DIFFERENTIAL PROTECTION AND ADAPTIVE OVER CURRENT PROTECTION FOR MICRO-GRID

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ABSTRACT

The demand and utilization of electrical energy has been on the increase in recent time and will continue to rise, this has facilitated the need for a more reliable and efficient grid network. The integration of distributed generation into the grid has giving rise to micro-grid and most of the sources are renewable energy which has change the entire structure of the grid from a radial network to a loop network. The change in network topology and reduced fault current level while the micro-grid is on Islanded mode has created new challenge to the existing protection scheme of the grid. Lower fault current due to their high impedance now presents protection challenges which are but not limited to bi-directional power flow, mesh configuration, changing fault current level due to the intermittent nature of DG and reduced fault current in an Islanded mode. So therefore, there is need to have a protection strategy that can detect and isolate faults in any of the micro-grid operation mode. In this work, we shall be exploring the use of differential protection for line and buses where communication link is available while adaptive directional overcurrent protection as an alternative where communication link is not available. Also, the use of overcurrent built-in MCCB and HRC fuse at various load point.

INTRODUCTION

Motivation

Micro-grid is fast becoming the center of attraction when it comes to the area of integrating distributed generation sources to the main grid. The operation of micro-grid basically is when it's connected to the utility and also when there is the absence of utility, this operation mode is called grid-connected and islanded mode respectively. Distributed generation sources range from renewable energy to smaller generating set, this makes up for the micro-grid and although its benefit is very attractive but its existence poses a new challenge on the existing protection scheme of the traditional grid. I am motivated by the complexity with which the micro-grid has brought to the main grid and this has to do with the area of protection. The inclusion of renewable energy source which are inverter based distributed generation has created a new problem to the existing protection schemes which renders them not suitable for protecting the entire system.

Problem statement

The inclusion of multiple inverters-based DG has created a change in the fault current level as compared to the fault current level in the traditional grid and this can be seen in the drastic change in short circuit current characteristic following the change in operation mode (Grid to Islanded). Other issues arising from this integration is the change in network topology when switching between grid and islanded conditions. Furthermore, power flow changes from unidirectional to bidirectional which contradicts the scheme of the existing unidirectional protection characteristic.

Overcurrent and directional overcurrent protection

Overcurrent protection

Overcurrent protection is that protection in which the magnitude of current exceeds the magnitude of pick up. The basic element in overcurrent protection is an overcurrent relay. The objective of overcurrent protectionis to prevent excessive current flow in an electric power circuit from damaging the circuit or from initiating fire in the circuit that could lead to more serious damage and even endanger people's lives. In this statement, the term "excessive current flow" refers to the flow of a current whose value greatly exceeds the nominal full-load current of the circuit, like the current resulting from a short circuit. Overcurrent protection works by first detecting excessive current flow in the protected circuit and then opening the path through which the excessive current flows as quickly as possible. Radial distribution network relies on overcurrent relaying for its protection. Once DG is connected to the distribution network, protection relays will experience changes in the fault current level It causes different issues towards the operation of the overcurrent protection like, overreached or under-reached of relay operation Inverter-Based DG in Islanded mode causes great challenge to the traditional overcurrent protection due to its lower fault current level Distribution network without DGs is a single-point feeding source network and overcurrent relay is widely used to furnish protection. As the traditional protection strategy for radial distribution network, the overcurrent relay work on basis of primary and backup protection with tripping signal based on abnormal current condition. The current-graded time overcurrent (definite time or inverse time) relays work superiorly to detect short-circuit current and isolate the faulty segment. Selectivity amongst relays is assured through certain coordination time interval

Directional overcurrent protection

This is similar to overcurrent protection in terms of operation but it has a distinct feature which makes is useful for the protection of meshed network structure. The directional relay recognises the direction in which the fault occurs, relative to the location of the relay. DG penetration in the distribution network has changed the network structure from radial to mesh. Directional overcurrent protection becomes attractive due to its bi-directional fault current capability, directional overcurrent protection provides protection of faults in forward and reverses direction because the relay responds in two directions. Overcurrent relays can be used when fault current can flow in both directions through the relay location. In order to have the ability to distinguish current direction, voltage measurement is required in addition to the current measurement. The changes in short circuit current levels in micro-grid pose challenges for current based protection. The short circuit current might be too low to differentiate between maximum load current and the lowest short circuit currents. As with non-directional overcurrent protection the selectivity is in some cases achieved by time grading. This is used for protection of a meshed/loop network structure. The directional relay recognizes the direction in which the fault occurs, relative to the location of the relay. DG penetration in the distribution network has changed the network structure from radial to mesh, DOCR becomes attractive due to its bi-directional fault current capability and provides protection of faults in forward and reverse direction because the relay responds in two direction

Adaptive overcurrent protection

Major issue with traditional technique protection with relating to micro-grid is the short circuit fault current level. Traditional-fuse protection rely on high levels of short-circuit current for its operation but in micro-grid operations, each mode has different short circuit characteristics which limits the suitability of traditional overcurrent protection devices. One of such way to overcome this difficulty is through the use of adaptive overcurrent protection. Adaptive overcurrent protection uses relays that allows for modification of its settings in response to grid condition. Adaptive protection was enabled by the increase of computer-based relaying which allowed the possibility to change relay characteristics. The evolving networks create the need for adaptive protection as existing relay settings and protection methods may become inappropriate. This requires adaptive characteristics in protection and creates the need for relays whose settings can be controlled in response to external conditions. The adaptive protection scheme is an online system that can modify the desired protective response to change under system conditions or requirements in an appropriate manner by the use of external control actions or generated signals. This protection scheme makes use of numerical directional overcurrent relays for its technical requirements and for practical implementation. For efficient protection, the use of communication systems and standard communication protocol is needed to enable relays to communicate and exchange information with a central computer or between different relays

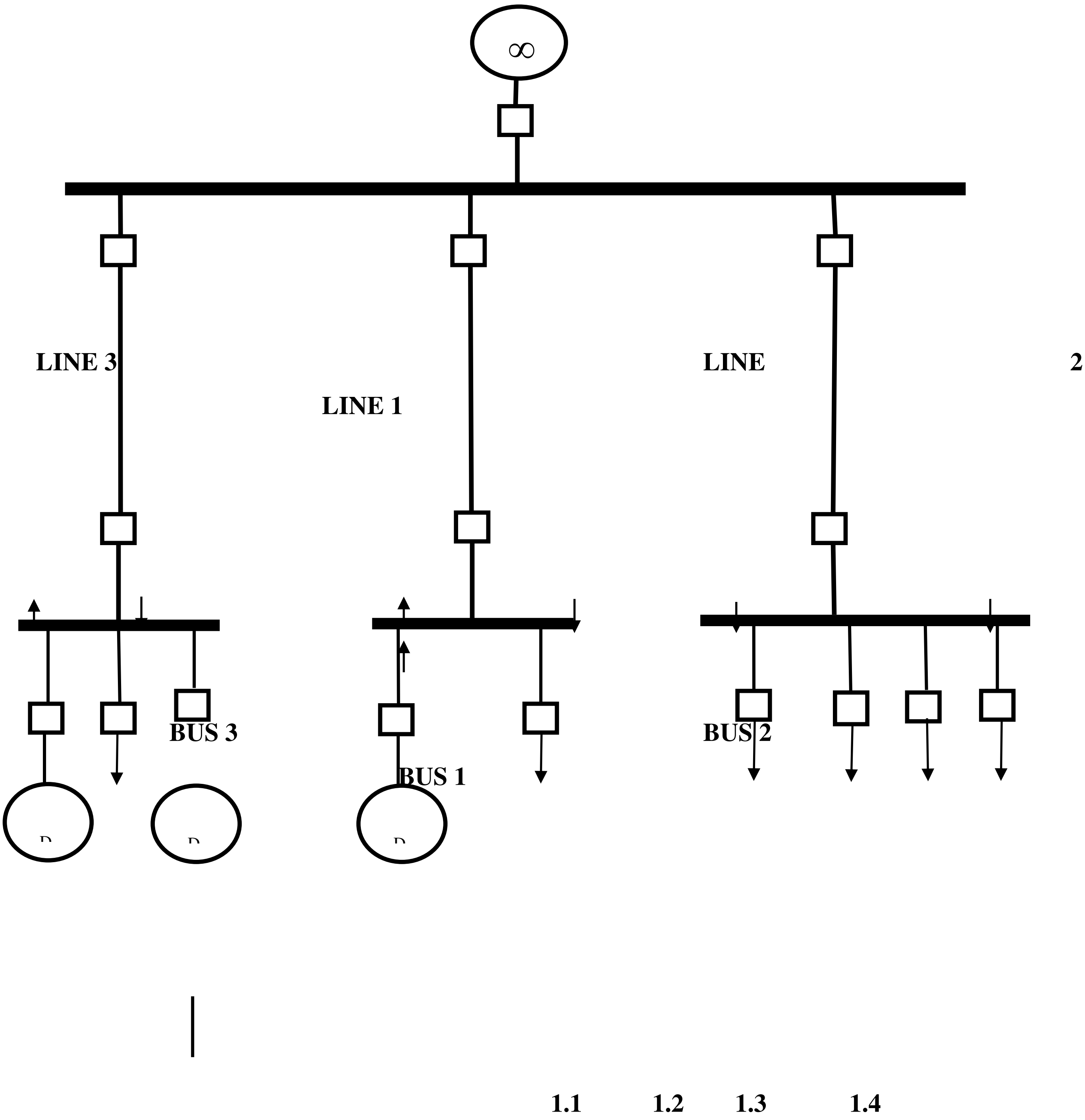
Adaptive directional overcurrent protection

Directional overcurrent relays can be used when fault current can flow in both directions through the relay location. In order to have the ability to distinguish current direction, voltage measurement is required in addition to the current measurement. The changes in short circuit current levels in micro-grid pose challenges for current based protection. The short circuit current might be too low to differentiate between maximum load current and the lowest short circuit currents. The need for making a directional overcurrent protection adaptive is to make it more sensitive to the operating mode of the micro-grid as the protection scheme will have the capacity to sense bi-directional power flow and with its dynamic current settings, it can function in both operating mode (Grid connected and Islanded mode). Adaptive directional overcurrent protection can be used for line protection where communication is not present as this is reliable as well and its cost effective as when compared to differential protection.

Differential protection of line

Each line in the micro-grid is protected using two relays which are located at the end of the line. In normal operating condition, current entering to a particular line should be equal to the current leaving from that line. However, this condition will not be satisfied during a fault on the line. Therefore, current differential protection is used to detect and isolate the line faults. The differential protection is capable of providing the protection for a specified line effectively while not responding to outside faults (out of zone). The current differential protection is chosen for the micro-grid since it is capable of handling bi-directional power flow, changing fault current level and the number of DG connections. It also provides the required protection for both grids connected and islanded modes of operation. Moreover, the protection relies on a communication link for effective coordination of both relays. Each relay at the end of the protected line is connected to its local CT while two relays are connected through a communication link. Each relay also calculates the negative sequence and zero sequence currents of local and remote end relay locations. The current differential elements of each relay then compare phase and calculated sequence parameters with respective remote end location quantities to identify a fault condition in the liner. If a fault is detected, each relay will issue a trip command to its local circuit breaker. The current differential protection is effective since it is sensitive, selective and fast

CASE STUDY OF MICRO-GRID PROTECTION



Protection of line 1

Implementation of a protection scheme is highly dependent on how sensitive, selective and reliable the protection strategy can be, Another important aspect to consider is the economics of having a protection strategy within a micro-grid which is at the distribution level hence it is not a viable option to invest so much on a protection scheme which is so expensive when there are other alternative which can protect the line at a cheaper cost. We shall be considering two different protection schemes for line 1 and which includes (a) Differential protection and; (b) Adaptive Directional overcurrent protection. It is also worthy to note that line 1 is a radial distribution line hence one direction flow of power. (from source to load) Differential protection scheme will be our choice if there is an existing communication link in the network because the relays situated at both end of the line needs to transmitting their independent signal at all time and by this the current entering and leaving line 1 will be monitored at all-time which is key in fault detection and isolation when fault occurs. In the absence of a communication link, it will be much cost intensive to install a communication link hence the need for another protection scheme will be adopted. Adaptive directional overcurrent protection scheme will be used in such case where there are no communication links as this protection scheme is a good alternative. The adaptive nature of this protection scheme is in relation with the relay settings while it has nothing to do with the direction of power flow. The need for communication in differential protection and the adaptability feature of the directional overcurrent protection is to curb the change in fault current level which occurs while on different mode of operation of the micro-grid

Protection of line 2

Line 2 is quite different from line 1 due to the fact that this line has a bi-directional power flow hence protection traditional protection scheme be reliable on this line. The change in fault current when in islanded mode is been critically considered here hence the need for proper protection strategy is needed. Differential protection is one of the suitable strategies for such line and this is only advisable when there is an existing communication channel installed already. Since we are dealing with a micro-grid which is smart hence there would be existing communication link hence differential protection will be used here. Alternatively, adaptive directional overcurrent protection can also be used in this setup in the absence of a communication link. Line 2 has bidirectional power flow hence the direction of fault and change in fault current level can be tackled by the directional features of the relay and the adaptive settings of the relay respectively.

Protection of bus 2

As seen from our case study, bus 2 is a very important part of the network, it has a load point and a DG source hence the protection of this bus is crucial in making sure continuous supply of power to the network in case there is an outage from the main grid. The current entering and leaving this bus must be monitored at all time to detect any abnormality within the bus hence differential protection will be employed to protect bus 2. There should be an effective communication link for better coordination of the protective relay within the bus; the relay will issue a trip command to all the circuit breakers connected to the bus during a bus fault

Protection of line 3

Differential protection and adaptive directional overcurrent protection can be used for line 3 but it depends on the availability of a communication link. If there are no existing communication links then the adaptive directional overcurrent protection scheme will be the best option due to the cost involved in integrating a communication link within the line/network. The bi-directional power flow and reverse power flow on the line can be taken care of the directional feature of this scheme while the adaptive feature can take care of the changes in the fault level current when operating in islanded mode. This low fault current is attributed to the presence of DG within the network and their fault current is twice the rating of the DG hence lower than the fault current which occurs when the grid is operational. Also, this DG's have large impedance hence low fault current as oppose the main grid with low impedance and high fault current. Hence line 3 has two alternative protection schemes depending on the availability of a key factor which is communication link.

Protection of bus 3

As seen from our case study, bus 3 is a very important part of the network, it has a load point and two DG sources hence the protection of this bus is crucial in making sure continuous supply of power to the network in case there is an outage from the main grid. The current entering and leaving this bus must be monitored at all time to detect any abnormality within the bus hence differential protection will be employed to protect bus 3. The reverse power flow and circuit coordination make differential protection better suited for this bus. There should be an effective communication link for better coordination of the protective relay within the bus; the relay will issue a trip command to all the circuit breakers connected to the bus during a bus fault hence protecting the bus and other feeders and their load connected to the bus.

Protection of Loads (1.1 to 1.4)

The load feeders on bus 1 are quite easy to protect owing to the fact that it's a radial network and there are no source DG connected to its bus bar. The primary method of protection on this load feeder is an overcurrent protection which is built into a MCCB. The loads on this feeder are also relatively small hence a HRC (high rupture capacity fuses) can also be used as backup protection to the MCCB which has overcurrent protection built in. HRC are sets of fuses which are very fast in its operation hence takes lesser time to rupture and isolate the load faster than any other conventional fuse. The other load in bus 2 and bus 3 also uses this overcurrent protection which is employed inside of a MCCB. The bus protection for bus 2 and bus 3 play a vital role in proper protection of their own local loads. The differential protection on each bus isolates the particular bus where the fault occurs and allowing other part of the network to be supplied by either the grid or another DG.

CONCLUSION

Micro-grid has the ability to curb the emergence of DG's in distribution network which is aim at providing reliable and better power quality. However, this integration comes with its own new technical challenges hence it is relevant that a robust solution is put forward to handle these new challenges, which will lead to a smooth operation of the micro-grid in its both operation modes (grid-connected modes and islanded mode). Several basic protection strategies have been introduced here which include overcurrent protection, adaptive directional overcurrent protection and differential protection was discussed to a great extent. In view of this, a good protection strategy is one which has the ability to protect the micro-grid against all faults and it's also economical to implement

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