Nidhi Patel, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 13, Issue 4, April 2023, pp. 102-107

RESEARCH ARTICLE OPEN ACCESS

A Review on Fault Detection on DC Microgrid

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Abstract: Due to inherent advantages of DC system over AC system such as compatibility with renewable energy sources, storage devices and modern loads, Direct Current Microgrid (DCMG) has been one of the key research areas from last few years. In the proposed work power has been produced by using solar pv and fuel cell which is combined on the same dc bus and given to a dc load. DC microgrid protection is an important part of power system studies. The basic think which is required for protection is to get to know, where it should be provided and which component must be used. So, to address the challenges of dc microgrid protection accurate fault detection strategies, fault current limiting method and dc circuit breaker has been used. The electricity load of the microgrid is satisfied by the power form fuel cell, pv array and battery altogether. Initially battery is charged up to 70% and at this time bidirectional converter work as a boost converter and when battery discharges till 30 %, battery starts charging and then bi-directional converter act as buck converter and battery remain in charging mode.

Key words: ***Micro grid, fault detection, fault classification, renewable energy***

Date of Submission: 02-04-2023 Date of acceptance: 12-04-2023

I. INTRODUCTION

A microgrid is a local electrical grid containing sources and loads. The micro grid is a cluster of distributed resources which have the ability to operate autonomously. Micro grids are being used to bring electricity into areas where transmission lines cannot reach. A traditional system with generation in one place and then distribution at high voltages is designed for high energy density fossil fuels. Distributed generation can be used to increase the reliability of a system and allow for the integration of renewables. Distributed generation is a much more suitable method of electricity distribution for renewables due to their lower energy density as compared to fossil fuels and since the power generation is on site losses due to transmitting electricity are proportionally eliminated. Energy storage can be used in micro grids to improve the power quality and smooth out the fluctuations of renewable energy generation. The recent trend in renewables is to use distributed power sources and energy storage to form a micro grid. DC micro grids are not very widespread but have the potential to present many advantages in terms of facilitating renewable energy integration and improving power quality. DC micro grids usually contain distributed energy resources (DER), loads and energy storage. Renewable energy sources such as photovoltaic modules and wind turbines are typically connected to the DC bus via power electronic converters. These converters have the ability to control the output voltage of DER in order to stabilize the bus voltage and extract maximum power. There are power electronic converters that have the ability to increase or decrease the output voltage. DC loads can be directly connected to the DC bus and if an AC load is required an inverter would be needed in order to invert the DC bus voltage into a usable AC voltage. Batteries are typically used in DC micro grids due to their relatively cheap price and longer backup times. A longer backup time and low losses are desirable for energy storage technologies for micro grids which contain renewable energy generation in order for the load to be met. The problem with batteries is that their service life is relatively short and therefore they need to be changed out more often. Charge controllers are used in order to control the flow of power in the micro grid. Devices are needed to control when power is sent to the batteries or sent to power the load. These controllers also help to improve the power quality in the micro grid. Why fault occur in DC micro grid? Due to the low impedance nature of DC micro grid system, the capacitive filters associated with converters will rapidly discharge into a fault, resulting a large current surge within very short duration.

The increased fossil fuel usage has resulted in increase in greenhouse gases and an alarming reduction in the fossil fuel resources. Here comes into picture, the importance of micro grid (MG), as an economically viable, clean and efficient power source. MGs are the low voltage grids, which connect group of micro sources along with the storage devices. These micro sources generate electricity at distribution level. This is called distributed generation (DG)

[1]. As the DG penetration increases, the unpredictable behaviour of the micro sources complicates the inter operation of DG with the distribution system. To overcome this

Problems, the DG's are connected to the MG with the help of power electronics based converters. This inverter based distributed generators (IBDGs), due to their inherent current control techniques, limit the fault current to 2 p.u. during the islanded mode of operation. This restriction imposes a cascading effect on protection of distribution system by commonly used cost effective overcurrent relays (OCR), which renders the fault being undetected [2-6]. These varying operating conditions and restriction in magnitude of the fault current make modification of over current relays an imperative requirement for smooth functioning. The MG protection issues like bidirectional power flow, protection blinding, sympathetic tripping, OCR selectivity & sensitivity and limitation of fault current leads to the demand of better and more effective protection schemes.

Solutions lie either in pre-designing the relays, factoring the operating conditions or by real time altering of relay settings as per the emergence of faults and location of DGs. In pre-designing of relays, multiple options exist of any particular operation, which enables the use of different optimization techniques such as adaptive modified firefly algorithm [6], teaching learning based algorithm [7], symbiotic organism search optimization [8], and particle swarm optimization [9]. In utilizing the second option, that is adaptive real time setting, use is made of an approximate thevenin equivalent circuit [10]. A linear programming based online coordination algorithm for relay adaptive protection is illustrated in [11]. One of the most important contributing factors towards OCR dependability and security is their coordination. As part of constant learning and getting adapted to varying network configurations, use of ANN is made in [12]. Relay coordination by utilizing multi-agent is given in [13]. OCR coordination by hybrid algorithm for radial network is proposed in [14]. Back up protection necessitates development of a digital protection scheme, while keeping in mind the relay time grading coordination. TMS and PSM settings are optimized in a microgrid model by utilizing particle swarm optimization (PSO) [15]. Machine learning is emerging out as yet another effective tool for adaptive protection of OCRs. This method aims at intelligent modification of OCR settings for varying operating conditions [16]. A hybrid method known as cuckoo linear optimization algorithm has been used for optimal protection coordination of OCRs. This hybrid algorithm converges to optimum value at much faster rate as compared to PSO or GA. Another attempt has been made in [17] for achieving adaptive overcurrent protection, by continuous monitoring of the micro grid, using information collected from different relays by Micro grid Control Centre.

Another attempt has been made in [21], where an adaptive relay using curve fitting technique has been proposed. This scheme proposes optimal 3D-curves in respect of selected relays by employing MATLAB curve fitting tool. In this paper, the adaptive relay performance is also compared with traditional OCRs and has been found more efficient, as far as protection issues are concerned. A novel time current voltage characteristic has been proposed in [22]. It uses not only current but voltage magnitude as well and has been found to reduce the overall time of operation of DOCR's, for meshed distribution network. In another approach [23], a dual setting DOCR was proposed. Here every DOCR has 2 relay settings depending on fault direction. It was found that the time of operation was reduced by almost 50% as compared to conventional method, irrespective of size and location of DG.

A novel technique is proposed in [24], to design and analyses DOCR protection with proper settings, in both the modes of microgrid operation.

Differential Protection

A number of researchers have aimed at achieving microgrid protection with the aid of differential protection. The basic concept of operating principle of the differential protection relays has been elucidated in [25]. A suggested method of symmetrical components of current based protection scheme is also elucidated, employed for detection of L-G, LLG faults in microgrids [26]. Another protection scheme making use of direction and magnitude of current employed for the protection of a microgrid, comprising both synchronous and inverter based DGs is explained in [27]. For the protection of both radial and meshed microgrids, a scheme based on instantaneous current differential protection is elucidated in [28]. In addition, the method has a capability of high impedance fault (HIF) detection. Another attempt has been made in [29], where a differential scheme based on spectral energy at either ends is proposed. The rationale behind tripping remains same as differential schemes based on current, where, relay trips when the energy differential exceeds the defined threshold. However, identification of the threshold poses some challenges as it depends on multiple factors, like fault impedance and operating modes to name a few. A current differential protection scheme utilizing power line carrier communication technique for protection of meshed micrograms is elucidated in [30]. Another current differential scheme with communication channel for islanded/ grid connected microgrid protection is shown in [31]. The implementation of fuzzy processes (FHSP) with hilbert space based power theory, has been used for microgrid protection using differential scheme. The underlying concept of functioning of this scheme is the power differential at either end of the feeder. The advantages accrued by this process include fault detection within two cycles from fault incidence as also the quality of detection being unaltered by threshold values and validity for all kinds of faults including internal faults.

Major advantages of differential protection schemes are that functioning of these schemes is unaffected by the bidirectional flow of power in grid connected mode or by lessening of fault current in islanded connection. Some shortcomings of the differential scheme can be listed as high dependence on communication performance, requirement of a dedicated communication link, saturation or current transformer ratio mismatch.

Voltage based scheme

These utilise voltage magnitude as an index and were proposed to protect the MG. The three phase voltages are transformed to dq reference frame using Park transformation and then the value of positive sequence voltage is assessed in comparison to that in dq reference frame, to identify the fault in the MG. Both symmetrical and unsymmetrical faults for highly penetrated system are detected by this scheme. In [32], DG output voltages are transformed to dq reference frame, to protect in-zone and out-zone faults in MG. Major disadvantages of voltage based scheme are its sensitivity towards voltage changes, dependency on MG configuration and limitation for HIF detection.

Communication based protection scheme

A microprocessor based relays incorporating directional elements can be used to protect a MG in both the modes of operation. In [28], digital relay communication network is used based on current differential scheme to protect a MG. It is applicable for HIFs detection. Digital relays are found quite effective for detection and isolation of faults in a MG, but at the same time are very costly due to communication network involved. It also requires some features which are absent in present time protection system.

Distance protection

In case of distance protection, admittance or impedance measurement is used as a parameter to detect faults. New types of admittance relay utilizing inverse time tripping characteristics is proposed in [33]. This admittance relay is able to identify faults in both the operating modes of a MG. In this scheme inverse time characteristics is to be added to each protection zone and at the same time it should be able to detect both forward and reverse faults. The scheme suffers with higher tripping time as a result of downstream source in feed, decreased accuracy due to current transients, reducing DC magnitude and time constant. Distance protection exhibits very less changes in its features for either of the operation mode of the MG as compared to over current protection. Relays show better coordination and effectiveness in the MG network.

Risks associated with short circuit currents

The building/facility may not be properly protected against short-circuit currents. These currents can damage or deteriorate equipment. Improperly protected short-circuit currents can injure or kill maintenance personnel. Recently, new initiatives have been taken to require facilities to properly identify these dangerous points within the power distribution of the facility.

Why short circuit is dangerous?

Short circuit current can be very large. If unusually high currents exceed the capability of protective devices (fuses, circuit breakers, etc.) it can result in large, rapid releases of energy in the form of heat, intense magnetic fields, and even potentially as explosions known as an arc blast. The heat can damage or destroy wiring insulation and electrical components. An arc blast produces a shock wave that may carry vaporized or molten metal, and can be fatal to unprotected people who are close by. Therefore, reliable protection scheme should be developed for the DC microgrid acting in both grid and islanded mode of operation. The objective of this paper is to propose a model for short circuit fault detection and protection of DC microgrid consisting of renewable energy generation. A DC microgrid model has been designed and simulated that comprises a protection model for multiple energy sources and equipments. The components of the DC microgrid and the protective devices will be modeled then whole DC microgrid will finally be simulated.

DC Microgrid Protection

In addition to salient protection challenges, in AC micro grids, DC micro grid is inherent with quick discharge of capacitor which manifests in a higher value of fault current. In order to mitigate any damages that can be caused to electronic devices, a very small time frame of 2ms must be utilized to isolate the micro grid. Current and voltage derivatives are much better utilized than pure current and voltage based methods, responses of earlier being more sensitive. [34] Elucidates a current derivative based fault detection method. Although the current and voltage change based fault detection methods are good enough for fault detection, however, these are easily affected by the inherent transient behavior of power system and the measuring noise. Schemes based on differential protection are much better solutions for protection of DC microgrid [35]. The vector difference between post fault and pre fault currents, termed as superimposed current, can be used as a parameter to design protection scheme. Differential scheme uses more number of relays and measuring instrument, which adds to the protection cost. Protection of DC microgrids with ring configuration can be achieved, where an intelligent device is used, to attain increased reliability and decreased protection cost. Moreover the scheme was found to identify low as well as high impedance faults in few milliseconds. Table 1. below elucidates comparison between the functioning of various protection schemes in a microgrid.

II. Conclusion

With the advent of faster communication systems, adaptive protection has emerged as one avenue which gives out a broad spectrum of possibilities towards the development of new age protection systems. This has opened doors for adaptive protection implementation in AC MGs. Differential protection is also a very good solution for protection of AC micro grids, as it is unaffected by bidirectional power flow in a MG. Other avenues towards addressing the protection challenges are implementation of voltage based and distance protection Schemes, which can be explored further . In DC MG, as fault has to be isolated quickly, differential protection becomes an obvious choice. The idea of hybrid AC-DC microgrids, having benefits over pure AC or DC MG is coming up recently. The development of hybrid AC-DC micro grid protection is still in nascent stage and there lies much scope of research in this direction.

TABLE 1. COMPARATIVE ANALYSIS OF VARIOUS PROTECTION SCHEMES AS APPLIED TO MICROGRIDS.

Parameter / Technique	Bidirectional flow	MG operation mode	Communication medium	Relay coord	Tripping time
OCR Protection	Highly affected	Highly affected due to reduced currents in islanded mode	Required for Adaptive OCR	Gets adversely effected	Faster
Differential Protection	Not affected	Not affected	Highly dependent	Good	Fast
Voltage Based Protection	Not affected	Depends on MG mode	Not dependent	<<Gets affected	Fast

Communication Based Protection	Not affected	Not affected	High cost medium	Very good	Fastest
Distance Protection	Not affected	Not affected	Not dependent	Relatively good	Slower

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