A NOVEL APPROACH OF LV MICROGRID PROTECTION SHIFTED FROM GRID CONNECTED MODE TO STAND ALONE MODE

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Abstract:
Due to penetration of many Distributed Generators (DGs) in the existing network make the whole system very complex. To handle this issue, segregate it into small manageable groups, each group is called a Micro Grid (MG). However due to their unrivalled arrangement not only the control and proper dispatch of power face problems, the MG experience austere issues regarding protection. In this paper a technique is considered, when low voltage (MG) operating in grid connected mode and shifted to standalone mode due to any transient or common abnormality such as over and under voltage as well as over and under current faults etc, its protection set points should be switched over to another set point group accompanied by switching of grounding breaker and excitation system of DG. For this a numerical relay algorithm will be developed having two groups of protection set points, one protection set point will be used when MG operating in Grid connected mode and other is used when operating in islanding mode and this algorithm will be implemented through auxiliary Relays.

Keywords: Micro Grid (MG), Grid connected mode, Islanding mode, Distributed Generator (DG).

1. Introduction

MG also called smart grid as an innovative and emerging technology comprises of renewable and non renewable distributed generation system, storage system, and loads for the safe, reliable and economic dispatch of power as well as reduce the transmission losses [1] as shown in figure 1. Different MGs integrated with utility grid form a complex network [2, 3], which makes the whole system very challenging from control and protection point of view.

MG protection is very essential in both islanding mode and grid connected mode [4]. Classic protection against over current faults faces challenges regarding sensitivity and selectivity during faults occurs in grid connected mode and autonomous mode because the fault current is not same for the same relay [5]. Numerous viable solutions and techniques have been suggested to solve this issue but the most promising one is the adaptive protection technique to make the smart grid self-monitoring and self-healing [6].

MG using renewable energy resources such as solar cells, wind energy including fuel cells and photovoltaic cells uses power electronic converters as interface between AC and DC grids which converts dc to ac supply however it faces problems using conventional protection schemes. Due to current limiting state of the converters, it causes protection problems and overcome by using Admittance relay based on inverse time characteristics [7].

A voltage based protection using abc-dq transformation method was introduced which monitors the terminal voltage in the form of abc supply and transform it into dc dq form and if any disturbance occurs it is reflected as a disturbance in dq form, consequently isolate the faulty section of the system based on these disturbance [8,9]. Discrete Fourier transforms and Total harmonic distortion techniques were used to monitor the output voltage of the inverter based generators, detect the fault and isolate it if any abnormality occurs [10]. Line protection is also very significant because of their unprecedented structure and concept of smart grid, so a new protection paradigm is implemented in [11], using remote interrupters implemented through fast communication, phasor measurement units (PMU,s) and line sensors for fault locations at different zones.

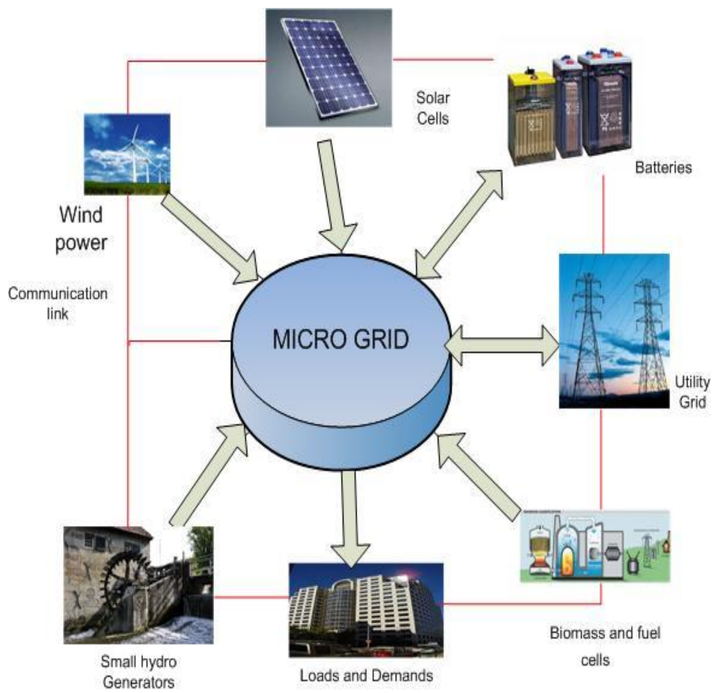

Figure.1 Micro grid Concept

In this paper a technique is used when MG operating in grid connected mode and due to any external abnormality/fault MG shifted to stand alone mode as a result, protection relay set point should be switched to another group setting, grounding breaker of the distributed generator should be closed and excitation system switched over to autonomous mode. For this an algorithm will be developed and it will be implemented through auxiliary relays. The tool used for analysis and simulation is Electrical Transient and Analysis Program (ETAP).

2. MG with Protection Strategy

A low voltage of 3.2 MW DG is connected through generator circuit breaker (GCB) to Bus bar 1which in turn connected to Bus bar 2 through tie breaker CB-05 as shown in figure.2, each bus bar having its own

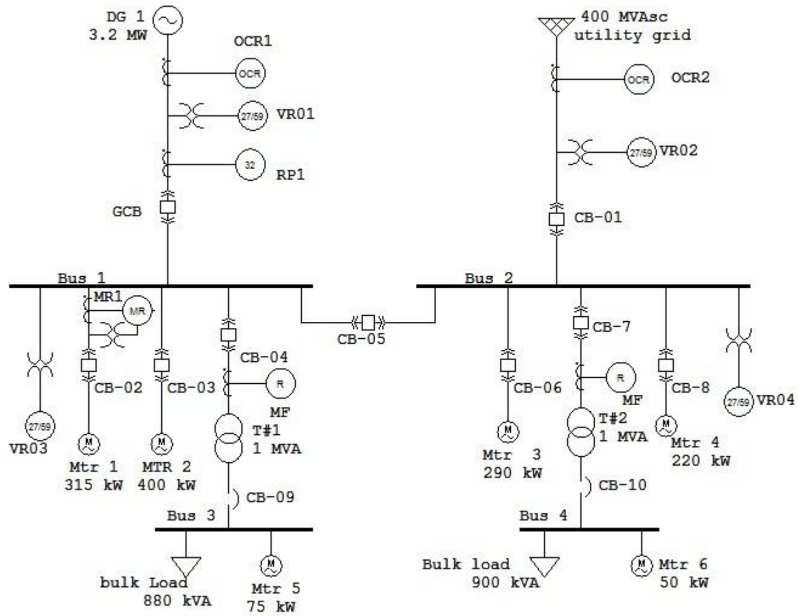

Figure.2 One line diagram

loads constitute a MG. Few but relevant protections like over current, over and under voltage, reverse power for DG along with motor protection relay (MR) and most crucial are multifunctional relays installed at Bus bar 3 and bus bar 4 respectively are depicted.

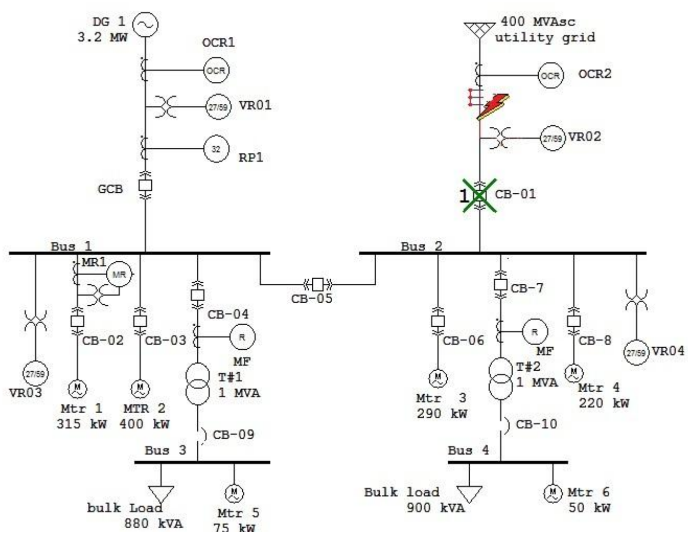

Figure.3 Fault outside the MG

MG connected to the utility grid through CB-01 breaker which is called point of common coupling (PCC).Normally when the MG is operating in Grid connected mode, power is shared between MG and utility grid according to their capability and ratings. Due to any external fault the CB-01 gets open and MG shifted to Islanding mode as shown in figure 3.As soon as the CB-01 gets open and GCB is in synchronized condition the multifunction protection relay installed at bus bar 3 and bus 4 respectively switched to another group of protection setting, the grounding breaker gets closed which is normally in open condition while operating in grid connected mode, if using the same grounding system for both the

DG and utility grid. Also the excitation system of DG also switched over to grid-off connected mode. The whole scenario in the form of an algorithm depicted in figure 4. When the status of GCB is closed and CB-1 gets open due to any external fault, the MG operating in grid connected mode shifted to islanding mode. As shown in algorithm n-numbers of sources can be integrated to utility grid to operate in grid connected mode as well as in islanding mode. By detection of CB's contact status, multifunctional relay changed its protection set points group along with switching of grounding breaker and automatic voltage regulator (AVR) to islanding mode with the assistance of auxiliary relays.

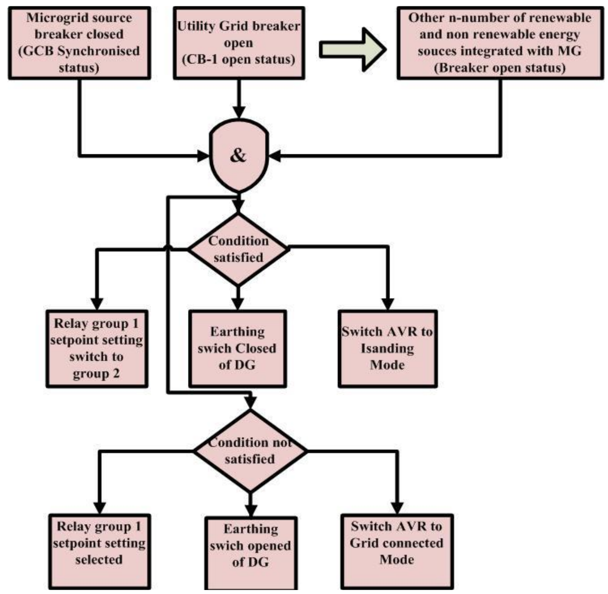

Figure.4 Algorithm for transition from Grid mode to islanding mode and vice versa

3. Fault at Bus 3

Over current and most importantly short circuit protection is the major issue in MG to handle it using conventional protection scheme. The fault current level is not same for both islanding mode and grid connected mode feeding the same relay used for protection.

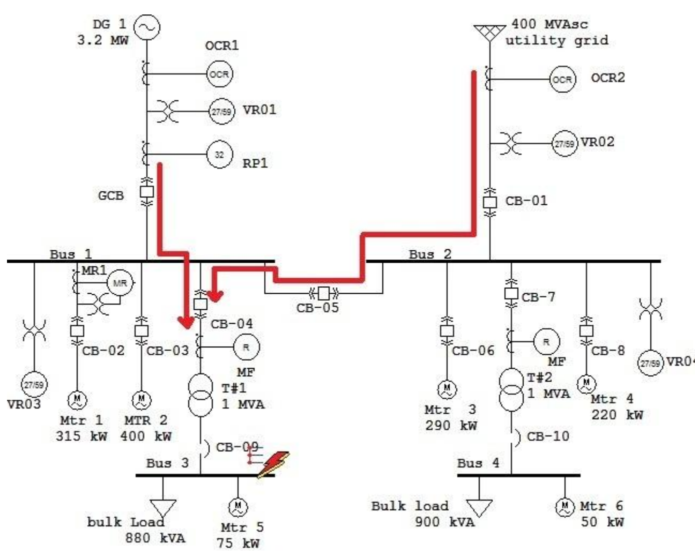

Figure.5 Fault at bus bar 3

Normally the fault current level in islanding mode is two to three times less than nominal operative value set in classical relay [12, 13]. A sensitive relay is required which may not cause a trip due to conventional relay. In spite of installing such sensitive relay, this may not be the actual and final solution because it may vulnerable to instability of the network by responding to spurious signals. To overcome this problem a multifunction relay is used having two groups of protection set points. Consider a fault occurs at bus bar 3 in the grid connected mode as shown in the figure 5, the fault current level will be high because both the DG source and utility grid feeding the fault current, however if fault occurs in the islanding mode, the fault current level will be very low depending upon the capacity of the DG. In this case two faults currents have been observed feeding the same relay, so there should be two groups of over current protection set points. Experimentally a 3.2 MW DG connected with the utility grid and a multifunctional microprocessor based relay installed at bus bar 3 and bus bar 4 each having two groups of protections set points shown in table 1 and table 2 respectively. Current transformers (CT's) used having ratio of 150/5A

Table 1 (Grid connected mode set points)

S.No	Over current $I>/I_n$	Instantaneous/ short circuit current $I>>/I_n$	zero sequence current I_0/I_n
Set points	1.2A	15.2A	0.1A
Trip Time	0.5sec	0.04sec	0.05sec

Table 2 (Islanding mode set points)

S.No	Over current $I>/I_n$	Instantaneous/ short circuit current $I>>/I_n$	zero sequence current I_0/I_n
Set points	1.2A	11.2A	0.1A
Trip Time	0.5sec	0.04sec	0.05sec

CT used 150/5A, I_n=5A

4. Grounding Breaker condition

During Grid connected mode the DG connected with the main grid using the same grounding system, the neutral point of the MG DG should be kept open as shown in figure 6, because normally the neutral set point for small DG's is typically low. An external fault in the grid may cause unbalance in the system, due to this unbalancing a zero sequence current may flow through the neutral of the DG which may cause nuisance tripping, so to avoid this the neutral breaker should be kept open in grid connected mode, however other protections of DG is active like differential protection, reverse power protection over and under voltage protection, overload and short circuit protection etc. The breaker should be closed during islanding mode**.**

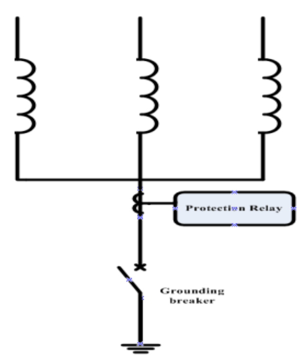

Figure.6 Neutral point of DG

5. Switching of Excitation System

In grid connected mode, frequency and voltage of the utility grid is used as a reference parameter for MG DG because DG are governed as PQ (active and reactive power) sources, so that it can deliver controllable amount of apparent power in to the network. While in Islanding mode, DG of MG switched to PV mode to govern frequency and voltage of its autonomous mode within acceptable limits.

6. Control circuitry

The practical implementation and control diagram of the aforementioned scenario is depicted in figure 7. (Auxiliary Relays of 220 V DC is used).
Normally GCB Auxiliary contact remains closed when GCB breaker is in closed position. Auxiliary relay A will remain picked and closed the Relay A auxiliary contact-1 and Relay A Auxiliary contact-2 respectively.

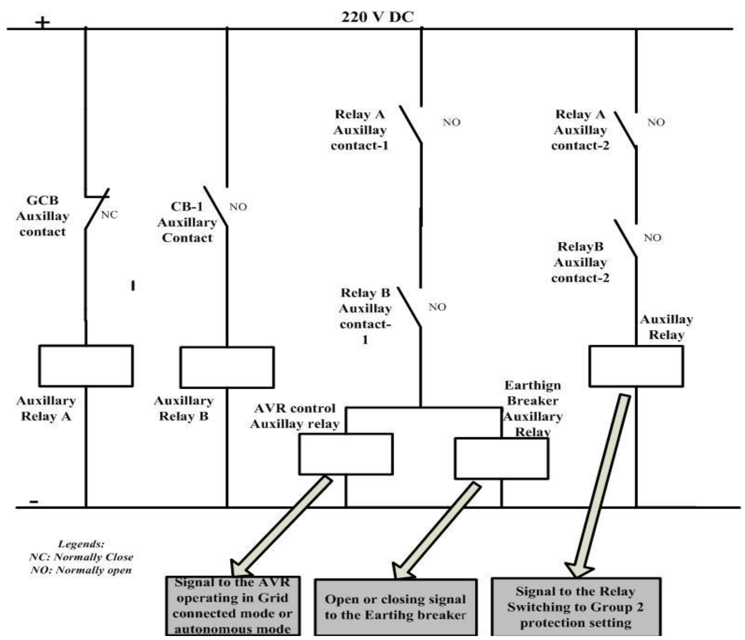

Figure.7 Control diagram

CB-1 Auxiliary contact remains normally open when CB-1 breaker is in closed position. Whenever CB-1 breaker gets open due to any fault, the CB-1 auxiliary contact turned to closed position as a result the Auxiliary Relay B gets picked which closed the Relay B auxiliary contact 1 and Relay B auxiliary contact 2 respectively. By closing the Relay A Auxiliary contacts-1 and 2 and Relay B Auxiliary contact-1 and 2 make a path for Auxiliary Relay (responsible for switching of Multifunction relay protection group set points), AVR Control Auxiliary relay and Earthling Breaker Auxiliary Relay to be picked. Multifunctional Relay has inputs in open or close status which change their groups according to signal from Auxiliary Relay. Similar technique is used for Excitation system and Earthing breaker system.

7. Conclusion

This paper is focusing on using multifunction microprocessor/numerical based relays instead of using conventional electromechanical and solid state relays. Although it makes the system much expensive and costly but makes the protection system much smarter. An extra feature can be added in the relay by deactivating some protections of DG like over and under frequency, over and under voltage etc when MG operating in autonomous mode (in case of station blackout) and where uninterrupted supply is at high priority especially for emergency purposes.

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