International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 20 Issue 3 – MARCH 2016

DC BUS PROTECTION SYSTEM USING NEW ECT BASED ON GATE LOGICS

T.SEVANTHI[#1] and Prof.V.GEETHA[*2]

[#]*Final year, M.E, Power Electronics and Drives, P.S.V College of Engineering and Technology, Krishnagiri (D.T) -635108*

[*]*Associate Professor, Electrical and Electronics Engineering, P.S.V College of Engineering and Technology, Krishnagiri (D.T) -635108*

***Abstract*— In this project work, we simulate an event-based protection scheme for a multi terminal dc power system, which includes hybrid energy resources and various loading schemes. The proposed protection scheme transfers less data when compared with commonly used data-based protection methods, and does not require high-speed communication and synchronization. Each protection unit is able to autonomously identify the type of event using the current derivative fault identification method, employing artificial inductive line impedance. In order to accurately set the protection relays, detailed fault current analysis considering low pass resistor capacitor filter effects are presented. The decision for fault isolation is made based on the unit judgment and the data received through high-level data communication from other interconnected units. The performance of the proposed protection scheme was evaluated under different dc feeder and bus faults. The sudden increase in the current has been sensed through a gating logic, when dc bus voltage is compared with a threshold. The results show that this scheme is able to accurately identify the type of fault, isolate the faulted area, and restore the system quickly while limiting the load voltage drop to its preset limit.**

***Index Terms*— Active Power Filter (APF), dynamic voltage restorer (DVR), Unified Power Quality Conditioner (UPQC), Shunt Active Power Filter (ES).**

INTRODUCTION

DC Micro grid is an effective architecture to achievea more reliable power with higher efficiency through the implementation of the power electronic converters and the storage energy devices. In various applications, such as telecommunication systems, shipboard and spacecraft, and distribution systems involving a large number of electronic loads and data centers dc architectures provide a more effective solution for electric power distribution. However there is a widespread concern over the means used to protect the system against short circuit faults especially in multisource distribution systems and multi terminal dc lines. The protection of a power system that includes a large number of buses and feeders can be categorized into the data-based and event-based protection schemes. In the data-based protection method electric variables such as the converter current or the bus voltage are measured and sent to the interconnected protection unit to execute fault identification algorithms. In the event-based protection scheme the measured fault parameters are locally analyzed to classify the type of event. Then the event judgment is sent to other interconnected protection units through high-level data communication. Event-based protection schemes have been recently deployed for ac power system protection. This paper proposes a new simple yet efficient and reliable event-based protection technique for a multi terminal dc power system. When compared to data-based protection methods, the event based protection scheme transfers much less data and does not require high-speed communication and synchronization. Moreover, the developed event-based protection scheme utilizes less measurement equipment since only the dc bus data is required while the traditional data-based protection methods require both the dc bus measurement and the feeder measurements. The notional hybrid dc micro grid considered for this paper that is implemented in our hybrid ac–dc power system test-bed. Also for dynamic operation and fault study the accurate model of this micro grid is implemented in MATLAB/Simulink environment and evaluated using the experimental test results.

In order to accurately set the protection relays the detailed fault current analysis is presented using analytical calculation and simulation model. Since the protection relays are microprocessor-based the input signals to the digital relays can be highly contaminated with noises and high-frequency components as a consequence of using power converter and load drive switching. Moreover, the transient short circuit currents contain exponential and high-frequency damped oscillation components in which improper analog filtering can cause aliasing error and may also saturate the analog to digital converters (ADC). In this paper, the transient fault current and the protection relay settings are evaluated while considering the effect of a low pass resistor capacitor (RC) filter. In the proposed protection strategy, each power unit is able to autonomously identify the type of fault; whether it is a bus fault, interconnected feeder fault, or adjacent feeder or bus fault. Since the dc bus and cable have low impedance, it is difficult to identify an interconnected feeder fault from a bus fault or an adjacent feeder fault. This paper proposes an effective event identification technique using the current derivative method and employing an artificial inductive line impedance (AILI). The AILIs are small inductors which are implemented in each feeder. The AILIs have a significant impact on the *di/dt* characteristic of fault current in transient condition which is utilized as a new technique for fault identification. The decision for fault isolation and grid restoration is made based on the unit judgment and the data that is received through high-level data communication from the other interconnected units. The performance of the proposed event-based fault identification method is verified under different fault conditions using the hybrid dc micro grid simulation model.

I. STRATEGIC MODELING

A. *High Voltage Direct Current*

A high-voltage direct current (HVDC) electric power transmission system (also called a power super highway or an electrical super highway) uses direct current for the bulk transmission of electrical power, in contrast with the more common alternating current (AC) systems. For long-distance transmission, HVDC systems may be less expensive and suffer lower electrical losses. For underwater power cables, HVDC avoids the heavy currents required to charge and discharge the cable capacitance each cycle. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be justified, due to other benefits of direct current links. HVDC allows power transmission between unsynchronized AC transmission systems. Since the power flow through an HVDC link can be controlled independently of the phase angle between source and load, it can stabilize a network against disturbances due to rapid changes in power. HVDC also allows transfer of power between grid systems running at different frequencies, such as 50 Hz and 60 Hz. This improves the stability and economy of each grid, by allowing exchange of power between incompatible networks. The modern form of HVDC transmission uses technology developed extensively in the 1930s in Sweden (ASEA) and in Germany. Early commercial installations included one in the Soviet Union in 1951 between Moscow and Kashira, and a 100 kV, 20 MW system between Gotland and mainland Sweden in 1954. The longest HVDC link in the world is the Rio Madeira link in Brazil, which consists of two bipoles of ±600 kV, 3150 MW each, connecting Porto Velho in the state of Rondônia to the São Paulo area. The length of the DC line is 2,375 km (1,476 mi)

B. *High Voltage Transmission*

High voltage is used for electric power transmission to reduce the energy lost in the resistance of the wires. For a given quantity of power transmitted, doubling the voltage will deliver the same power at only half the current. Since the power lost as heat in the wires is proportional to the square of the current for a given conductor size, but does not depend on the voltage, doubling the voltage reduces the line losses per unit of electrical power delivered by a factor of 4. While power lost in transmission can also be reduced by increasing the conductor size, larger conductors are heavier and more expensive. High voltage cannot readily be used for lighting or motors, so transmission-level voltages must be reduced for end-use equipment. Transformers are used to change the voltage levels in alternating current (AC) transmission circuits. Because transformers made voltage changes practical, and AC generators were more efficient than those using DC, AC became dominant after the introduction of practical systems of distribution in Europe in 1891 and the conclusion in 1892 of the War of Currents, a competition being fought on many fronts in the US between the DC system of Thomas Edison and the AC system of George Westinghouse. Practical conversion of power between AC and DC became possible with the development of power electronics devices such as mercury-arc valves and, starting in the 1970s, semiconductor devices as thyristors, integrated gate-commutated thyristors (IGCTs), MOS-controlled thyristors (MCTs) and insulated-gate bipolar transistors (IGBT)

C. *Thyristor Values*

Since 1977, new HVDC systems have used only solid-state devices, in most cases thyristor valves. Like mercury arc valves, thyristors require connection to an external AC circuit in HVDC applications to turn them on and off. HVDC using thyristor valves is also known as line-commutated converter (LCC) HVDC.Development of thyristorvalves for HVDC began in the late 1960s. The first complete HVDC scheme based on thyristor valves was the Eel River scheme in Canada, which was built by General Electric and went into service in 1972.

i. Capacitor-Commutated Converters (CCC)

Line-commutated converters have some limitations in their use for HVDC systems. This results from requiring the AC circuit to turn off the thyristor current and the need for a short period of 'reverse' voltage to effect the turn-off (turn-off time). An attempt to address these limitations is the Capacitor-Commutated Converter (CCC) which has been used in a small number of HVDC systems. The CCC differs from a conventional HVDC system in that it has series capacitors inserted into the AC line connections, either on the primary or secondary side of the converter transformer. The series capacitors partially offset the commutating inductance of the converter and help to reduce fault currents. This also allows a smaller extinction angle to be used with a converter/inverter, reducing the need for reactive power support. However, CCC has remained only a niche application because of the advent of voltage-source converters (VSC) which completely eliminate the need for an extinction (turn-off) time.

ii. Voltage-Source Converters (VSC)

Widely used in motor drives since the 1980s, voltage-source converters started to appear in HVDC in 1997 with the experimental Hellsjön–Grängesberg project in Sweden. By the end of 2011, this technology had captured a significant proportion of the HVDC market. The development of higher rated insulated-gate bipolar transistors (IGBTs), gate turn-off thyristors (GTOs) and integrated gate-commutated thyristors (IGCTs), has made smaller HVDC systems economical. The manufacturer ABB Group calls this concept HVDC Light, while Siemens calls a similar concept HVDC PLUS (Power Link Universal System) and Alstom call their product based upon this technology HVDC MaxSine. They have extended the use of HVDC down to blocks as small as a few tens of megawatts and lines as short as a few score kilometres of overhead line. There are several different variants of VSC technology: most installations built until 2012 use pulse width modulation in a circuit that is effectively an ultra-high-voltage motor drive. Current installations, including HVDC PLUS and HVDC MaxSine, are based on variants of a converter called a Modular Multi-Level Converter (MMC). Multilevel converters have the advantage that they allow harmonic filtering equipment to be reduced or eliminated altogether. By way of comparison, AC harmonic filters of typical line-commutated converter stations cover nearly half of the converter station area.With time, voltage-source converter systems will probably replace all installed simple thyristor-based systems, including the highest DC power transmission applications.

iii. Advantages of HVDC over AC transmission

A long distance point to point HVDC transmission scheme generally has lower overall investment cost and lower losses than an equivalent AC transmission scheme. HVDC conversion equipment at the terminal stations is costly, but the total DC transmission line costs over long distances are lower than AC line of the same distance. HVDC requires less conductor per unit distance than an AC line, as there is no need to support three phases and there is no skin effect. Depending on voltage level and construction details, HVDC transmission losses are quoted as about 3.5% per 1,000 km, which are 30 – 40% less than with AC lines, at the same voltage levels. This is because direct current transfers only active power and thus causes lower losses than alternating current, which transfers both active and reactive power. HVDC transmission may also be selected for other technical benefits. HVDC can transfer power between separate AC networks. HVDC powerflow between separate AC systems can be automatically controlled to support either network during transient conditions, but without the risk that a major power system collapse in one network will lead to a collapse in the second. HVDC improves on system controllability, with at least one HVDC link embedded in an AC grid—in the deregulated environment, the controllability feature is particularly useful where control of energy trading is needed.The combined economic and technical benefits of HVDC transmission can make it a suitable choice for connecting electricity sources that are located far away from the main ausers. Specific applications where HVDC transmission technology provides benefits include:

- Undersea cables transmission schemes (e.g., 250 km Baltic Cable between Sweden and Germany, the 580 km NorNed cable between Norway and the Netherlands, and 290 km Basslink between the Australian mainland and Tasmania).
- Endpoint-to-endpoint long-haul bulk power transmission without intermediate 'taps', usually to connect a remote generating plant to the main grid, for example the Nelson River DC Transmission System in Canada.
- Increasing the capacity of an existing power grid in situations where additional wires are difficult or expensive to install.
- Power transmission and stabilization between unsynchronised AC networks, with the extreme example being an ability to transfer power between countries that use AC at different frequencies. Since such transfer can occur in either direction, it increases the stability of both networks by allowing them to draw on each other in emergencies and failures.Stabilizing a predominantly AC power-grid, without increasing fault levels (prospective short circuit current).

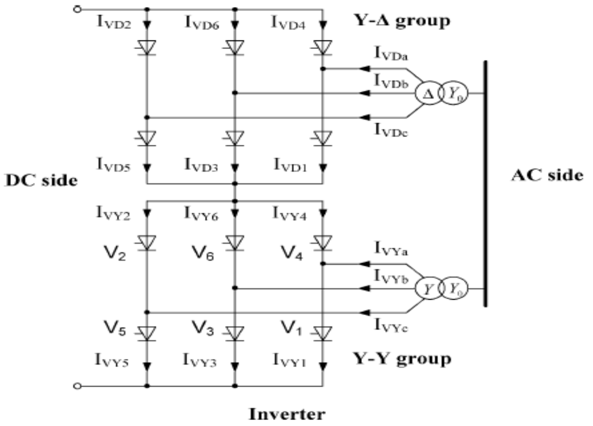
Integration of renewable resources such as wind into the main transmission grid. HVDC overhead lines for onshore wind integration projects and HVDC cables for offshore projects have been proposed in North America and Europe for both technical and economic reasons. DC grids with multiple voltage-source converters (VSCs) are one of the technical solutions for pooling offshore wind energy and transmitting it to load centers located far away onshore

D. *Cable systems*

Long undersea underground high-voltage cables have a high electrical capacitance compared with overhead transmission lines, since the live conductors within the cable are surrounded by a relatively thin layer of insulation (the dielectric) and a metal sheath. The geometry is that of a long co-axial capacitor. The total capacitance increases with the length of the cable. This capacitance is in a parallel circuit with the load. Where alternating current is used for cable transmission additional current must flow in the cable to charge this cable capacitance. This extra current flow causes added energy loss via dissipation of heat in the conductors of the cable raising its temperature. Additional energy losses also occur as a result of dielectric losses in the cable insulation. However, if direct current is used, the cable capacitance is charged only when the cable is first energized or if the voltage level changes; there is no additional current required. For a sufficiently long AC cable, the entire current-carrying ability of the conductor would be needed to supply the charging current alone. This cable capacitance issue limits the length and power carrying ability of AC powered cables. DC powered cables are limited only by their temperature rise and Ohm's Law. Although some leakage current flows through the dielectric insulator. This is small compared to the cable's rated current.

E. *Overhead Line Systems*

The capacitive effect of long underground or undersea cables in AC transmission applications also applies to AC overhead lines, although to a much lesser extent. Nevertheless, for a long AC overhead transmission line, the current flowing just to charge the line capacitance can be significant, and this reduces the capability of the line to carry useful current to the load at the remote end. Another factor that reduces the useful current carrying ability of AC lines is the skin effect, which causes a non-uniform distribution of current over the cross-sectional area of the conductor. Transmission line conductors operating with direct current do not suffer from either of these constraints.



The 12-pulse bridge inverter topology

Finally, depending upon the environmental conditions and the performance of overhead line insulation operating with HVDC, it may be possible for a given transmission line to operate with a constant HVDC voltage that is approximately the same as the peak AC voltage for which it is designed and insulated. The power delivered in an AC system is defined by the root mean square (RMS) of an

AC voltage, but RMS is only about 71% of the peak voltage. Therefore, if the HVDC line can operate continuously with an HVDC voltage that is the same as the peak voltage of the AC equivalent line, then for a given current (where HVDC current is the same as the RMS current in the AC line), the power transmission capability when operating with HVDC is approximately 40% higher than the capability when operating with AC.

F. Asynchronous Connections

Because HVDC allows power transmission between unsynchronized AC distribution systems, it can help increase system stability, by preventing cascading failures from propagating from one part of a wider power transmission grid to another. Changes in load that would cause portions of an AC network to become unsynchronized and to separate, would not similarly affect a DC link, and the power flow through the DC link would tend to stabilize the AC network. The magnitude and direction of power flow through a DC link can be directly controlled, and changed as needed to support the AC networks at either end of the DC link. This has caused many power system operators to contemplate wider use of HVDC technology for its stability benefits alone.

G. Converter Transformers

At the AC side of each converter a bank of transformers often three physically separated single-phase transformers isolate the station from the AC supply to provide a local earth and to ensure the correct eventual DC voltage. The output of these transformers is then connected to the converter. Converter transformers for LCC HVDC schemes are quite specialized because of the high levels of harmonic currents which flow through them, and because the secondary winding insulation experiences a permanent DC voltage, which affects the design of the insulating structure (valve side requires more solid insulation) inside the tank. In LCC systems, the transformer(s) also need to provide the 30° phase shift needed for harmonic cancellation.

H. Faults

Electrical power system have a dynamic and complex behavior. Different types of faults can interrupt the healthy operation of the power system. Some of the major Electrical faults are phase faults include phase to phase faults and phase to ground faults and three phase faults. Other Electrical faults are of not major significance but still are considered, Open circuit faults occurs due to the parting of the overhead line or failure operation of the circuit breaker, Inter turn fault occurs due to the overvoltage or insulation breakdown, Electrical Faults results in the overloads is due to the passing the current throughout the conductor which is above the permissible value and faults due to real power deficit occurs due to mismatch in the power generated and consumed and results in the frequency deviation and collapse of grid.

In an electric power system, a fault is any abnormal electric current. For example,a short circuit is a fault in which current bypasses the normal load. An open-circuit fault occurs if a circuit is interrupted by some failure. In three-phase systems, a fault may involve one or more phases and ground, or may occur only between phases. In a "ground fault" or "earth fault", charge flows into the earth. The prospective short circuit current of a fault can be calculated for power systems.In power systems, protective devices detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure. In a polyphase system, a fault may affect all phases equally which is a "symmetrical fault". If only some phases are affected, the resulting "asymmetrical fault" becomes more complicated to analyze due to the simplifying assumption of equal current magnitude in all phases being no longer applicable. The analysis of this type of fault is often simplified by using methods such as symmetrical components. Design of systems to detect and interrupt power system faults is the main objective of power system protection.

i. Transient Fault

A transient fault is a fault that is no longer present if power is disconnected for a short time and then restored. Many faults in overhead power lines are transient in nature. When a fault occurs, equipment used for power system protection operate to isolate the area of the fault. A transient fault will then clear and the power-line can be returned to service. Typical examples of transient faults include:

- momentary tree contact
- bird or other animal contact
- lightning strike
- conductor clashing

Transmission and distribution systems use an automatic re-close function which is commonly used on overhead lines to attempt to restore power in the event of a transient fault. This functionality is not as common on underground systems as faults there are typically of a persistent nature. Transient faults may still cause damage both at the site of the original fault or elsewhere in the network as fault current is generated.

ii. Persistent Fault

A persistent fault does not disappear when power is disconnected. Faults in underground power cables are most often persistent due to mechanical damage to the cable, but are sometimes transient in nature due to lightning.

iii. Symmetric Fault

A symmetric or balanced fault affects each of the three phases equally. In transmission line faults, roughly 5% are symmetric. This is in contrast to an asymmetrical fault, where the three phases are not affected equally.

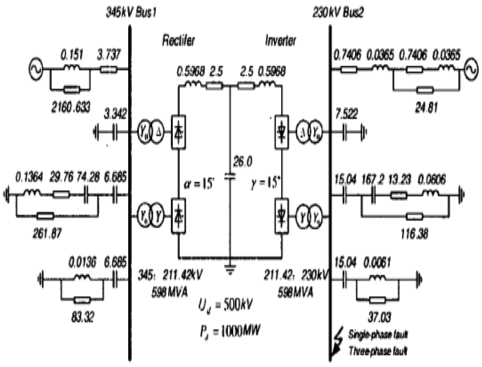
iv. Asymmetric Fault

An asymmetric or unbalanced fault does not affect each of the three phases equally. Common types of asymmetric faults, and their causes:

line-to-line - a short circuit between lines, caused by ionization of air, or when lines come into physical contact, for example due to a broken insulator.

line-to-ground - a short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other storm damage.

double line-to-ground - two lines come into contact with the ground (and each other), also commonly due to storm damage.



Configuration of the testing system

v. *Arcing &Bolted Faults*

Where the system voltage is high enough, an electric arc may form between power system conductors and ground. Such an arc can have a relatively high impedance (compared to the normal operating levels of the system) and can be difficult to detect by simple overcurrent protection. For example, an arc of several hundred amperes on a circuit normally carrying a thousand amperes may not trip overcurrent circuit breakers but can do enormous damage to bus bars or cables before it becomes a complete short circuit. Utility, industrial, and commercial power systems have additional protection devices to detect relatively small but undesired currents escaping to ground. In residential wiring, electrical regulations may now require Arc-fault circuit interrupters on building wiring circuits, so as to detect small arcs before they cause damage or a fire. When calculating the prospective short-circuit current in a circuit, to maximize the value, the impedance of the arc is neglected. Notionally, all the conductors are considered connected to ground as if by a metallic conductor; this is called a "bolted fault". It would be unusual in a well-designed power system to have a metallic short circuit to ground but such faults can occur by mischance. In one type of transmission line protection, a "bolted fault" is delibrately introduced to speed up operation of protective devices.

I. *Analysis*

Symmetric faults can be analyzed via the same methods as any other phenomena in power systems, and in fact many software tools exist to accomplish this type of analysis automatically (see power flow study). However, there is another method which is as accurate and is usually more instructive. First some simplifying assumptions are made. It is assumed that all electrical generators in the system are in phase, and operating at the nominal voltage of the system. Electric motors can also be considered to be generators, because when a fault occurs, they usually supply rather than draw power. The voltages and currents are then calculated for this base case. Next the location of the fault is considered to be supplied with a negative voltage source, equal to the voltage at that location in the base case, while all other sources are set to zero. This method makes use of the principle of superposition. To obtain a more accurate result, these calculations should be performed separately for three separate time ranges:

- Subtransient is first, and is associated with the largest currents
- Transient comes between subtransient and steady-state
- Steady-state occurs after all the transients have had time to settle

An asymmetric fault breaks the underlying assumptions used in three-phase power, namely that the load is balanced on all three phases. Consequently, it is impossible to directly use tools such as the one-line diagram, where only one phase is considered. However, due to the linearity of power systems, it is usual to consider the resulting voltages and currents as a superposition of symmetrical components, to which three-phase analysis can be applied. In the method of symmetric components, the power system is seen as a superposition of three components: a positive-sequence component, in which the phases are in the same order as the original system, i.e., a-b-c.a negative-sequence component, in which the phases are in the opposite order as the original system, i.e., a-c-b.a zero-sequence component, which is not truly a three-phase system, but instead all three phases are in phase with each other.

To determine the currents resulting from an asymmetrical fault, one must first know the per-unit zero-, positive-, and negative-sequence impedances of the transmission lines, generators, and transformers involved. Three separate circuits are then constructed using these impedances. The individual circuits are then connected together in a particular arrangement that depends upon the type of fault being studied (this can befound in most power systems textbooks). Once the sequence circuits are properly connected, the network can then be analyzed using classical circuit analysis techniques. The solution results in voltages and currents that exist as symmetrical components; these must be transformed back into phase values by using the A matrix. Analysis of the prospective short-circuit current is required for selection of protective devices such as fuses and circuit breakers. If a circuit is to be properly protected, the fault current must be high enough to operate the protective device within as short a time as possible; also the protective device must be able to withstand the fault current and extinguish any resulting arcs without itself being destroyed or sustaining the arc for any significant length of time. The magnitude of fault currents differ widely depending on the type of earthing system used, the installation's supply type and earthing system, and its proximity to the supply. For example, for a domestic UK 230 V, 60 A TN-S or USA 120 V/240 V supply, fault currents may be a few thousand amperes. Large low-voltage networks with multiple sources may have fault levels of 300,000 amperes. A high-resistance-grounded system may restrict line to ground fault current to only 5 amperes. Prior to selecting protective devices, prospective fault current must be measured reliably at the origin of the installation and at the furthest point of each circuit, and this information applied properlyto the application of the circuits.

J. *Detecting and Locating Faults*

Overhead power lines are easiest to diagnose since the problem is usually obvious, e.g., a tree has fallen across the line, or a utility pole is broken and the conductors are lying on the ground.Locating faults in a cable system can be done either with the circuit de-energized, or in some cases, with the circuit under power. Fault location techniques can be broadly divided into terminal methods, which use voltages and currents measured at the ends of the cable, and tracer methods, which require inspection along the length of the cable. Terminal methods can be used to locate the general area of the fault, to expedite tracing on a long or buried cable. In very simple wiring systems, the fault location is often found through inspection of the wires. In complex wiring systems (for example, aircraft wiring) where the wires may be hidden, wiring faults are located with a Time-domain reflectometer. The time domain reflectometer sends a pulse down the wire and then analyzes the returning reflected pulse to identify faults within the electrical wire.

K. *Study of 3 Phase System Faults*

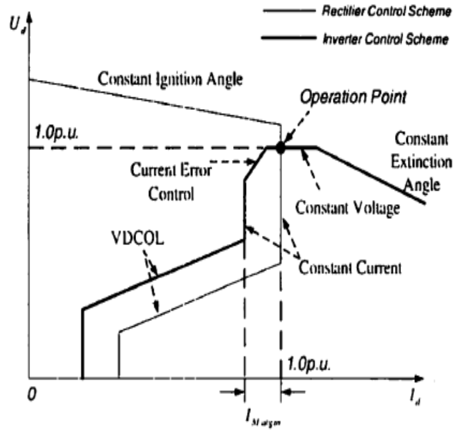
Three-phase ac system faults are initiated at 0.1 s and its duration is 50 ms. is gradually decreased to simulate the closer electrical proximity from the fault location to the 230-kV bus. With the decrease of , the voltage reduction becomes larger. In this case of fault instant being 0.1 s, commutation failure first occurs when decreases to its critical value of 1.12 H. The simulation indicates that the voltage reduction is an affecting factor as to the onset of commutation failures. It can be seen that with the simulation cases of failing to initiate commutation failures, the are much smaller than the ones which set on commutation failures. Taking fault time instants 0.1 s and 0.104 s, for example, the corresponding are 0.0631 and 0.0083. The former is nearly ten times larger than the latter. Therefore, it can be assumed that is another affecting factor with respect to the onset of commutation failures. In order to verify the conclusion, additional simulations are also performed. Taking the fault time instant 0.104 s, for example, comparison of Tables I and II shows that in the cases of H and H are almost the same, while deviates significantly. It can be seen that the onset of commutation failures requires a relatively larger. Therefore a conclusion can be drawn that and can jointly decide whether a commutation failure occurs.

L. *Study of Single Phase AC System faults*

Simulation of various three-phase ac system faults reveals that and are the two most affecting factors as to the onset of commutation failures. In order to see whether the conclusion stands with single-phase ac system faults, taking phase line-to-ground faults for instance, similar simulations are conductedwith the results. As for single-phase ac system faults at the inverter side, commutation failure first occurs when decreases to 0.76 H with fault time instant being 0.1 s. It can be seen that simulation results conform to the conclusion drawn above; and it can assert that and should be the inputs of the fuzzy controller.

M. *Verification with 3 Phase AC System faults*

The effect of the fuzzy controller on the group valves. Under three-phase ac system faults are given. It can be seen that the effectiveness of the fuzzy controller is apparent in the cases of less severe three-phase ac systems faults. For instance, the commutation failures can be avoided completely with the proposed fuzzy control when is above 0.91 H. When ac system faults are relatively severe, the fuzzy controller is effective in avoiding the second commutation failure. However, with much more severe faults when is less than 0.36 H or bus voltage drops below 0.74 p.u..The fuzzy controller contributes little. This performance of the fuzzy controller is in accordance with practical power system operation. When severe ac system fault occurs, it is not dc control but such ac protection system as circuit breakers that should take the responsibility to respond first. Since the commutation failure mechanism of the group valves is analogous to that of the group valves, a similar effect in mitigating the commutation failures of group valves can be founded. Direct current response can best reflect the effect of controllers while the advanced firing angle can quantify the effort taken by controllers. Therefore, both the direct current response and the advanced firing angle with the fuzzy control and with the conventional control under the three-phase ac faults of H and H are presented respectively.



Control scheme of the rectifier and inverter

The fault of H can be regarded as less severe, with the resulting ac bus voltage being above 0.76 p.u. In the event that the fuzzy controller is not applied, the direct current will undergo a sudden increase. It can be seen that with the fuzzy controller, commutation failure is avoided and the direct current is limited by advancing the firing angle by as illustrated. With H the resulting ac bus voltage is merely 0.60 p.u. so that the fault is considerably severe. Therefore the implementation of the proposed fuzzy controller can have little effect in terms of commutation failure mitigation. More effective emergency methods are needed to prevent the commutation failures from occurring consecutively. As should be noticed, the system responses with the fuzzy control and conventional control. Indicate that both controllers are of approximately equal effectiveness in mitigating the commutation failures caused by the three-phase ac faults of different severity.

N. *Verification with Single-Phase AC System faults*

The effect of the fuzzy controller on the group and group valves under single-phase ac system faults respectively. Similar to three-phase ac system faults, the effectiveness of the fuzzy controller is apparent with less severe ac system faults. When ac bus voltage reduces to below 0.76 p.u. with H, the fuzzy controller is of little use. In order to gain insights into the system responses, both the direct current response and the advanced firing angle with fuzzy control and with the conventional control under the single phase ac faults of H, H, and H are presented respectively. With the resulting ac bus voltage being above 0.85p.u., the single-phase fault of H can be regarded as less severe. Compared to the direct current response without control. It can be seen that the successive commutation failures can be avoided with the proposed fuzzy control and direct current increase can also be limited during the fault. In the case of the single-phase fault of H in which ac system voltage drops to 0.76 p.u., the proposed fuzzy controller is superior to the conventional controller in mitigating the second commutation failure and limiting the direct current increase. The direct current response is smoother with the proposed fuzzy control in comparison to the conventional controller. It can also be noted from that the advanced firing angle generated by the fuzzy controller is smaller, which means less reactive consumption is required at the inverter side and which is beneficial to the recovery of the ac and dc system. The benefit is evident. It can be seen that with the fuzzy controller, the direct current exhibits relatively faster and more stable recovery.

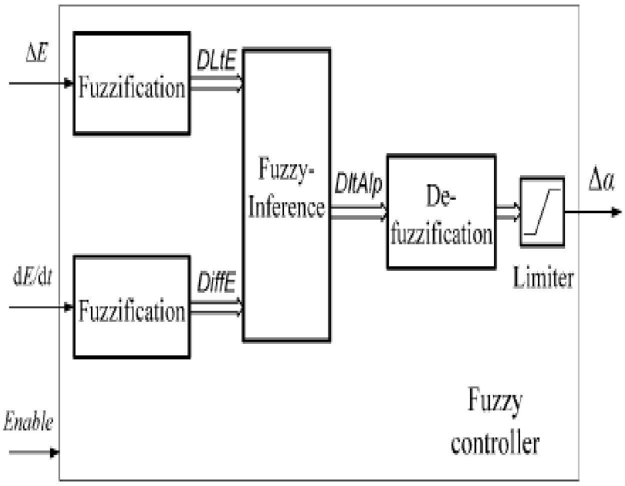
O. *Design of Fuzzy Controller*

A fuzzy logic system is based on a set of intuitive rules. The proposed system uses the following rules to obtain fuzzy control.

- When error is large (positive or negative) and error-dot is positive, the system is quickly diverging from its equilibrium point. Thus, there should be a large increase in control action (large-positive, LP).
- When error is small (or zero) and error-dot is positive, the system is diverging from its equilibrium point, but is not as far away as in the first case. Thus, there should be a smaller increase in control action (small-positive, SP).
- When error is large and error-dot is small (or zero), the error is not quickly increasing, and thus, there should be a small increase in control action (SP).
- When error-dot is negative, the system is converging to its equilibrium point. As a result, the control action should be decreased to prevent the system from oscillating (smallnegative, SN).
- When error and error-dot are zero, the standard PI gains should be used, with zero increase or decrease from the fuzzy controller (zero, Z). The rules show that using three input membership functions (P, Z, N) and four output membership functions (LP, SP, Z, SN) will provide the necessary functionality. The rules dictate that the results of each input membership function are combined using the AND operator, which corresponds to taking the minimum value found that the shape (whether triangular or Gaussian) did not have a noticeable effect on the fuzzy response, while the width did have a significant effect. As a result, Gaussian membership functions are used in this study.

where is varied to change the center (1 for N, 0 for Z, 1 for P) and is varied to change the width of the curve shows a representative selection of the membership functions tested, along with a numbering system to facilitate their reference. After applying the AND operator for each rule, the root-sum square inference method is used. For example, the inference process for LP. The inference process outputs a value, or “strength,” for each output membership function. The defuzzification process is implemented to obtain a single output for the system by using a fuzzy centroid calculation given by where, for example, LPs represents the calculated strength and LPc the center of the output membership function. The crisp output of the fuzzy controller is then passed on to modify the variable-gain PI controller.

Under steady-state conditions, the adaptive fuzzy controller operates as a base controller. From the steady-state operating point, there are two types of events that may occur: changes in operating point and faults. This study first aims to determine which controller should be used (conventional PI or fuzzy-modified PI) to reduce the number of commutation failures and improve the commutation margin. Secondly, to generalize the results for any HVDC system, trends are derived so that in a real-world application, much fewer test simulations would have to be run in order to determine the best controller for each system event. The values for the Gaussian membership functions corresponding to the best controller are stored in a four-dimensional lookup table. The inputs to the look-up table are: rectifier-side rms voltage, inverter-side rms voltage, dc current order, and the event type. These operating conditions have been chosen because they have been found to greatly affect the control response.

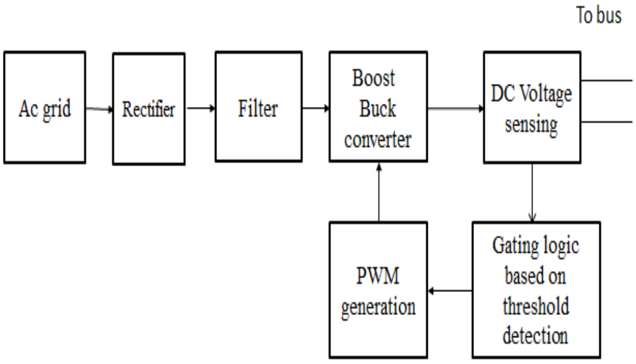


Topology of the fuzzy controller

The output of the look-up table is sent to the fuzzy controller block to choose the appropriate Gaussian membership function. If the look-up table indicates that the regular PI controller is the best option, then “1,” rather than the fuzzy controller output, is multiplied by the PI parameters. When the system has returned to steady-state conditions after the event, the base controller regains control of the system.

II. OPERATIONAL ANALYSIS

In this paper, we investigate an event-based protection scheme for a multi terminal dc power system, which includes hybrid energy resources and various loading schemes. The proposed protection scheme transfers less data when compared with commonly used data-based protection methods and does not require high-speed communication and synchronization. Each protection unit is able to autonomously identify the type of event using the current derivative fault identification method, employing an artificial inductive line impedance. In order to accurately set the protection relays, detailed fault current analysis considering low pass resistor capacitor filter effects are presented. The decision for fault isolation is made based on the unit judgment and the data received through high-level data communication from other interconnected units. The performance of the proposed protection scheme was evaluated under different dc feeder and bus faults. The results show that this scheme is able to accurately identify the type of fault, isolate the faulted area, and restore the system quickly while limiting the load voltage drop to its preset limit. And also we found the voltage level of the system using new electric current transformer based on gate logics.



Block diagram of DC protection scheme

A. Source (Asynchronous Generator)

It is a three-phase asynchronous machine (wound rotor or squirrel cage) modeled in a selectable dq reference frame (rotor, stator, or synchronous). Stator and rotor windings are connected in wye to an internal neutral point.

B. 25 KV-260V 50 KVA Three Phase Transformer

This block implements a three-phase transformer by using three single-phase transformers. Set the winding connection to 'Yn' when you want to access the neutral point of the Wye.

C. Choke

A choke is an inductor used to block higher-frequency alternating current (AC) in an electrical circuit, while passing lower-frequency or direct current (DC).The choke's impedance increases with frequency. Its low electrical resistance passes both AC and DC with little power loss, but it can limit the amount of AC due to its reactance.

D. Breaker

It is a circuit breaker with internal resistance Ron. Ron is required by the model and cannot be set to zero. When the external control mode is selected, a Simulink logical signal is used to control the breaker operation. When the signal becomes greater than zero the breaker closes instantaneously. When it becomes zero, the breaker opens at the next current zero-crossing.

E. Inverter

It implement a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. For most applications the internal inductance Lon of diodes and thyristors should be set to zero.

F. Rectifier

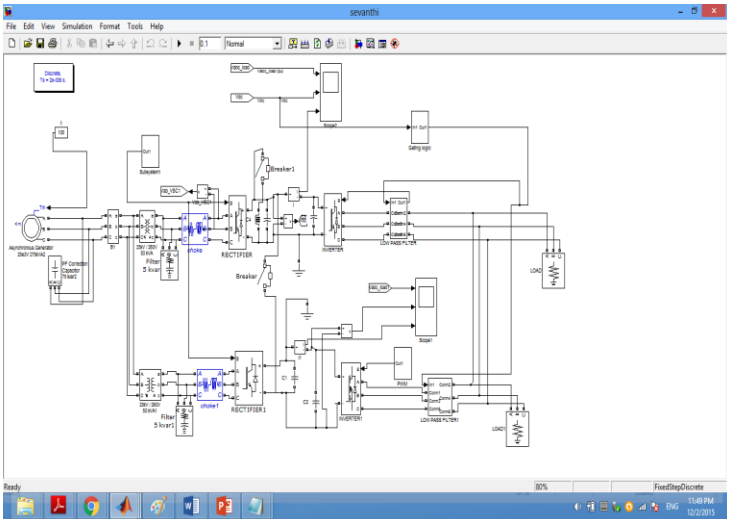
It is a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. For most applications the internal inductance Lon of diodes and thyristors should be set to zero. The value of snubber resistance 1e5 ohms and inductance inf.

G. Load

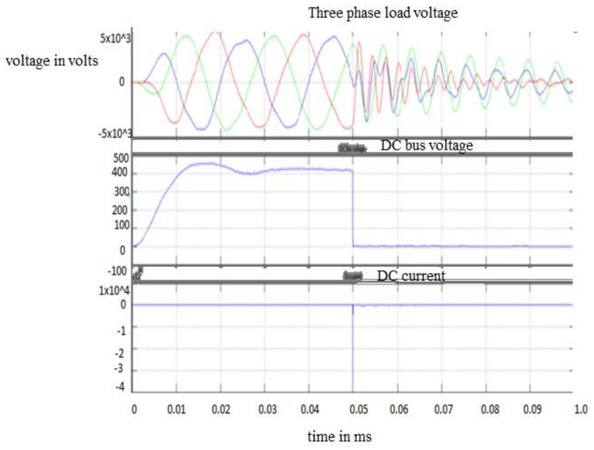
It implements a three phase parallel RLC load. The range of voltage is 50vrms and the frequency is 50hz.Active power is 250w.

This system is more advantageous where, the DC source is kept at a distance. Online tracking is possible, and hence source damage is avoided.Its applications are Telecommunication systems, Shipboard and Spacecraft and distribution systems involving a large number of electronic loads and data centers, dc architectures provide a more effective solution for electric power distribution.

III. SIMULATION RESULTS

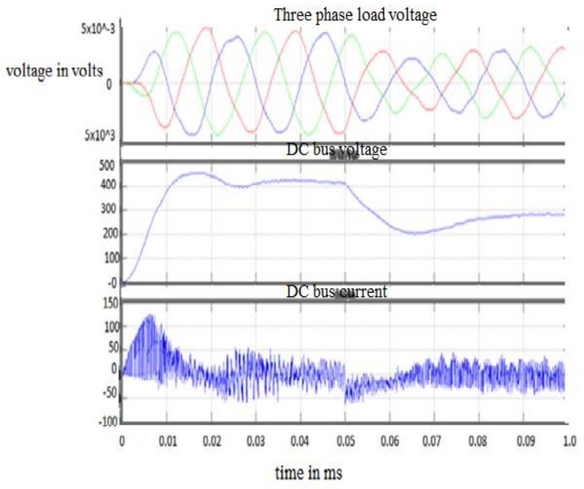


simulink of bipolar DC faults



simulation of without protection

X-axis denoted as time in ms and Y-axis is denoted as load voltage in volts.The grid was supplying load 1 with 250 W, load2 with 2500 W, and load 3, a pulse load with 3.25 kW before the fault occurred. The fault incident, the protection of the first unit detected a bus fault since the derivativeof the fault current exceeded the 2000 A/ms threshold. Then, CB1 was completely opened at *t* = 5.15 ms. Also, the protection of the second and third power unit detected a 493 and 376 A/ms maximum fault current derivative, respectively and classified the fault as an adjacent bus or feeder fault initially. Then, upon receiving the bus fault event from the first unit, an adjacent bus fault was concluded.



Simulation of DC bus voltage with protection

X-axis is denoted as time in ms and Y-axis is denoted as load voltage in volts. The results show that the developed protection scheme and the EMS were able to accurately identify the type of fault, isolate the faulted area, and restore the system very quickly while the load voltage drop was limited to 2.88%.

IV. CONCLUSION & FUTURE WORK

An event-based protection scheme for a multi terminal hybrid dc micro grid was investigated. The notional micro grid considered for this project was implemented in hardware and its dynamic operation was experimentally tested. The current increase has been sensed through a voltage dip, through a threshold based gating logics. Also, for dynamic operation and fault study, an accurate model of this micro grid was implemented in the MATLAB/Simulink environment and evaluated using the experimental test results and the analytical calculations. In the proposed protection strategy developed here, each power unit was able to identify the type of event autonomously. Since high-level data communication was utilized, the protection system did not require high-speed communication and synchronization. The performance of the grid and the proposed protection scheme were evaluated using analytical fault current calculation and a simulation model. The results confirm that the proposed protection scheme is fast and accurate and the grid can ride-through the fault uninterrupted. The detailed analytical analysis given in this project provided essential guidelines to set the protection relays for an event-based protection scheme. This can be utilized in multi terminal dc micro grid, such as renewable energy distributed generation micro grids, data centers, or shipboard power systems where self-diagnosing and self-reconfiguring capability is in high demand. Presently the fault have been detected only at the commutator side and the DC capacitor faults. There could be a still more implementation to solve both DC and AC tolerant systems. The control algrithms can be programmed via an ASIC (application specific integrated circuit) to implement a hardware part of the same. Breakers connected to ethernet would be highly useful for online tracking and instaneous decisin making based on the faults occurred.

REFERENCES

[1] A. Mohamed, C. Cossio, T. Ma, M. Farhadi, and O. Mohammed, “Operation and protection of photovoltaic systems in hybrid AC/DC smart grids,” in Proc. IEEE 38th Annu. Conf. IEEE Ind. Electron.Soc. (IECON), Montreal, QC, Canada, 2012, pp. 1104–1109.

[2] D. Salomonsson, L. Soder, and A. Sannino, “Protection of low-voltage DC microgrids,” IEEE Trans. Power Del., vol. 24, no. 3, pp. 1045–1053, Jul. 2009.

[3] IEEE Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships, IEEE Standard 1709-2010, Nov. 2010.

[4] J. Brozek, “DC overcurrent protection—Where we stand,” IEEE Trans.Ind. Appl., vol. 29, no. 5, pp. 1029–1032, Sep./Oct. 1993.

[5] L. Tang and B. T. Ooi, “Locating and isolating DC faults in multiterminal

a. DC system,” IEEE Trans. Power Del., vol. 22, no. 3, pp. 1877–1884, Jul. 2007.

[6] M. Farhadi and O. Mohammed, “Real-time operation and harmonic analysis of isolated and non-isolated hybrid DC microgrid,” IEEE Trans. Ind. Appl., vol. 50, no. 4, pp. 2900–2909, Jul./Aug. 2014.

[7] M. Farhadi and O. Mohammed, “Adaptive energy management in redundant hybrid DC microgrid for pulse load mitigation,” IEEE Trans. Smart Grid, vol. 6, no. 1, pp. 54–62, Jan. 2015.

[8] M. Farhadi, A. Mohamed, and O. Mohammed, “Connectivity and bidirectional energy transfer in DC microgrid featuring different voltage characteristics,” in Proc. IEEE Green Technol. Conf., Denver, CO, USA, 2013, pp. 244–249.