Improve Protection of Distributed Generation by using Autoground System

M. LAXMI DURGA¹, G. MALLAMMA², M. LAXMAN RAO³

¹PG Scholar, Sri Rama Institute of Technology & Science, Kuppanakunta, Khammam, Telangana, India.  
²Asst Prof, Sri Rama Institute of Technology & Science, Kuppanakunta, Khammam, Telangana, India.  
³Asst Prof, Sri Rama Institute of Technology & Science, Kuppanakunta, Khammam, Telangana, India.

Abstract: Because of the variety of distribution generation (DG) dimensions along with technology linking in order to distribution networks, along with the issues connected with out-of-step iso are shutting, anti-islanding landing has long been a worry in which no apparent solution is present. This particular cardstock offers an automobile terrain approach that had been recommended within the wording of an IEEE working team in guidelines regarding DG safeguard. The prototype process had been constructed making use of common distribution equipment along with a iso are better controller, and yes it had been tested within the utility’s distribution analyze series. Outcomes demonstrate how the anti-islanding detection time is around a routine for a longer time compared to the delay connected with request on the auto terrain. When the auto terrain had been put on, this DG had been shut off in 1 routine in above existing safeguard. The most effective is inherently salable, relevant to everyone DG sorts, is configurable in order to different also are shutting practices along with isn't going to call for more apparatus as well as settings adjustments for the producer’s internet site.

Keywords: Distribution Generation(DG), Autoground System.

I. INTRODUCTION

The integration of distributed generator has grown over the past decade and some utilities have reached very high penetration levels. Despite this experience the debate between utilities and private producers still rages on a number of technical issues. Possibly the most contentious is that of anti-islanding protection, where a reliable high speed communication based transfer-trip scheme and a local passive approach that relies only on the measurement of the voltage waveform represent, respectively, the most conservative and most liberal approaches. The anti-islanding and line protection are the two fundamental protection requirements that need to be met by all distributed generation (DG) installations, as detailed in the DG interconnection standards. Line protection consists of being able to detect all faults on the distribution feeder to which the DG is connected, while not disconnecting for faults on an adjacent feeder. Generally over current relaying is sufficient to meet this requirement, although in power electronic based generators, other strategies may be necessary due to the limited contribution to short circuits by these installations. Anti-islanding has been the subject of a number of studies.

These approaches can be typically divided into the following two classifications: passive approaches (using the local measurements of voltage and current, and variables derived from using these quantities, to delineate between islanding and grid connected operation) and active approaches (whereby the DG perturbs either the grid voltage or frequency, an approach intended to be benign while the grid is present, and to destabilize the system when the substation is open. A third approach is in fact a variant on communication based approaches, whereby using thyristor valves connected to ground, a disturbance is periodically injected at the substation- its presence at the DG’s location indicates a normal condition, whereas its absence is indicative of an islanded grid. Wang et al. have also suggested these thyristor based devices for fault identification in. Similar to active islanding techniques, this approach could be criticized alone on the impact on power quality. Additionally, in noisy grids or feeders that are particularly long, the issue of nuisance tripping is an issue. This paper proposes an approach to anti-islanding protection that is based on applying a three-phase short circuit to the islanded distribution system just prior to reclosing or reenergization. Section II provides the theory and methodology for construction of this utility-owned equipment. Section III presents the experimental set-up and results, and we conclude with a summary of various practical considerations.

A. Anti Islanding System

Islanding refers to the condition in which a distributed generator (DG) continues to power a location even though electrical grid power from the electric utility is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, and it may prevent automatic re-connection of devices. For that reason, distributed generators must detect islanding and immediately stop producing power; this is referred to as anti-islanding. The common example of islanding is a grid supply line that has solar panels attached to it. In the case of a blackout, the solar panels will continue to deliver power as long as irradiance is sufficient. In this case, the supply line becomes an "island" with power surrounded by a "sea" of unpowered lines. For this reason, solar inverters that are designed to supply power to the
grid are generally required to have some sort of automatic anti-islanding circuitry in them. In intentional islanding, the generator disconnects from the grid, and forces the distributed generator to power the local circuit. This is often used as a power backup system for buildings that normally sell their excess power to the grid. Detecting an islanding condition is the subject of considerable research. In general, these can be classified into passive methods, which look for transient events on the grid, and active methods, which probe the grid by sending signals of some sort from the inverter or the grid distribution point. There are also methods that the utility can use to detect the conditions that would cause the inverter-based methods to fail, and deliberately upset those conditions in order to make the inverters switch off. A Sandia Labs Report covers many of these methodologies, both in-use and future developments. These methods are summarized below.

II. RENEWABLE ENERGY

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services. Based on REN21's 2014 report, renewable contributed 19 percent to our global energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively. Both, modern renewable, such as hydro, wind, solar and bio fuels, as well as traditional biomass, contributed in about equal parts to the global energy supply. Worldwide investments in renewable technologies amounted to more than US$214 billion in 2013, with countries like China and the United States heavily investing in wind, hydro, solar and bio fuels.

Fig 1. Wind, solar, and biomass are three emerging renewable sources of energy.

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power. At the national level, at least 30 nations around the world already have renewable energy contributing more than 20 percent of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond. While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development. United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity.

Fig 2. Global public support for different energy sources (2011).

Fig 3. Global energy potential by source.

Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains: Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the
sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

III. THEORY AND METHODOLOGY

A. Introduction

Anti-islanding protection is required of any distributed generator connecting to the distribution network, in order to protect against the case that the DG continues to energize the feeder when the utility has opened—creating an unintentional island. An unintentional island, although rather unlikely in real life, could be created by one of two scenarios. The first case is a result of the inadvertent opening of the substation feeder breaker/recloser or one of the protection devices further down the feeder. This could be done in error or as a planned operation where the utility personnel do not realize that there is a DG present on the line. Eventually the line is re-energized and the risk of out-of-phase reclosing exists, if the DG remains online. The second, even less likely situation would be a temporary fault that leads to operation of the utility protection device but the DG’s protection does not operate before the self-clearing fault extinguishes, creating the temporary island. For example, a tree branch might touch the line and it is cleared at the moment the vacuum bottle interrupter of a recloser operates. Although less likely, the latter of the two cases is generally used to define the anti-islanding requirements, which links the requirement to first period reclosing time of the local utility (2 s is given in IEEE 1547, the typical first operation reclosing time of many North American utilities, although some are as fast as 0.5 s).

This defines the speed at which the DG’s anti-islanding protection must detect the island. The solution proposed in the present work, termed an autoground, is seen as a compromise in terms of cost and performance between the transfer-trip and local passive measurements. Fig5 presents the autoground concept, where the autoground system is installed just downline of the utility protection device (substation breaker or inline recloser). In this configuration, following opening of the utility breaker, the autoground opens the substation side device, denoted sectionalizing switch (SS) and closes the autogrounding switch (AS) effectively applying a three phase to ground fault. All DGs that have not already disconnected Disconnected based on their anti-islanding protection will be forced to disconnect based on line protection.

B. Distribution Apparatus

The autoground framework comprises of three principle parts: the sectionalizing switch; the autoground switch, and the controller, which can be executed utilizing an assortment of recloser or breaker controls. Here we depict each of these parts thus. The SS is obliged just to reflect the condition of the substation breaker. It is desirable over have the SS as a different gadget for switch and ground associations (right), the basic reason that expenses raise when work inside of the substation is needed. Any reserve funds connected with incorporation of the SS capacity into the feeder breaker would be exceeded by the expense of connecting it with the AS. For this situation, it is not needed to intrude on flaw current so any gadget that can give computerized sectionalizer capacities would be adequate. For applications where the autoground is combined with an in-line recloser, the SS is not needed as its usefulness can essentially be coordinated into the recloser itself. Fig. 6 represents the vacuum jug based recloser utilized as a part of the trial set-up as the SS. As the AS is joined in parallel with the dissemination organize just so as to apply the shortcoming, it doesn't have to intrude on deficiency current either.

As a result, the apparatus is even simpler, and was realized by a slight modification to an automated capacitor bank assembly. The same vacuum bottle switches were used but with their secondary connected to the neutral conductor rather than capacitor banks (Fig. 7). In this case, the switches were actuated by relays, controlled by a simple circuit housed at the base of the pole. This circuit was used to integrate outputs from the SEL-351 relay, installed at the base of the SS pole, and used to control both the SS and the AS. The SEL-351 was chosen for the experimental set-up but any relay used for control of distribution protection devices would likely suffice.

Fig 5. Description of the autoground concept.

Fig 4.World energy consumption by source. Renewables accounted for 19% in 2012.
Again, in the case that the inline recloser served also for the SS functionality, its controller would only need to be reprogrammed to output signals for the AS, installed on the adjacent pole. The next section defines the logic required in order to realize the autoground system’s functionality.

**C. Control Logic**

The sequence of events for an action of the autoground is illustrated in Fig. 8. Within this sequence, the control needs to perform three separate functions: coordinate opening of the sectionalizing switch with the upline protection device; application of autogrounding switch for a predetermined duration; and closing of the sectionalizing switch, again
coordinated with the upline device. Implicit is an understanding of the reclosing strategy in place, as the design is meant to respond to the unintentional islanding cases created during a protection device action. Fig. 8 illustrates the connection of the controller to the network and the logic for opening and closing of the sectionalizing switch. It is proposed to detect the opening of the upline protection device using an undercurrent relay. However, detecting a sufficiently small undercurrent on the three phases could not be done directly in the relay logic. Therefore, two alternatives were considered: using the complement of an overcurrent relay [NOT(50)] or convert the current to a voltage and use an undervoltage relay of the resulting signal. The latter was chosen as the 50 does not permit settings of less than 5 A on the medium voltage level (it is configured to measure large currents).

Thus, the output of the CT was connected through an appropriate burden (to convert the current to a voltage signal) to the controller external inputs (Fig. 8). Applying these signals to an undervoltage relays (27) then enables detection of the undercurrent condition. The sequence of events is described here. Upon opening of the upline breaker, an undercurrent is detected on the three phases (defined as 10% of the minimum load current on the line), signaling an opening operation of the SS. Even in the presence of distributed generation, zero current will never occur with the breaker closed, due to the inductive component of the line. Once the logic signal LT9 returns to zero (representing opening of the autoground switch, see Fig. 9) the sectionalizing switch can be reclosed, either upon presence of voltage or by a manual close operation. In the experimental set-up, the manual close was replaced simply by a counter, corresponding to just before the reclosing operation. Finally, the autogrounding switch is controlled by two logic circuits that then output the closing and opening pulses to two of the outputs, Fig. 10. These outputs are connected to the actuation circuit, installed at the base of the AS on the adjacent pole.

As can be noted, the trip signal from the SS causes LT9 to change state, initiating a number of delayed step functions (SV3, SV4, SV8, and SV10). The combination of these steps through two flip-flops leads to two pulses of 30 cycles, at 100 and 600 cycles (1.67 and 10 s) from the opening of the upline breaker. These two pulses are respectively used to close and open the AS. Obviously, each of these times is configurable in order to be compatible with the utility’s reclosing practices and the disconnection time of the different DGs. The application time of the autoground, must be compatible with the fault detection time of all DGs for a bolted fault (symmetrical or asymmetrical) at the autoground’s location. For example, if the protection study demonstrates that the DG will trip within 6 cycles for this case, must be longer than these 6 cycles. Otherwise, some form of voltage check must be integrated into the logic to ensure that all DGs have indeed disconnected prior to removal of the autoground.

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**D. Other Considerations**

The previous section detailed the realization of the autoground system; however, there are a number of considerations prior to integration into a particular utility’s system. We discuss some of the most important ones here. The autoground system is there to serve as back-up anti-islanding protection to the DG’s passive settings; however, first and foremost it needs to be compatible with the distribution protection practices already in place. Logically, application of the autoground is only required for the first reclosing period, as the DG is required to remain disconnected for 5 min after tripping. However, if different reclosing times are used and it is decided to apply the autoground during each period, the delays within the above logic need to be compatible with each of the reclosing periods. An autoground will be installed at each protection device (substation breaker, recloser) that is upline of the furthest DG along the feeder. For example, the DG might be installed down line of two in-line reclosers, requiring three autogrounds (one for the substation breaker, and one for each recloser). In certain cases, if possible, it may be preferable to have a device moved in order to simplify coordination and limit the number of autoground systems that need to be installed. With regards to the autoground itself, the vacuum bottle switches are very reliable (rated for 1200 operations) but the design still needs to handle the case that it may fail to open.

This problem is taken care of by the selection of an appropriately rated fuse that would clear the phase that failed to operate upon reclosing of the system. Subsequent operation of the autoground would then apply an asymmetrical fault, until the issue was identified and the fuse replaced. The selection of the fuses must be done in order to coordinate with the substation protection so that the fuse would blow before the substation protection operates. The time for which the autoground is applied, needs to take into account the line protection tripping time for all DGs. Additionally, the fuses need to be appropriate selected so that the fuses will not blow when the fault is fed from the DGs. Obviously if a DG remains online until the operation of the autoground, it will be subjected to a fault and the resulting electromechanical stresses. This could be met with resistance from the DG proponent; however there are two arguments to address this issue. The first is that the application of the autoground can be timed to be towards the end of the reclosing period, providing ample time for the DG to detect the islanding condition and disconnect. Secondly, the DG needs to be designed in order to handle these types of fault anyways so it is a bit of a non-issue, although the frequency of faults may be slightly increased.

**IV. SIMULATION AND RESULTS**

The testing was conducted on IREQ’s distribution test line, configured according to Fig. 11. The autoground system was installed at the end of the first feeder. The synchronous generator was connected to the second feeder through a 600 V/25 kV transformer, as indicated. The parameters of the synchronous generator and the overcurrent protection are provided in the Appendix. Switches on feeders 2 and 3 were
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opened in order to feed them both from feeder 1. The testing consisted of first synchronizing the generator, balancing its output power with the 150 kW load and then initiate opening of the SS for three different configurations of the autoground: with all three fuses in service; with one fuse removed; and with two of the three fuses removed. Synchronized data was acquired using the LX-TEAC data acquisition system, monitoring the following parameters: three-phase currents and voltages at 25 kV (point 1), 600 V (point 2) and the generator torque (point 3). Additionally, measurement of the ground voltage at 1 m, 5 m and 75 m (taken to be the zero reference) was performed in order to investigate the earth voltage rise during operation of each of the cases.

![Diagram](image-url)

Fig.11. IREQ distribution test line configuration for autoground testing.

Table I. Results for Symmetrical and Asymmetrical Operation of the Autoground

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Peak Current at 600 V [A]</th>
<th>Step voltage at 1 m [V]</th>
<th>Neutral current [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase</td>
<td>3500</td>
<td>0.729</td>
<td>92</td>
</tr>
<tr>
<td>Two-phase</td>
<td>3900</td>
<td>3.608</td>
<td>394</td>
</tr>
<tr>
<td>Single-phase</td>
<td>4100</td>
<td>3.438</td>
<td>856</td>
</tr>
</tbody>
</table>

V. RESULTS

The results for the three cases are summarized in Table 1. The magnitudes of the peak current (which includes the DC component) are given, along with step voltage measured at 1 meter, and the neutral current. Torque measurements were taken but they are not presented as the reading saturated in each case at 45 N m. As can be noted, the magnitude of the phase current is roughly equivalent for the three cases; however, the neutral current is much higher, as expected, for the unbalanced autoground cases. This is reflected in the step voltage measurement, showing that it is around 3.5 volts for the unbalanced cases. Compared with the limit of 174 volts for wet soil defined by the Electrical Code, the measured value represents no issue. Figs. 12–15 illustrate the case for balanced operation of the autoground, that is, with the three fuses in operation. The SS is opened at roughly 14.2 s and the AS is closed 100 cycles later (1.67 s) (Fig. 12). As can be noted, there is little change in the magnitudes of the voltages and currents of the synchronous generator due to the fact that load and generation are well balanced (Fig. 12).

![Graph](image-url)

Fig.12. Substation voltages (top) and currents (bottom) during opening of SS and application of the AS.

![Graph](image-url)

Fig. 13. Current waveforms of the synchronous generator during application of the autoground.

![Graph](image-url)

Fig.14. Three phase voltages (top) and currents (bottom) of synchronous generator during opening of SS and application of the autoground.
The application of the autoground provokes a fault current between 10 and 20 times the generator’s prefault value, leading to isolation of the generator within a cycle, Fig. 13. Given that the generator is installed right next to the autogrounding system, this represents the worst case in terms of stress on the machine. This fault current induced a small signal on the substation current measurement, which can be noted in Fig. 12. In terms of the stress on the generator, it is clear that the fault current translates to a large instantaneous torque, as can be observed in Fig. 6.5. As mentioned, the torque measurement saturated in the three cases, but the negative swing is of the order of 2.5 per unit (from 1 pu to pu). This suggests that the peak instantaneous torque would be around 3.5 pu, assuming symmetry about the 1 pu value. Although the risk of damage to the generator may appear significant, it can be managed through various approaches.

![Graph showing Torque measurement on the synchronous generator shaft during test](image)

Fig. 15. Torque measurement on the synchronous generator shaft during test (expressed on the base of the real power prior to the islanding event).

### Table II: Synchronous Generator Parameters

<table>
<thead>
<tr>
<th>$S_G$ (kVA)</th>
<th>$P_G$ (kW)</th>
<th>$V_G$ (V)</th>
<th>$I_G$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>200</td>
<td>600</td>
<td>240</td>
</tr>
</tbody>
</table>

1 – The synchronous generator is in reality rated at 750 kVA but it is driven by a 200 kW motor, thus the reason for its derated value of 250 kVA. The larger generator translates to a reduced $X_s$, allowing generation of larger fault currents for testing purposes.

Firstly, the magnitude of the fault current—and consequently the shaft torque—can be reduced by introducing an impedance between the generator and the autoground. This could be achieved by either not installing synchronous generator based distributed generators directly at the autoground site (thereby introducing the impedance of the line), or by incorporating an impedance into the autoground system, such as connecting the output of the vacuum bottle switch to the neutral through a transformer. Secondly, the risk can be reduced statistically by lengthening the delay associated with application of the AS to just prior to reclosing. We have selected 1.67 s, in part to coincide with the IEEE 1547 requirement of 2 s for anti-islanding detection. Opening of the AS should correspond to the reclosing time (at Hydro-Québec 10 seconds is used for systems with DG). By selecting a delay that is just prior to reclosing would provide the DG with the maximum time for islanding detection, through its passive settings. Thus, in the Hydro-Québec system, an autogrounding closing time at 9.5 s instead of 1.67 s, would greatly limit the cases where the DG is still online when the autoground is operated.

### V. Conclusion

This paper has conferred a climbable, low price approach for anti-islanding protection of distributed generation, employing a utility closely-held associated operated system remarked as an autoground. The planning of the system and its management were conferred and a epitome system was created victimisation commonplace distribution utility instrumentation. Testing results were conferred for symmetrical and asymmetrical operation of the system. Altogether cases, the DG’s over current protection isolated the generator from the system in but 2 cycles. The height force determined exceeded momentarily around four times the pre-fault price. The results valid the thought for one generator supported a synchronous machine, whereas future work can study its pertinence to systems with massive numbers of decigram, as well as those with power electronic interfaces. The answer shows promise as a result of its comparatively low price and inherent quantifiability

### VI. References


**Author’s Profiles:**

**M. Laxmi Durga** received B.Tech degree in Electrical and Electronics Engineering from JNTU, Hyderabad, T.S. And currently pursuing M.Tech in Electrical Power Systems at Sri Rama Institute of Technology & Science, Kuppenakuntla, Khammam, T.S. My areas of interest are Power Systems, and Power Electronics, Electrical Machines.

**M. Laxman Rao,** presently working as Assistant Professor & Head of the Department in Sri Rama Institute Of Technology & Science, Kuppenakuntla, Khammam, Telangana, India. He received his B.Tech degree in Electrical & Electronics Engineering from JNTU, Hyderabad. And then completed his P.G in Electrical & Electronics Engineering, specialization in Power Electronics & Electrical Drives at JNTUH Hyderabad, He has a teaching experience of 7 years. He installed and supervised a Bloom Energy box of generating capacity 200W and also researched area includes Non-conventional energy systems and Power systems. His areas of interest are Power Semiconductor devices and the application of power electronics in power systems.

**G. Mallamma,** presently working as Assistant Professor in Sri Rama Institute of Technology & Science, Kuppenakuntla, Khammam,TS, India. She received her B.Tech degree in Electrical & Electronics Engineering from JNTU, Hyderabad. And then completed her P.G in Electrical & Electronics Engineering, specialization in Power Electronics at JNTUH Hyderabad, She has a teaching experience of 5 years. She installed and supervised a Bloom Energy box of generating capacity 200W and also researched area includes Non-conventional energy systems and Power systems. His areas of interest are Power electronics, Electrical Circuits and the application of power electronics in power systems.

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