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Ideal Scheme of Protection in Micro-Grid System

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Abstract

This review establishes two major protection issues that must be dealt with to ensure stable operation of a Micro grid during any contingency. To determine at what instant the Micro grid should be islanded under a specific contingency To sectionalize the stand-alone Micro grid and provide the sections with sufficiently co-ordinate fault protection. Although the characteristics and performance of most protection elements of a Micro grid are consistent with those present in the utility distribution systems, it is not the same for the micro source power electronic inverter systems because of the following reasons. Characteristics of inverters may not be consistent with the existing conventional protection equipment. Various inverters have various constants and they do not have any uniform flexibity, which would identify the inverters as a class of equipment.

Keywords: Micro grid, Central unit controller.

Contents

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1. Introduction

The major problem obtained by the inverter units is its low-fault current capacity capability. It ranges as 50% of the rated current, with specifically designed to provide a high fault current. This drastically reduces the fault current available from the micro sources in comparison to utility generators. If a significant number of micro sources have power electronic inverter interfaces, then the transition from grid-connected to stand-alone operation results in a marked reduction in Micro grid fault level. This affects the sensitivity and operation of the over current relays in the system. The relays are kept for high current process grid operation, then according to operation it will operate slowly and also standstill condition. Protection issues for Micro grids cannot be properly resolved without a thorough understanding of Micro grid dynamics before, during and after islanding. Also, time of islanding the Micro grid should be preceded by a realistic assessment of what benefits the Micro grid will gain from rapid separation.

Although the equipment standard suggests that manufacturers would benefit from shorter separation times of less than 50 ms after the occurrence of any contingency in the utility, such times cannot be realized with currently available protective devices. If very high speed of separation is required and spurious trips are to be avoided at the same time, then transfer trip mechanisms should be installed between the utility grid sub-station and the PCC circuit breaker. Installation of high-speed communication channels between utility and Micro grid would also help in rapid islanding during non-fault conditions. For secure and reliable operation of the stand-alone Micro grid, the protection system should ensure the following:

(1) Appropriate grounding must be provided for stand-alone Micro grid.

(2) Fault detection devices in Micro grid must work in compliance with the fault detection system in the grid-connected mode.

(3) The fault detection does not dependent on a maximum ratio of variation between fault current and maximum load current, it assists to visualize the islanding operation.

(4) Any existing anti-islanding schemes should be examined and modified if necessary, to prevent instability or undesirable loss of micro sources with sensitive settings.

(5) Any load shedding scheme set up by the utility in the Micro grid area must be closely co-ordinate.

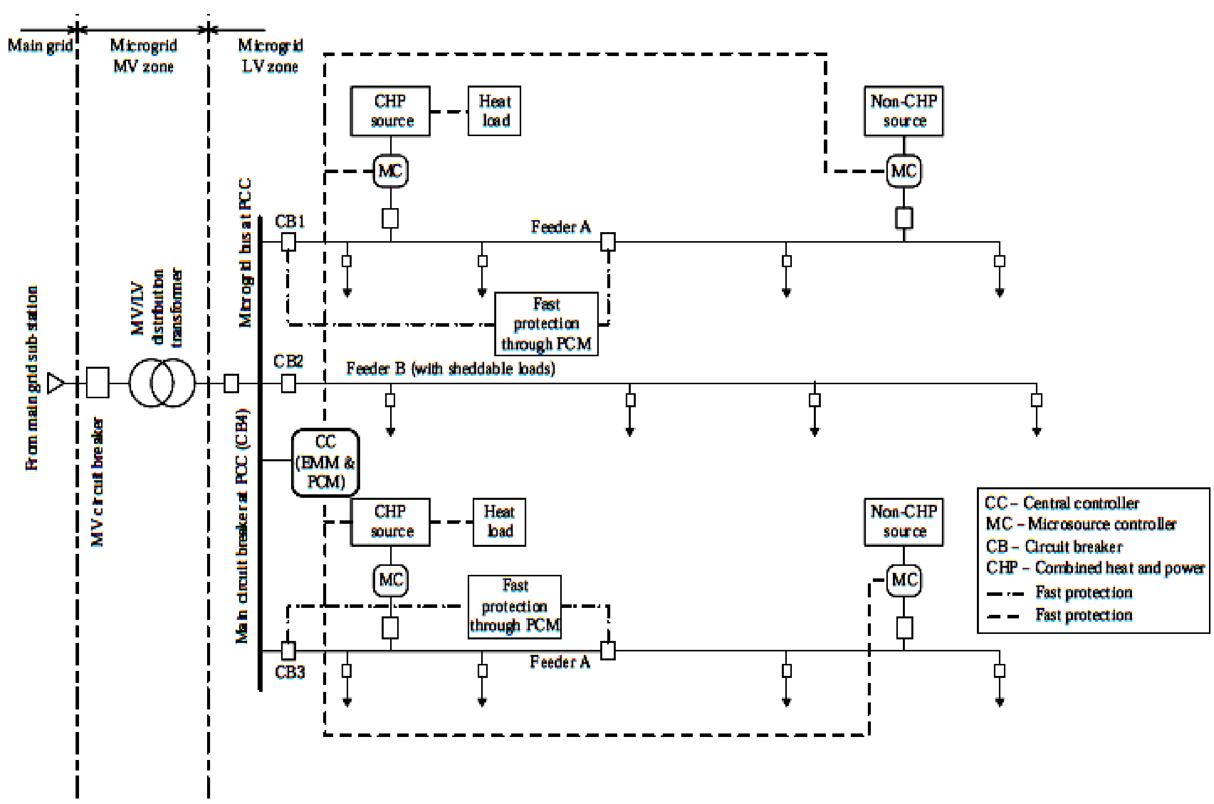

Figure-1. Ideal Protection Scheme in Micro grid system

2. Islanding: Segregation from Utility

Micro grids normally have a capacity less than 10 MVA that is very small compared to the utility. Micro grids must have sufficient generation to supply a significant portion of its load. If islanding does not occur at the PCC, then the Micro grid may carry a part of the utility with it. In this matter IEEE standards suggest minimum interconnection protection criteria, which a Micro grid should meet during grid connected operation. Cost of implementation and technical limitations are important for designing protection schemes for Micro grids. Following issues should be duly considered for islanding of the Micro grid:

3. Various Islanding Methodology

3.1. Fast Separation from a Faulted Feeder

One major service provided by Micro grid is uninterrupted power supply to priority loads during any outage. Basically, the secure relay time is to detect an under- or over-voltage and it is set up to two cycles with a medium voltage (MV) breaker which requires three to five cycles to valuate and trip the signal. Therefore, if the Micro grid does not have a very fast acting solid-state circuit breaker at PCC, other means must be adopted to prevent the voltage from falling below 50% for three cycles or longer. The design consideration is never provided.

3.1.1. Without Partition

Microgrids can also generate revenue for constituent consumers and businesses by selling the Microgrid power back to the grid/utility when not islanded. The ancillary services they can sell could include demand response, real-time price response, day-ahead price response, voltage support, capacity support and spinning reserve, etc. In such cases, one option of preventing sags is to install electronic sag correctors or replacing the Y–Y connected transformer at PCC with D–Y connected transformer and adding a high voltage side breaker. For single phase-to-ground faults in the utility, D–Y transformer would ensure that the phase-to-ground voltage in the Micro grid does not drop below 58%. These two options demonstrate how protection considerations and design options must be considered together in developing economic Micro grids. Sag protection are much more costlier to install.

3.1.2. Segmentation is Necessary

When a fault occurs on its main incoming feeder at the PCC, the Micro grid must separate itself from the utility. The fault point is ‘upstream’ to the PCC breaker CB4 as indicated. due to the infancy of the Microgrid concept and deployment there is limited information on the true total cost of operation for Microgrids and the associated payback periods. It also notes that the business case for Microgrid deployment is difficult since they can be of different sizes, varying geographic footprints and involve so many different types of devices.

3.2. Spurious Separations

From operation point of view, maintaining a tie between the Micro grid and the utility is highly desirable. But if fault occurs on the tie, then the Micro grid should be separated from the utility using fast tripping devices as per SEMI F47 requirements. Currently, the only reliable method of fast tripping the PCC breaker is to have a transfer trip from the utility grid sub-station breaker. False tripping problems may arise not only from electromechanical relays and breakers but also from the sophisticated microprocessor-based protection packages acting solely on information available at the PCC.

(1) If Micro grids are to shed non-priority load upon islanding, then allowing spurious separation may cause unwarranted outages to these loads.

(2) For exporting Micro grids, spurious separations would lead to loss of revenue and a period of over frequency operation while the Micro grid frequency stabilizes. Hence, current Microgrids are viewed as expensive because they require newly developed advanced power electronics and sophisticated coordination among different customers or areas that are still in their infancy.

3.3. Partition in Non-Fault Conditions

Low voltages (LVs) rises in non-faulty condition. Therefore, whether an LV condition is associated with a fault between the PCC and the utility substation may be difficult to ascertain without a high-speed communication between the Micro grid and the utility controllers. For under-voltage, it is generally desirable for the Micro grid and the utility to stay connected, while the latter tries to eliminate the LV, provided it is not caused by any fault that requires tripping at the PCC. The Micro grid and the utility may also negotiate a trip control to co-ordinate with the voltage limits for balanced voltage conditions as specified by the SEMI F47. The Microgrid concept also reflects a new way of thinking about designing and building smart grids.

Specifically, the Microgrid concept focuses on creating a design and plan for local power delivery that meets exact needs of the constituents being served. The Microgrids efficiently and economically integrate customers and buildings with electricity distribution and generation – and energy distribution such as heat – again at a local level.Although such trip restraint can be designed using the currently available devices, but still the under-voltage trip setting would be finally determined by operational restraints of Micro grids, viz. voltage sensitivity of loads and the ability of the Micro grid to recover from the LV condition after tripping.

The under-voltage tolerance limit for the Micro grid (i.e. voltage setting under which the Micro grid will island itself) depends on factors like transformer connections and grounding points within the Micro grid. The sensitivity to voltage unbalance of loads, micro sources and other distribution equipment should be considered to determine the criteria for establishing the under voltage tolerance limit. For voltage unbalances, however, it becomes difficult to ascertain whether their cause lies within the Micro grid or is external to it.

3.4. Partition of Exporting Micro Grids

Exporting Micro grids are not in a position to use simple reverse power relays to determine utility contingency conditions. Also, simple over-/under-voltage relaying schemes may not ensure tripping for utility faults as the exporting Micro grid itself has adequate generation capacity. As an exporting Micro grid contains excess generation than its maximum load, its impedance ratio is much closer to that of the utility. This is a major difference between an exporting Micro grid and an importing (or non-exporting) one. Hence, the voltage division in exporting Micro grids during fault is considerably different from that in grid-connected importing Micro grids. Implementing an exporting Micro grid would require a major redesign of the protection and control systems as compared to conventional protection practices suitable for importing Micro grids connected to secondary or spot networks. Manufacturers of network-protection systems and devices are putting in substantial effort in developing equipment suitable for protection/control of exporting Micro grids.

3.5. Re-Circular Operation

Relay and control schemes are generally used for re-synchronizing a conventional synchronous generator either manually or automatically and for re-synchronizing a power electronic inverter-interfaced micro source automatically. If the Micro grid contains only a single micro source, then the choice for manual or automatic re-synchronization will depend largely on the skills and availability of operator. But, if multiple micro sources are there at various locations, then automatic re-synchronizing schemes should be incorporated in PCM design. PCM may also include other refined controls like delayed re-synchronizing during storm conditions, where disturbances may be frequent, and communication facilities with at least the larger micro sources.

4. Major Protection Issues of Stand-Alone Micro Grid

When a Micro grid operates in the stand-alone mode, the protection considerations become significantly different from those for the grid-connected condition. This section discusses four main protection considerations, assuming a proper separation of the Micro grid at the PCC, which are as follows:

(1) Distribution system fault protecting system.
(2) Protection of micro sources
(3) National Electric Code (NEC) is applicable and required for the distribution systems
(4) Neutral grounding necessity is needed.

4.1. Micro Grid Distribution System Protection

4.1.1. Micro Grid Value Protection System

The faults rises in MV region (i.e. the utility side) of the Micro grid can be easily cleared just by tripping all the micro sources. However, before developing any protection scheme for MV zone, the probable impacts of MV faults on Micro grid operation must be carefully studied. Moreover, it should also be decided whether at all to go for selective isolation of MV faults and keep the rest of the Micro grid operating, particularly if the fault is a second contingency. Designating the fault as a second contingency implies that the first contingency has already occurred and has resulted in separation of the Micro grid and that the MV fault is only a second contingency in the stand-alone Micro grid. Assuming the Micro grid to be a typical on-site active LV distribution system, the only MV protective devices it would include are the distribution transformer fuses on the MV/LV transformer connecting it to the utility

. Thus, with extremely inverse time–current characteristics, the distribution transformer fuses will be extremely slower to operate for such faults and it would be very difficult to co-ordinate them with micro source protection. Under this condition, there are only two choices: (i) to accept that an MV fault within a Micro grid would lead to a total Micro grid outage or (ii) to install additional protective devices to the MV system that is properly co-ordinate with the micro source protection systems under stand-alone condition.

4.1.2. Fault Detection under Low Voltage

The maximum fault and load current is protected generally. They are usually time–current co-ordinate with one another so that the device closest to the fault operates firstFrom the electric grid's perspective, the primary advantage of a Microgrid is that it can operate as a single collective load within the power system. Customers benefit from the quality of power produced and the enhanced reliability versus relying solely on the grid for power. Distributed power production using smaller generating systems – such as small-scale combined heat and power (CHP), small-scale renewable energy resources can yield energy efficiency and therefore environmental advantages over large, central generation Time-graded coordination takes the advantage of the natural falling off of fault current as the fault moves away from the source of generation. The falling off depends on the magnitude of impedance of lines/transformers between the generation point and the fault point. For MV and LV distribution networks, inverse-time over current (51) and high-set instantaneous over current.

The key capability and feature of a Microgrid is its ability to island itself (i.e., separate and isolate itself) from a utility's distribution system during brownouts and blackouts.. Production under fault studies in infinite bus. One major problem is that the stand-alone Micro grid is not likely to appear as an infinite bus on the MV side of the MV/LV transformer and the apparent impedance of the Micro grid source may be much greater than that of the transformer. In and around fault current change will into the LV side of the system over the MV zone. Thus, in over current co-ordinate protection schemes as described in the preceding text, transition of a Micro grid from grid-connected to stand-alone mode may slow down fault clearing and limit backup protection. Overall these effects depend on:

(1) Whether the time-impedance characteristics of the micro sources exhibit sub-transient, transient and/or synchronous time effects.
(2) The value of pickup setting of the high-set instantaneous over current relay with respect to the maximum fault current available from Micro grid.
(3) How much inverse the time–current characteristic of the relays is in the region of fault currents provided by the Micro grid.

4.1.3. Presence of Dispersed DERs in a Micro Grid

The impact of having dispersed DERs on Micro grid protection system must be compared with that of having a central Micro grid generation facility. If the Micro grid has dispersed generation arranged in the form of a quasi network (i.e. if there is no central generation located at the Micro grid bus at PCC), the changes in fault protection scheme must consider not only the reduction in fault current (typical of a stand-alone Micro grid) but also the chances of bidirectional fault current flow in some feeders. A Microgrid is any small or local electric power system that is independent of the bulk electric power network. For example, it can be a combined heat and power system based on a natural gas combustion engine (which cogenerates electricity and hot water or steam from water used to cool the natural gas turbine), or diesel generators, renewable energy, or fuel cells.

A Microgrid can be used to serve the electricity needs of data centers, colleges, hospitals, factories, military bases, or entire communities. Hence, high-speed communication between the PCM and all Micro grid circuit breakers is the only reliable way to achieve selective tripping.

4.2. Protection of Micro Sources

The design of a reliable micro source protection scheme should consider the following issues and extensive dynamic simulation studies should be carried out to address them:
(1) Deciding acceptable voltage and frequency protection tolerances for a standalone Micro grid.
(2) Assessing whether there is any need for the anti-islanding protection of DERs and if such protection exists, how it may be disabled or overridden while the Micro grid is operating in the stand-alone mode.
(3) Examining whether the existing anti-islanding techniques may lead to voltage and/or frequency instability if used in a stand-alone Micro grid.
(4) Assessing the needs for an under-frequency load shedding scheme for Micro grid's own reliability and co-coordinating it with the same scheme of the utility.

4.2.1. Change in Voltage and Frequency in Microgrid

The tolerance range during the stand-alone Micro grid operation seems desirable for stand-alone Micro grid with low generation capacity, its impact on the safety of existing equipment must be carefully studied before actually implementing the change. These are the originally set which protects boundaries for preventing damage to the connected equipment, then it is not be changed.. Moreover, this change should be effected only through the intelligent Micro grid central controller (CC).

4.2.2. In-Islanding

Whether there is any need for the anti-islanding protection for the micro sources or whether the anti-islanding controls on their power electronic interfaces should be disabled can only be decided by carrying out extensive dynamic simulation studies. In general, it is desirable to deactivate these controls, unless the ratio of utility generation to micro source generation is too high. The Micro grid will be in islanding operation. As most ant islanding controls cause very fast tripping, it might be necessary to have these deactivated instantly on the detection of forming an isolated Micro grid. The most reliable way for achieving this would be to transmit a blocking signal from the Micro grid CC to deactivate the anti-islanding trip signal.

4.2.3. Load Sharing Management

This system is deals with local or system-wide overload conditions which valued its faults along with the equipment failures. This is done through load shedding and demand side management schemes designed to stabilize system voltage and frequency during disturbances. To have the switching flexibility, the utilities provide the non-critical customers with more favorable rates as incentives. Once an agreement is drawn up between the utility and the customer regarding load shedding, the utilities trip these loads rapidly but selectively through their load shedding systems just to restore supply–demand balance by demand side management. The loss of generation or ties is usually characterized by system under frequency.

4.3.3. NEC Protection Schemes

Before designing any protection scheme for the MV/LV distribution transformer, it should be carefully checked whether the NEC transformer over current protection requirements would suit Micro grids with much lower fault current capacity. As per Article 450 of the NEC, over current protection for transformer can be set as high as 600% of the transformer rating. The NEC attempted to short circuit in maximum load current ratio values. But depending on the location and rating of transformers and the low-fault current capacity of the stand-alone Micro grid, transformer protection system may not pick up faults at all with a high setting and may leave the transformers practically unprotected against short circuits.

5. Requirement of Neutral Grounding

The neutral grounding system for a Micro grid must ensure effective fault protection, insulation integrity and safety under the islanded or stand-alone mode of operation. The design and development of Micro grid grounding system should consider the following issues:
(1) How to provide an effective neutral grounding for the MV system in a standalone Micro grid when the MV/LV distribution transformer is D–Y connected.
(2) Neutral Grounding in MV/LV.
(3) How to maintain compatibility between grounding of the MV system within the Micro grid and that of the utility feeder supplying the Micro grid.
(4) Whether the grounding system for the Micro grid complies with the grounding requirements of the existing DER installations. The design of Micro grid grounding system requires a thorough knowledge of the impact of different distribution transformer connections on the effectiveness and suitability of grounding system.

6. Interconnecting Transformer in Alternative Connection

Most power utilities have Y-grounded/Y-grounded connected step-down distribution transformers on their MV multi-grounded Y-connected distribution networks. Although, this connection provides several advantages for supplying conventional customer loads, but it may lead to certain problems in the operation of a Micro grid with interconnected micro sources. For Micro grids, other connections like grounded Y–D or D–D should rather be considered.

6.1. Ground Relay Strength

Relays, recloses and fuses connected serially along the distribution circuit should be co-ordinate such that farther a device is from the fault, more will be its tripping time. For a micro source, fault tripping should take place in the following sequence (arranged from lower to higher tripping times): LV breaker or contactor of the micro source → Fuse of reclose just upstream to the micro source breakerMain PCC circuit breaker of the Microgrid→Device at the MV side of the distribution transformer → Circuit breaker at utility sub-station This implies that the operating times for the extreme upstream devices may be quite high for certain faults.

As previously discussed, the protective devices in the Micro grid may not face any co-ordination problem for three-phase, phase-to-phase and solid phase-to-ground faults in grid-connected mode.

This is because the ratio of phase fault current to load current would be very high in those cases. Microgrid's power system and whether there should be a single point of common coupling with the main grid or multiple coupling points. However, for the "islanding" concept to work the Microgrid needs to have the ability to be isolated from the main grid either by a single or multiple disconnection points In this case, the Y–D transformers have an advantage over the Y–Y ones, as they are able to isolate the zero sequence circuits. The Y–D transformer zero sequence current will not flow in the feeder for faults on the LV micro source system. Thus, the MV ground fault relays may be set with a lower pickup current for faster operation since they need not co-ordinate with the ground relays of the micro sources.

7. Conclusion

Protection requirements for a Micro grid are quite different from those of conventional distribution systems and conventional DER installations. Two protective methods in Microgrid (i) the interconnection requirements imposed by the utility or specified by appropriate technical standards and (ii) the requirement of separating from the utility in time to maintain the desired power quality and reliability within the Micro grid. These two criteria is tolerate to each other.

Reliable operation of the Micro grid protection system requires sufficient fault current capacity of the stand-alone Micro grid so that all the over current devices within the Micro grid get a fault current magnitude at least three to five times more than the maximum load current.. This can be achieved only if the Micro grid contains a large percentage of synchronous generation or inverters with high fault current delivery capability. For too low-fault currents, new protection schemes that are not based on over current sensing must be developed and installed, in spite of some uncertainty regarding their cost effectiveness and efficiency. High speed of operation of the protective devices is very crucial to reliable operation of the Micro grid protection system.

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