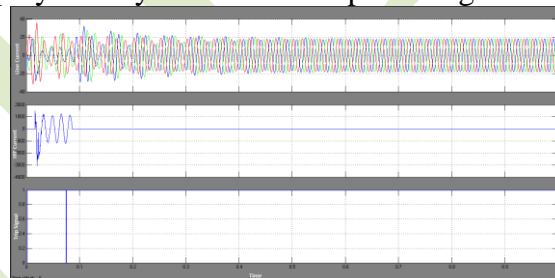
**Fig7:- current waveform of HIF**

Phasor shift in waveform detects the presence of HIF and distinguishes it from load switching conditions. Load switching waveforms are shown in figure 8 below. It can be seen that there is no phase shift occur in load switching case.



**Fig 8:- Load switching waveforms**

Numerical Differential relay deployed in system is used to protect against HIF types of fault.



**Fig 9:- Clearance of HIF fault using differential relay**

## CONCLUSION

The economical and environmental merits of microgrids have motivated extensive researches and development efforts toward resolving the technical challenges of this new and fast-growing technology. The main objective of this study is to address some concerns related to the protection of microgrids. The issues studied in the thesis are modeling of distribution generation and protection of the microgrid against different fault scenarios in both modes of operation.

Microgrids can be protected using digital current differential relay deployed at each line end in system. Relay structure thus proposed is able to protect all types of fault in medium voltage microgrid. In this way complete protection of microgrid system can be achieved



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