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Dc Micro grid Monitoring and Protection

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***Abstract* - With the proliferation of distributed energy resources (solar, fuel cell, etc.) and DC loads, the installation and deployment of DC microgrid is seeking more attention in the contemporary paradigm of power system evolution. DC microgrid adds advantage of overall system efficiency increase due to decrease in the conversion losses and ohmic losses. Also, energy storage components are directly connected to the DC bus with the help of bidirectional converters, thus increasing the reliability of the system. However, this stochastic integration of renewable and dynamic operations of controlling poses protection problems for the DC microgrids. The main challenge in DC micro grid protection and control operations is the lack of standards and guidelines. The fault clearing time is also affected due to the lack of inertia and resistive of nature of the network. There is no zero crossing in DC system which affects the operation of the circuit breaker for fault isolation. The presented state-of-art is focused on identification of types of fault protection device, challenges in the DC microgrid system, architecture of DC microgrid controller strategies and different protection techniques are also discussed. This paper review various types of parameter estimation techniques are discussed in detail to improve the protection scheme. Superimposed current based unit protection scheme, protection using the oscillation frequency and transient power, and parameter estimation approach are help to determine the fault location and type of fault..**

***Keywords* - DC micro grid, transient power, fault analysis, intelligent-electronic-device (IED) coordination, communication, oscillation frequency.**

I. INTRODUCTION

Micrograds are intentional or unintentional islands formed either at a consumer facility a or location that integrates parts of the local utility distribution network having at least one distributed energy resource (DER) associated with the loads [1]". Nowadays, deployment of micrograds has resulted into significant advantages to electrical consumers and power grid operators. Some of them are improvement in the power quality of the system, transmission losses reduction and increase in the energy efficiency of the system economically. Micrograds have proven to be the most promising power system structure for the remote locations electricity demand.

Also, the microgrid has a unique islanding proficiency in response to any fault or disturbance on grid side to strengthen the reliability and resilience of the system. Microgrids can be characterized according to the location such as the campus, military, residential commercial, and industrial, secondly based on the size as small, medium, large scales and thirdly on the connectivity i.e. remote and grid connected .However, based on the type of supply service to the customers, can be identified as AC microgrid, DC microgrid and hybrid microgrid. In the AC microgrid, power generated by the distribution resources (DER) can be converted to AC by using the inverters to supply the AC loads. In dc microgrid, rectifiers are used for connecting DERs and DC to AC converters are used for supplying power to AC loads. Moreover, both AC and DC buses are deployed in hybrid microgrid with the type of connection to each bus depending on the loads and DERs connect. In 2005, DOE and CEC jointly commissioned a Navigant consulting report which defined micro grid on the basis of only "two points of universal agreement."

1. Microgrids have interconnected distributed energy resources which supply sufficient power to the loads continuously which are connected in that area.
2. A microgrid performs functions like independent control, and intentional islanding activities with minimum interruption of service.

The revolution in the field of power electronic devices made the DC voltage regulation a simple task. However, a boost in the penetration of distributed energy resources and DC loads also encouraged the research interests in the field of DC Microgrid to increase the overall efficiency of the power system. A DC micro grid supplies power to a residential building, mining area, ships, or college campuses. Various voltage levels of the DC distribution are 380V, 48V and 24V DC. These levels of voltage can be obtained by either 120/230V 3-phase four wire AC distributions or 277/415V as of most of the common DC distribution systems. Emerging semiconductor technologies and continuous improvement in power electronic converter topologies nowadays has led to an easy management with the DC power system. Although, there are several other plausible reasons to rethink about the DC distribution development which can be related to the DC sources, loads and storage elements like batteries etc.

II. DC MICROGRID CONFIGURATION

A microgrid refers to an autonomous and self-sufficient system consisting of multiple distributed generators, energy storages, energy conversion devices, monitors, loads and protection devices. Accordingly, this system is autonomously able to comprehend protection, self-control and management requirements. Micrograds can moreover be connected to the main grid or be remote as an island. Microgrids can be divided into AC, DC and AC-DC hybrid microgrids conferring to the variances of the bus form. A DC microgrid scheme mainly comprises of key components including sources, converters, loads and energy storage.

The typical ring busbar structure of a DC microgrid is shown in Fig. 1. Distributed generations in a DC microgrid are separated into AC and DC sources. Typical DC sources, such as photovoltaic arrays are connected to the DC bus through a DC/ DC converter. Similarly, wind turbine generators are rather connected to the DC bus via an AC/DC converter and greatly decrease the conversion period compared to being connected to an AC bus. Hence, compared with the AC microgrids, the energy conversion stages are significantly abridged.

As per the sources and loads characteristics, AC/ DC, DC/AC and DC/DC converters are required. Various converters are applied to connect dissimilar sources and loads in order to match the necessities such as nominal voltage, galvanic isolation and efficiency. Furthermore, DC microgrids have a lead on conversion over AC microgrids. Usually, converters used in DC microgrids are considerably simpler as there are fewer conversion sections.

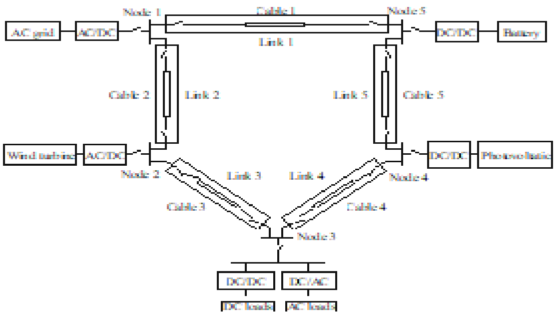

Fig. 1. Typical structure of a DC microgrid.

As a result of the intermittent circumstances of renewable sources, energy storage is essential to poise the power transient response. Besides, energy storage is accountable for power quality improvement and the backup power supply. Common energy storing devices include batteries, flywheels and super capacitors. Flywheel devices must be connected to a DC bus through a machine and converter although batteries and super capacitors can be linked directly.

DC microgrids are utmost appropriate to supply sensitive electronic loads. The power supply characteristics are highly accessible therefore they can compete the demands of the lighting system, data and communication system in addition to the safety scheme. Some DC loads have direct link to the DC bus, whereas other DC loads and AC loads must be fed via converters.

III. USE OF COMMUNICATION IN PROTECTION DEVICES IN MICROGRID

In DC microgrid protection, a dedicated communication channel is also required to transfer the voltage and current signal from one end to the other in both end data based protection scheme. Protection scheme is faster than the controller of DC microgrid; therefore communication system in DC micro grid should be fast and accurate.

Addition of communication channel and network in DC microgrid will significantly improve the performance of the system in the context of stability, MPPT, power sharing, reliability and online system monitoring. DC microgrid communication network with centralized and decentralized control strategy are there to optimize the system performance. Communication systems have the ability to reconfigure the system during abnormal operating conditions. These communication channels may be used to play a significant and important role in the field of protection.

There are different protection solutions for different communication challenges. One of the methods utilizes the use of IEDs at different zones of DC microgrid and the data is thereby used to monitor the fault conditions. Depending upon the application and size of DC microgrid, the communication network may be a home area network, building area network, neighborhood area network, industrial area network, wide area network etc.. When double ended protection schemes are used in DC microgrid, communication delay is the main factor which is responsible for controlling the fault clearing time. Knowing the fact that a DC microgrid consists of a small geographical area and hence the length of the transmission line is short as compared to the length of conventional AC transmission line. Therefore, the impedance of the line is mostly resistive and the rate of increase of fault current is high which limits the fault clearing time of DC microgrid to few milliseconds.

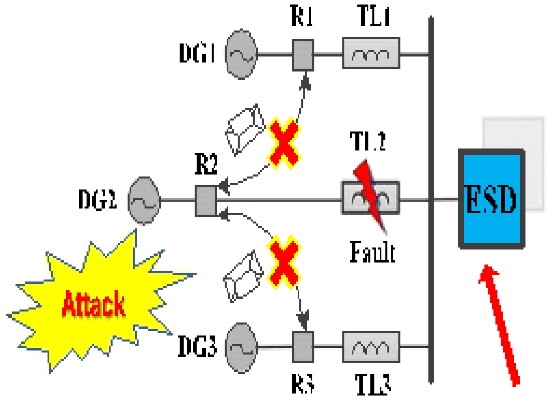

Fig. 2. Configuration of microgrid during islanded mode of operation. Islanded mode of operation.

are different type of DC microgrid mode in which fault current changes according to type of mode use to connect with microgrid. In grid connected mode of microgrid if fault happened at grid side then fault current is 4 to 9 time higher than rated line current so to isolate this fault from heathy part of microgrid the protection devices near to the PCC should be adjusted to higher current ratting and all microgrid protection devices should not be consider it as a fault so that device at PCC end should have enough fast as compare to devices connected in microgrid architecture. In isolated mode of operation the current is 1.3 to 1.8 time of rated current so protection devices should have good communication between them so the can detect type of fault and change their current setting accordingly. Fig 3. So well-designed communication channel to communicate with protection devices and change device setting accordingly.

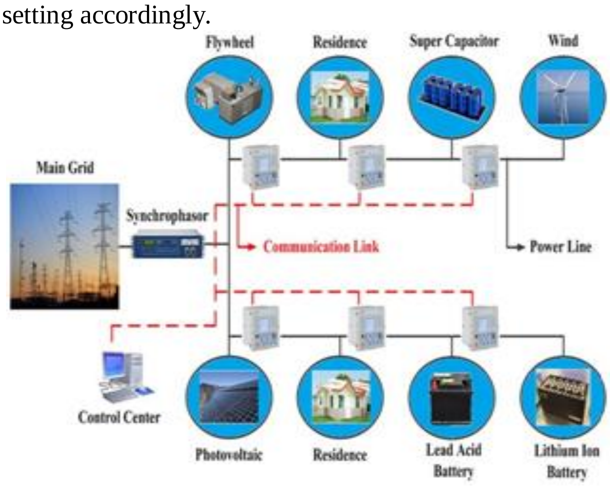

Fig.3. protection devices with communication link.

IV. FAULT ANALYSIS IN DC MICROGRID

1.Fault detection using current difference at both end of bus

Consider a DC microgrid shown in figure 4. For study of fault microgrid is divided in different protection segment. An intelligent electronic device (IED) is installed for each segment to derive protection decision using currents observation of both ends.Due to presence of different type of disturbance as switching phenomena, load change, weather condition and fault the current at each buses change [5]. To measure such a disturbance and initiate main algorithm current information data over a time interval is check. To observe the change and trigger main algorithm disturbance index is check from the below Relation

$$g = \frac{1}{N\Delta t}\left(\sum_{j=1}^{N}\left|i_{j+1} - i_j\right|\right)$$

Where i_j represent sample value of current at jth instant and with the help of selected value of N and sampling interval ξ value is calculated for different type of disturbance and threshold value is decided. When g cross the $\xi limite$, the algorithm triggers the main algorithm where the protection decision is derived. This provides high security in protection decision.

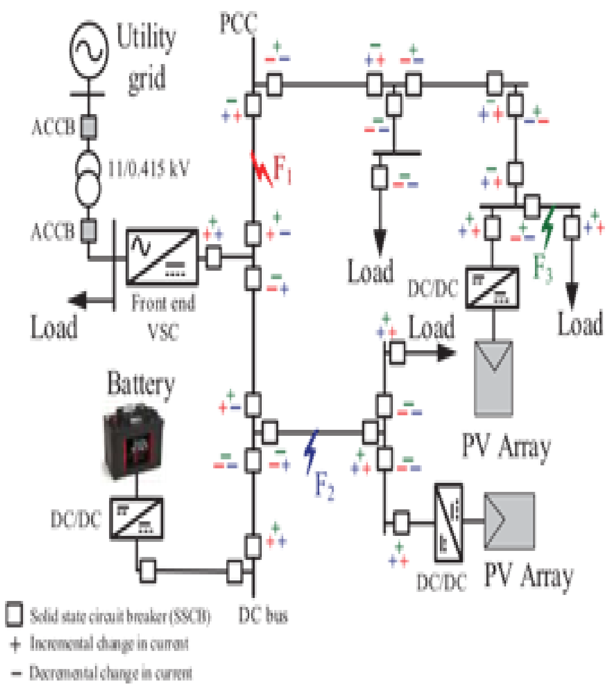

Fig .4. DC microgrid single line diagram.

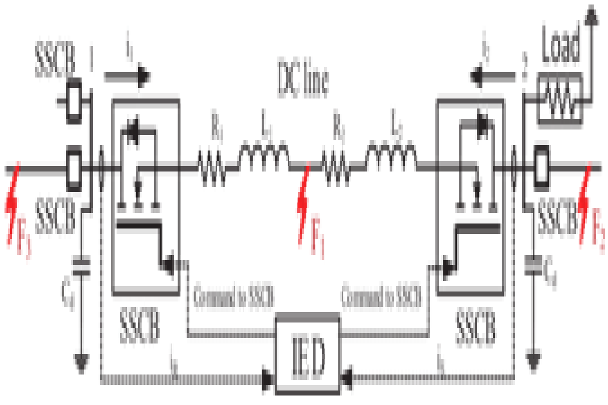

Fig.5. Case of internal fault in DC microgrid.

In state-1 fault analysis, considering switches in blocked state and loop resistance is small in magnitude, the current during fault at F1 will be result from the sources present at the section and existence of loop capacitance till the fault point.

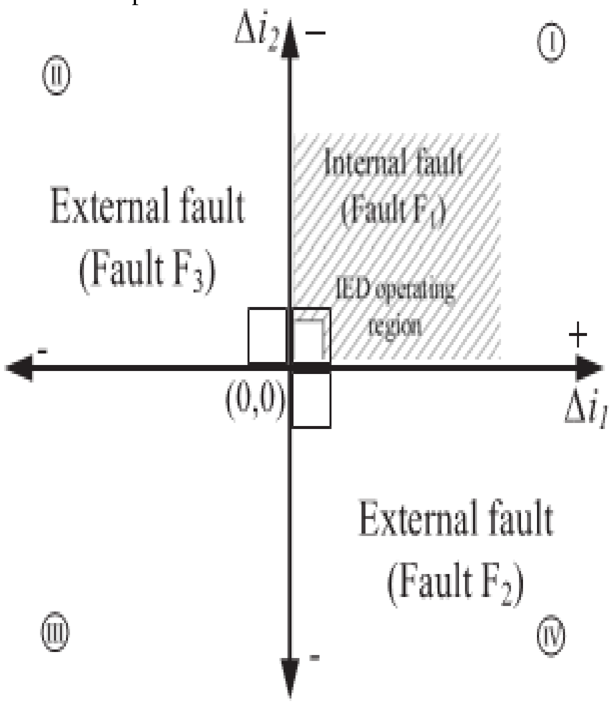

Fig. 6. Δi2 vs. Δi1 in four-quadrant.

$$i_1^{f_1}(t) = \frac{v_{dco}}{R_1}\left(1 - e^{R_1/L_1 t}\right) + \frac{v_{dco}}{Z_{01}} e^{-\alpha 1 t} sin(\omega_1 t + \phi \quad (2)$$

Where $\alpha_1 = {}^{R_1}/_{2L_1}, \omega_1 = \sqrt{\frac{1}{L_1 Cd} - \left(\frac{R1}{2L1}\right)^2}$

$\omega_0 = \sqrt{\alpha_1^2 + \omega_1^2}.Z_{01}$ where $Z_{01} = \sqrt{\frac{L_1}{C_d}}$ represent the surge impedance of the line from fault point to the source end at point 1.for the give case change in current of first bus due to fault in line segment 1-2 of Fig. 5 Δi_1 is find as

$$\Delta i_1(t) = i_1^{F_1}(\mathrm{t}) - i_1^{pre} \quad (3)$$

Where $i_1^{pre} = \frac{v_{dco}}{R_{eq}}$ and $R_{eq} = R_{line} + R_{load}$ it is clear from (3)that Δi_1 is positive during a fault within the section. in similar way at bus 2

$$i_2^{f_1}(t) = \frac{v_{dco}}{R_2}\left(1 - e^{R_2/L2\, t}\right) + \frac{v_{dco}}{Z_{02}} e^{-\alpha 2t} sin(\omega_2 t + \phi)$$

(4)

And as convention of direction of currents as shown in the fig.5, $i_2^{pre} = -i_1^{pre}$

(5)

Where $\alpha_2 = {}^{R_2}/_{2L_2}, \omega_1 = \sqrt{\frac{1}{L_2 Cd} - \left(\frac{R2}{2L2}\right)^2}$ $\omega_0 = \sqrt{\alpha_2^2 + \omega_2^2}.Z_{02}.Z_{02} = \sqrt{\frac{L_2}{C_d}}$ represent the surge impedance of the line from fault point to the source end at point 2.Further from fig. 5 it is clear that for an internal fault i_2^F and i_2^{pre} are in opposite direction thus

$$\Delta i_2(t) = i_2^{F_1}(\mathrm{t}) - i_2^{pre} \quad (6)$$

Thus Δi_2 is positive during a fault within the section.

When an external fault exist at point F2 the current superimpose value change and modification in expression is shown in below equation

$$\Delta i_1(t) = i_1^{F_2}(\mathrm{t}) - i_1^{pre}$$
$$\Delta i_2(t) = -i_1^{F_2}(\mathrm{t}) - (-i_1^{pre}) \quad (7)$$

From the derivation it is observed that fault within any section the IEDs devices connect to that section observe positive value of current change and if fault present out of any section the device near that section observe negative value of current change, so detection of faulty section is become easier by using current superimpose method. Fig. 6 show the area of current change and corresponding faulted section.

2.Fault analysis using oscillation frequency

Oscillation frequency help in determine whether the system running healthy or some fault presence in the system. The oscillation frequency (fosc) during the fault is a define as function of line inductance and capacitance from the source to the point where the fault occurs. IEDs present in the range of this distance detect same foscand different magnitude of fault currents. The frequency of oscillation of the current is measured by the time-derivative method. The first derivative of current gives sinusoidal part of waveform in which oscillating part of current is present as shown in Fig. 6. when second derivative of iosc(t) = 0, at that instant the corresponding value of iosc gives value of the fault current. The oscillation period can be find out by observing the time between two consecutive zero cross point in second derivative of ioscand fosc is obtained .IEDs present at A and B record same frequency fosc for fault F2 as shown in Fig. 5.

$$f_{osc} = \frac{1}{2\pi\sqrt{L_{eq1}.C_{eq1}}}$$

Different fault currents result in different transient power associated at each IED. The transient power is considered in the method to identify the correct faulted section in the microgrid.

Two criteria are used in the proposed method for the protection Decision. Criterion-1: frequency of oscillation of current help to detect the fault in the system. It gives information that fault happen somewhere in system. For this, fault analysis is carried out by using proposed algorithm and mathematics and a threshold frequency (fset) is set for the system. Presence of fault is confirmed, when fosc>fset.Criterion-2: transient power help us to detect faulty section in the microgrid.so for a faulty section Ptr should be positive and P_tr>P_set.

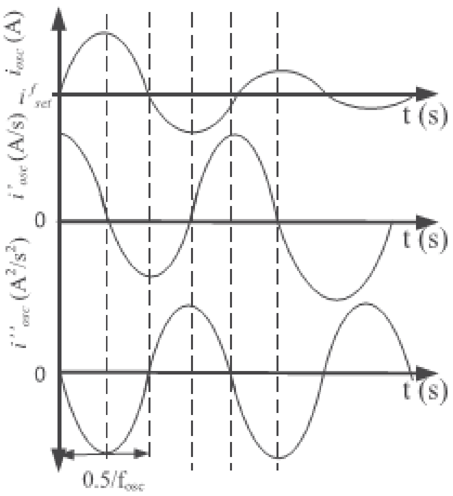

Fig.7. Oscillation of current and its derivatives.

According to operation of circuit tripping signal for protection devices is generated. A flowchart for tripping signal generation is given in figure 7. Which show the algorithm for fault detection and decision making for trip the particular sections protection devices. so faulty part from the system can be isolated and system work healthy.

3. Protection devices

In present time, fuses and circuit breaker are the available protection devices. Due to absence of zero crossing point in DC interruption of current produces arc who's extinguishing is a complicated task .This problem make challenges for applying DC power system technology. Due to running researches helping to overcome this challenges.

Circuit breakers (CB) are the basic devices in DC systems; however the circuit breaker cannot be fulfill the protection requirement. Traditional molded case circuit breakers (MCCB) are the most basic protection devices in existing DC systems. The tripping device of the MCCB could either be thermal-magnetic or electronic so according the manufacturing mechanism the device rating is change. The magnetic tripping devices sense the instantaneous values and the thermal tripping

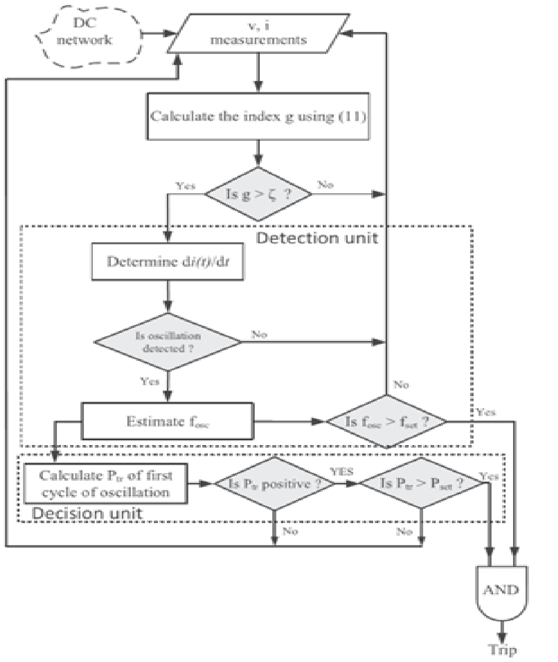

Fig. 8. Algorithm for transient power and frequency method.

devices sense the RMS values of the current. In order to achieve required voltage blocking capacity, the contactors could be connected in a series manner. However the discharging current of capacitor connected to converter have short duration but considerably high magnitudes there may be some case where current force would not be sufficient to open the contact of circuit breakers because of availability of less time for fault clearing.

In order overcome the limitation of the usage of fuses and MCCBs, power electronic based protection devices were come in existence. But these devices have more power losses so some changes are needed to meet the protection requirement. DC microgrid protection devices are shown in fig. 9. Some devices are theoretical basis which will came in existence when some smart technique will develop. So dc microgrid is a good area under the research and has a improved method to overcome problem which are present in conventional grid and AC microgrid.

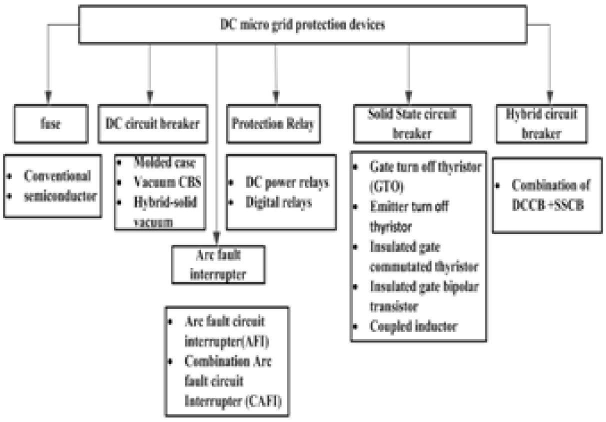

Fig .9. DC microgrid protection devices.

V. CHALLENGES AND OPPORTUNITY

1.Challenges

Due to presence of AC conventional grid, transformation of whole system in DC microgrid is a difficult task.

Some of the following issue found in DC microgrid manufacture

1. Lack of standards in DC system operation is quite complex because DC microgrid is in researching phase.
2. Absence of zero crossing current point in DC current AC circuit breaker was not used in DC application and no standard DC circuit breaker is present so protection issue become major problem in DC microgrid.
3. Lack of DC infra structure.
4. Higher power losses in LVDC distribution network.

2.Opportunities

Increasing of integration of Distribution energy resources(DERs) in conventional grid DC microgrid come in to picture because of some advantage over the existing AC grid system. The following are some of main advantage of DC microgrid over an AC microgrid or conventional AC grid.

1. Number of conversion stages in DC microgrid is less as compare to AC microgrid.
2. No problem of reactive power, harmonics and frequency control.
3. No synchronization issues and controlling become easier as compare to AC grid.
4. Eddy current, hysteresis losses and skin effect are absent.
5. Due to absence of reactance in DC line voltage drop is less so voltage regulation is improved in case of DC microgrid.

So due to existence of energy storage devices of DC in nature and all lightning load in DC nature and integration of Renewable energy resources (PV-cell) DC microgrid become better option from AC microgrid. So there are opportunities for researchers to develop new methods for stability and protection of DC system. Great opportunities for industries also to design new DC devices.

V. CONCLUSION

This latter proposes basic idea of DC microgrid protection strategies and communication between protection devices when operating conditions changes due to load curtailment And unavailability of DGs due to its weather dependency. In the above explanation we also discusses some protection scheme which are superimposed current based unit protection, DC microgrid protection by using oscillation frequency and transient power calculation. Different advantages of DC microgrid over the existing AC conventional grid and AC microgrid also discussed and also Chalanges in upgrading AC grid in DC microgrid.

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