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The challenges of protection for Microgrid

SUCHETA CHATTERJEE, MAYANK AGARWAL, DEBOJYOTI SEN[2]

Assistant Professor, EN Dept, IMS Engineering College, Ghaziabad[2]

Abstract: Since the late 1970s, intensive efforts have been made to utilise renewable energy sources, such as wind, hydro, solar and tidal. However, the application of individual distributed generators can cause as many problems as it may solve. A better way to realise the emerging potential of distributed generation is to take a system approach that views generation and associated loads as a subsystem or a microgrid. Microgrids are, in fact, modern, small-scale versions of the centralised electricity system. They use distributed energy, which shortens the distance between power source and load, reducing transmission loss. They use renewable energy sources, greatly decreasing carbon emissions. They use energy storage, increasing power supply reliability. They are controlled by power electronic devices, so power sources can vary supply according to demand. Plug-and-play power sources and loads make for a more user-friendly grid. And thanks to real-time monitoring and control technology, every disturbance on a microgrid can be detected and adjusted. In fact, generation and loads can be isolated, keeping a high level of service without harming the grid's integrity.

I. INTRODUCTION

In recent years, all eyes in the energy business have been turning to microgrids, smaller versions of centralised systems that can connect to the main grid or act alone as an island. Researchers are looking to microgrids for answers to changing con- sumer demands and a need for increased reliability. Take the example of Japan. There, energy sources are in short supply, and researchers are paying particular attention to renewable energy, focusing on microgrid energy control and storage. In Europe, power sources and loads are much closer to each other, and researchers are looking closely at intercon- necting microgrids into smart grids. There is also research on microgrids in Canada, Australia, China and many other countries, for different power grid situations and different demands.But why, exactly, are people so interested in them? Clearly, a system based on distributed energy could improve reliability and provide service differentiation. However, connecting distributed energy sources to the existing networks does not magically provide the benefits promised and can even have an adverse impact on power quality with, for example, power fluctuations associated with renewable energy sources. Microgrids, however, offer an efficient energy delivery and supply system – based on collocating distributed energy sources and loads – that can operate independently in case of outages or energy crises. According to Dr Zhiqian Bo, China Research Manager, "The concept of microgrids actu- ally varies from country to country, but they all share some common elements. They have distributed energy sources (DER), renewable generation, bi-directional power flow, energy control, and power electronic devices. They offer a number of benefits, making them very 'smart grids'. They do, however, raise a number of challenges, among them the issue of protection."

II. PROTECTION ISSUES IN MICRO GRID

Fault currents for grid connected and islanded operation of micro grid are different. The short circuit power varies significantly. Faults also causes loss of sensitivity, over current, earth leakage, disconnection of generators, islanding, reducing reach of over current relays, single phase connections and loss of stability .Depending upon location of faults with respect to distributed generators and existing protection equipment, problems like bidirectional power flow and change in voltage profile occurs. The power output of distributed generators like synchronous generators, induction generators and inverter interfaced protection units is unpredictable due to which whenever there is a fault, power output of these DG sources changes .Modification in fault current level, device discrimination, reduction in reach of impedance relays, reverse power flow, sympathetic tripping, islanding, single phase connection, selectivity are the key protection issues.

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1 Modification in fault current level

When large number of small distributed generation units that uses synchronous or induction generator units are connected to distribution network or grid it changes fault current level as both types of generators contribute towards fault currents. When inverter interfaced DG units are used, fault current is limited to a lower value . As fault current is not high as compared to load current, some of the relays do not trip, others that respond to fault operate with the time delay. The undetected fault spreads out in the system and can damage the equipment .

Fault impedance also decreases when DG is connected into network in parallel with the other devices. When faults occurs downstream of the point of common coupling, both the main source and DG contributes fault current. Relay placed at upstream of DG measure fault current supplied by upstream source. In below figure the relay placed at the upstream of DG measure the fault current supplied by upstream source. Actual fault current is different, relays will not function properly and there will be coordination problems. If there is short circuit fault, when DG is integrated with the main grid it will affect the amplitude, direction and duration of fault currents.

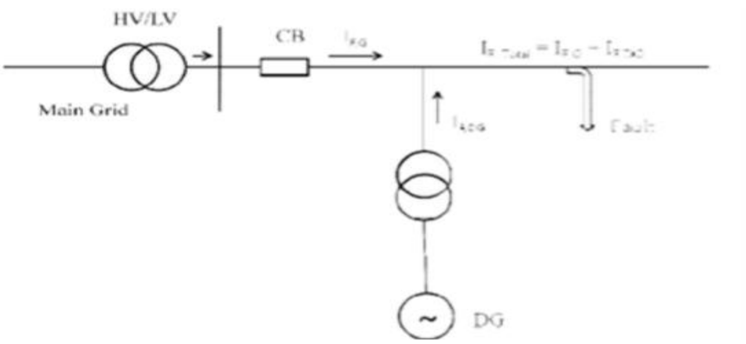

Fig 1: Fault Current contribution from DG and Grid

(Source: Dynamic modeling of hybrid micro Grid by Lin Ye)

2 Device discrimination

In the power system network that has generation sources at the end of network, fault current decreases with increase in distance as the impedance increases. The variation in magnitude of fault current is used for discrimination. In case of islanded micro grid with inverter interfaced distributed generation units , fault is limited to a lower value ,fault level at the locations of feeder will be almost constant .The traditional current protection scheme which uses the variation in magnitude of fault current for discrimination does not work properly. New protection system for device protection is required.

3 Reduction in reach of Impedance relays

The reach of impedance relay depends upon the distance between the relay location and fault point , maximum distance means minimum fault current that is detected . When DG is according to defined zone settings. When faults occurs downstream of the bus DG connected to utility network, impedance measured by relay located in upstream is higher than real fault impedance. This affects grading of relays and causes delayed operation or sometimes relay does not operate at all.

4 Reverse Power flow

Main challenge for protecting the micro grid arises because power can flow in both the directions in each feeder of micro grid. Sources are located in both sides of load due to which power flows in opposite direction from two sources towards the load. Power flow also changes its direction in case of distribution network with embedded generation when local generation exceeds local consumption . The reverse power flow can also cause power quality problems resulting in variation of voltage.

5 Sympathetic Tripping

This occurs when protective device operates for faults in an outside protective zone. DG contributes towards the fault; relay operates along with another relay which actually sees the fault resulting in malfunctioning of protective scheme.

6 Islanding

The DG creates a problem when part of distributed network with DG unit is islanded. Islanding is due to fault in the network. If generator continues to supply power despite the disconnection of utility, fault might persist as fault is fed by DG . If the control for the voltage is not provided, it results in unexpected rise in voltage levels in case of islanded operation.

7 Single phase connection

Some DG sources inject single phase power into the distribution grid, for example PV systems. This affects balance of three phase currents, due to unbalance current in the neutral conductor increases which also results in flow of stray currents to earth. This current should be limited to prevent overloading.

8 Selectivity

Protection system is said to be selective if the protection device closest to the fault operates to remove the faulty Section. Without DG, there is power flow in only one direction, during normal operation as well as when there is fault, by using time graded over current relays selectivity can be obtained .When DG is integrated with the grid ,this systems becomes inadequate. There is possibility of disconnection of healthy feeder by its own protective relay because it contributes to the short circuit current flowing through fault in the neighboring feeder. The tripping current for electrical protective device is between maximum load current and minimum fault current. Fault current and load current depends upon the state of grid, state of distributed generators and whether micro grid is operating in islanded mode .

The main challenge for protecting the micro grid arises from the fact that power can flow in both the directions in each feeder of the micro grid. Close to each local load, there may exist two or more sources that contribute to the loaded power. The sources are located in both sides of load due to which power flows in opposite direction from two sources towards the load.

III. POSSIBLE SOLUTIONS FOR PROTECTION ISSUES

There are various solutions available to overcome protection challenges in the micro grid network. Whenever there is reverse power flow or bidirectional power flow, main relays of feeders which are fed from the substation can be interlocked . The use of directional over current relays can also solve this problem. The other solution is main feeder relay adjustment in terms of time settings.

1 Protection of inverter interfaced DG units

Conventional protection systems cannot give reliable protection for inverter interfaced units, because there is limited fault current. The solution can be achieved by using inverters which have high fault current capability that is up rating the inverter, using faster communication system between Inverter and protective relays, and introduction of energy storage devices that are capable of supplying large current incase of faults.

2 Differential protection scheme

The conventional differential protection cannot give the reliable protection. The protection scheme for micro grid with Inverter interfaced DG units cannot differentiate between fault current and an overload current, which results in nuisance tripping when system is overloaded, in some instances traditional protection scheme. For proper clearing of fault in an islanded micro grid and to ensure selectivity, it is important that different distributed generators should effectively communicate with each other. Use of evolving distribution system version of pilot wire line differential scheme is required for protection .

3 Balanced combination of different types of DG units

To obtain the protection of an isolated micro grid is to use DG units with synchronous generators or to use inverters having high fault current capability or to use combination of both types of DG units so the conventional protection schemes can be properly used.

4 Inverter Controller design

Protection scheme for islanded micro grid is dependent on type of inverter controller, controller can actively limit the available fault current from inverter interfaced distributed generator units.

5 Protection based on symmetrical components and differential components of currents

Micro grid can be protected against unsymmetrical faults based on symmetrical components. As per the studies carried out for differential and symmetrical component of currents , a symmetric protecting the micro grid against all single line to ground and line to line fault is developed.

Conclusion

One of the major challenges is finding a protection system that responds to both main grid and microgrid faults. In general, microgrids can operate in both grid-connected mode and islanding mode. So protection functions are expected to detect all types of fault in the microgrid for both operation modes. A fast semi- conductor switch, called static switch, is used to connect the microgrid to the main power grid, and the basic approach to protection is to disconnect the static switch for all types of fault, including main grid faults and microgrid faults. Most conventional feeder protections are based on short circuit current sensing.

Over-current protection devices detect faults on the main power grid, but power elec- tronic-controlled micro-sources cannot provide high enough levels of fault current. So, new algorithms will be needed to detect microgrid faults. Furthermore, once you add sources, energy can flow in either direction through protec- tion system sensing devices, making it more like a transmission line than a feeder. Also, there are no bi-directional flows on most radial systems. Harmonics generated by power electronic devices and uncontrollable energy sources like wind and solar create further challenges. To resolve these issues, Dr Bo, says, "micro- grid protection should be independent of high-fault current, power-flow direction, unbalanced load and plug-and-play generators. Relays should adapt to the energy source (wind, solar, etc.) change, and controls should limit harmonics.Micro- grid protection in the future will very likely have more cross-content with grid control, to achieve both flexibility and reliability. It will depend on the latest communications technology and will follow the development of microgrids, meaning we should see reliable schemes in the next five to 10 years.

"There may still be many solutions to find, but one thing is sure: microgrids will play an increasingly important role in the power supply industry."

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