Islanding detection and protection with neutral point grounding using two layer soil model

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Abstract— India will have the enormous measure of small & micro DG entrance on the lattice in coming five years to build adaptability in power system structure. The mammoth of endeavors must be accomplished for accomplishing such target yet it will likewise challenge the solidness of the network especially for India. India is second biggest populated nation and appealing arrangement and endowment embedded by state and local government will prompt countless of rooftop solar power plant in the urban and provincial region. Such expansive number of situation will enhance the vitality situation for power utility yet while making them synchronized with lattice will danger the dependability of framework and also the wellbeing of utility individual and ordinary citizens having RE plant. We have the references to gauges and strategies of other globe areas like (Germany, Ireland) yet we can't straightforwardly embed those arrangements and standard for Indian culture, it has various reasons like absence of mindfulness among us, absence of legitimate rule to follow and our mindset to spare the little piece of capital venture by dismissing little alerts like establishing. To adapt up to all difficulties and trouble in islanding identification author proposed a basic yet full of feeling specialized rule for security of smaller scale matrix operation amid the both mode i.e. framework associated and separated mode. This paper addresses the accessible strategies (dynamic, latent and cross breed) for discovery and operation of islanding mode and their impediments in Indian situation. Authors also proposed that grounding of all the neutral points of load using two layer soil model which will increase the level of fault current of micro grid during isolated mode as well as provide the low resistance path for heavy fault current during grid connected mode which in turn also reduced the ground rise potential and touch potential. The paper orientation begins with challenges in islanding operation then examines the accessible strategies and their confinement for detection and protection during islanding operation and lastly proposed a procedure counter the limitation by using load neutral point grounding on two layer soil model. The adequacy of displayed procedure is appeared by reenactment comes about on MATLAB stage.

Keywords- Renewable energy sources, islanding operation, protection schemes, neutral point grounding, soil resistivity, soil model

I. INTRODUCTION

The limited amount of presence of fossil fuels and the effects of their uses have pushed humans to look for an alternative and renewable source of energy. In India, we have higher solar irradiance compared to many other countries and its solar electricity potential is between 4 and 7 kWh per sq. m / day in its most parts. So, Solar PV Rooftop has emerged as a potential green technology reducing dependency on conventional fossil fuel based energy. World combined introduced sun powered vitality limit of 3.7 GW in 2004 has achieved 177 GW in 2014 i.e., expanding just about 50 times in ten years. Worldwide interest in Renewable Energy (RE) has been developing consistently and expanded five circumstances since 2004, from $62 bn to $316 bn in 2014 in ten years. Looking inwards, India is having fourth biggest power era limit on the planet after US, China and Russia. Its Renewable Energy (RE) share expanded to 13.16% in 2015 with sunlight based vitality having a share of 11.62% in it. Between 2005 and 2015 the renewable network availability has expanded from 6.2 GW to around 36 GW for both sun oriented and wind. Increasing RE source and their penetration on distribution grid converted the passive network into bidirectional power flow network. Technical solution for power flow in distribution network is no longer valid; therefore it's also affects the protection relay operating conditions. The distributed micro grids are small power system includes photovoltaic (PV), wind generation system, fuel cell, batteries, super capacitors etc. [1-3]. These micro grids are also having the demand from local loads and hence they operate in both islanded and grid connected modes [1-3]. Many protection schemes have been proposed for distributed MG integrated with DT (distribution) grid and also for the islanded mode [4-16]. The presented paper reviews the pros and cons of available techniques for protection [4-13] and proposed a simple scheme to enhance the performance of available techniques.

II TECHNICAL PROBLEM IN CONVENTIONAL PROTECTION SCHEME WITH RE INTEGRATED SOURCES

Bidirectional power flow – The present distribution systems are mostly in form of radial feeders and have unidirectional power flow. Whereas the upcoming RE integrated distribution systems have bidirectional power flow and hence these systems are not protected by conventional protective devices and relays.

Low fault current – Another problem in RE integrated DT gird occurs during islanding mode [17,18] and remains absent during grid connected mode. If any fault takes place somewhere in grid which will lead to voltage drop, frequency variation and unbalance condition that can be remain non detected by the protective devices. This is known as non-detected islanding condition and may lead to dangerous situation for utility personnel and cause unstable distributed generation system. Therefore a quick islanding detection method should be set to avoid any failure or disaster.

Voltage fluctuation – Voltage quality specifically of PV can be affected by change in natural radiation due to play between cloud and sunshine [19]. These alterations of sun radiation can produce voltage fluctuation in feeder, which in turn make voltage profile unbalanced. These ups and downs in voltage can produce malfunction operation of relays and voltage regulating devices.

Severity of these problems depends on penetrating level of RE sources on grid and also on installed location of RE sources in distribution system.

III ISLANDING MODE AND OPERATION

The islanding mode can be defined as the condition of state after grid isolation from the RE sources bus and after this isolation operation RE sources maintain the frequency and voltage within permissible limit [20]. The change in state occurs due to disturbance in grid which forces the system to change the state of RE sources from grid connected to islanding mode. Therefore, to protect the system in both states the efficient and reliable protection schemes are desirable. The subsequent sections give the overview of islanding detection technique and also discuss the limitations associated with them.

3.1 Communicated adaptive protection (CAP) schemes – The main advantage of CAP scheme is that it can protect the system in both states (ie grid connected and islanding mode). In this scheme the relays settings will be updated which based on the communication between grid utility and RE source units [20-21]. The communication can be based upon of PLCC (power line carrier communication) or SCADA (supervisory control and data acquisition). The main advantage of this scheme its high reliability and it minimize the Non detection zone (NDZ) nearly to zero. However despite of its high reliability advantage its implementation cost can be considered as its main drawback.

3.2 Locally measured parameters protection (LMP) schemes - The said scheme employ the techniques which depend on state of the measured system parameter to propagate the desire control action. The scheme locally (on PCC) observes the system parameters like voltage variation, frequency deviation, change in phase angle etc. The techniques falls under this protection scheme are over/under voltage protection, over/under frequency protection [22,23], harmonic detection [22,24], jump in inverter's terminal voltage [23,25], rate of change of frequency and power [26,27].

3.3 Intentionally perturbation injection (IPI) schemes – In this scheme disturbance are intentionally inserted on the inverter terminal and therefore altering the power balance of the system. The injected disturbance will pose the small percentage change in parameters under scrutiny in grid connected mode whereas the percentage change shoots up in islanding mode. This change in islanding mode is observed and corrective action take place. The techniques falls under this scheme are harmonic injection [28, 29], additional phase shift introduction [30, 31], frequency drift using positive feedback and dead zone insertion [22 ,32, 33].

3.4 Combined LMP & IPI (CLI) techniques- The advantage of both LMP & IPI scheme have incorporated by many authors to increase the reliability of protection scheme. In [34, 35] authors have created positive feedback like IPI and observed the voltage unbalance locally just like LMP. The difference between IPI and CLI scheme is the level of injected disturbance, in the later one disturbance injection are minimal which increase the detection possibility in LMP scheme. This combination reduces the NDZ as compared to other two techniques but also increase the islanding detection time due to employment of two different methods.

The entire reviewed schemes above have most challenge of low fault current during islanding mode. When system runs in grid connected mode the fault current is about 5-7 times of full load current whereas in islanding mode the fault current level drops down to 1.25-1.5 times of full load current. This happens mainly because of electronics interfacing devices between RE sources and PCC (point of common coupling). The inverters employed in interfacing limits the fault current to 1.5 times of full load current to protect the used semiconductor devices in it. To overcome this problem authors in this paper suggest a simple technique which also bring up the safety measures at consumer end. The author proposed first establishment of two layer soil model based grounding for RE sources micro grid connected with local loads. Then connection of all the neutral point of connected load on RE sources bus to the grounding wire of RE micro grid. The main aim behind to make this arrangement is to bring up the fault current level during islanding mode and the same time provide the safety measures to the consumers having rooftop solar plant and micro wind turbine in connection with their own load.

IV TWO LAYER SOIL MODEL GROUNDING

The main objective of grounding is to provide a low resistance path for heavy fault current. This further helps by providing safety to working personnel and installed equipment. Accurate soil model to design grounding system of the micro grid ensures that the resistance of the grounding grid through the earth is sufficiently low. Soil resistivity data is of fundamental importance in performing grounding system analyses; therefore reliable data is required to achieve good correlation between design and measured grounding system performance. As discussed earlier in section-3 that inverter used in interfacing, limits the fault current to 1.5 times of full load current by using fault current limiter (FCL). So while designing grounding system, inverter's FCL must be model by appropriate impedance value. IEEE 80-2000 (2013) [36] standard is used for determination of the grounding parameters (namely step, touch and ground potential rise) using a

uniform soil model but this paper suggest to use two layer soil model to get accurate soil resistivity.

4.1 Soil resistivity measurement - Many methods have been proposed and used for measurement of resistivity. But the four point method [37] of resistivity measurement is most referred by researchers and design engineers. In this method four auxiliary electrodes are placed in a straight line with spacing of electrodes equal to *a* and driven into the soil, at depth *b* usually it is taken *0.1a*. Then current I is flow through the two outer electrodes, and the potential V between the two inner electrodes is measured with a potentiometer or high-impedance voltmeter as shown in figure 1, and V/I ratio gives the resistance R in ohms and resistivity calculated by equation 1.

$$\rho = 2\pi a \frac{V}{I} \quad (1)$$

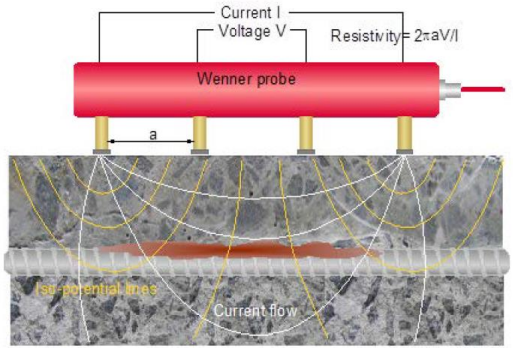

Fig. 1 Four point method

4.2 Empirical formula to design two layer soil model parameters - Empirical formulas which can be used to compute the apparent resistivity of two layer soil model of grounding grid has been developed with different data available. Two constants are used in the available formulas and given in Eq. 2 & 3 for calculation of grid resistance of grounding system laid in two layer soil resistivity model i.e.

$$\text{mf} = \frac{\rho_1}{\rho_2} \quad (2)$$

$$\text{rr} = \frac{\rho_2}{\rho_1} \quad (3)$$

The other terms used in the empirical formula are given below:

ρ1 = Resistivity of Layer 1

ρ2 = Resistivity of Layer 2

ρa = Apparent Resistivity

Table 1 shows the empirical formulas for different subcases.

TABLE.1. EMPIRICAL FORMULAS FOR APPARENT RESISTIVITY

CASE	SUB-CASE	FORMULA/ EQUATION
$\rho 2 < \rho 1$ (NEGATIVE K)	$1 < mf \leq 3$	$\rho_a = \frac{\rho_1}{\left[1 + [(mf) - 1]\left[1 - e^{\overline{K(0.9h+0.9H)}}\right]\right]}$
$\rho 2 < \rho 1$ (NEGATIVE K)	$3 < mf \leq 5$	$\rho_a = \frac{\rho_1}{\left[1 + [(mf) - 1]\left[1 - e^{\overline{K(1.9h+1.9H)}}\right]\right]}$
$\rho 2 < \rho 1$ (NEGATIVE K)	mf > 5	$\rho_a = \frac{\rho_1}{\left[1 + [(mf) - 1]\left[1 - e^{\overline{K(4.5h+4.5H)}}\right]\right]}$
$\rho 2 > \rho 1$ (POSITIVE K)	1<rr≤ 3	$\rho_a = \rho 2 \times \left[1 + [(rr) - 1]\left[1 - e^{\overline{K*\text{mf}(1.5h+1.5H)}}\right]\right]$
$\rho 2 > \rho 1$ (POSITIVE K)	$3 < rr \leq 5$	$\rho_a = \rho 1 \times \left[1 + [(rr) - 1]\left[1 - e^{\overline{K*\text{mf}(2.1h+2.1H)}}\right]\right]$
$\rho 2 > \rho 1$ (POSITIVE K)	rr> 5	$\rho_a = \rho 1 \times \left[1 + [(rr) - 1]\left[1 - e^{\overline{K*\text{mf}(4.5h+4.5H)}}\right]\right]$

V PROPOSED SCHEMATIC

The previous section describes the methodology and formulas to calculate the soil resistivity for two layer soil model. To cater the problem of low level fault current at the fault location the neutral point of 3-phase local loads has been connected with grounding rods at RE sources location. The idea is to provide least resistance path to fault current which will overcome the effect of FCL in inverter and also provide the protection for semiconductor devices employed in interfacing between RE sources and DT grid. The load neutral point connection with micro grid grounding increases the level of fault current by providing direct least resistance path. This scheme also improve the safety measures for working personal and consumers having connected load on RE buses. The proposed scheme will have the active participation only in islanding mode and will have no affect or remain inactive during grid connected mode. This is happen because during grid connected mode, the grid which considered as infinite voltage bus as compared to RE sources injects very high fault current [17]. The limitation of presented scheme is that it only works for line to ground (L-G) fault and double line to ground fault (LL-G) and does not have any impact during 3-phase symmetrical fault and line to line (L-L) fault. This happens because during three phases symmetrical fault any type of earthing systems whether based on uniform layer or two layer soil model and load neutral point connection have no effect on protective device fault performance. In case of L-L fault the zero sequence current components becomes zero and the proposed schematic will have no impact for this type of fault.

VI CONCLUSION

In this paper the impact of RE sources penetration on DT grid has been presented, specifically the issue related to protection and islanding operation. The islanding detection techniques broadly categorized into 4 schemes namely CAP,

LMP, IPI & CLI. The upper hand and drawbacks of each scheme were also characterized in subsequent section of 3. Further to overcome the main problem of low level of fault current during islanding mode the 3-phase load neutral point connection with grounding wire has been suggested. To provide the least resistance path the grounding of micro grid has been developed by using two layer soil model. The empirical formula has also been developed presented in the paper. The neutral point load connection with grounding sufficiently increases the fault current level during islanding mode and which is more pronoun to initiate the relay control action also load neutral point connection reduces the touch potential at all the RE source buses. The local load earthing not only increase the level of fault current at fault location but also at all the RE buses and consumers. The presented technique is only suitable for single line to ground fault (L-G) and double line to ground fault (LL-G). The proposed technique is simple and also very essential from safety point of view. It serves two purposes primarily the safety for working personnel and consumer and additionally provides a way to detect islanding mode.

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