A Novel Approach for Improving Wind Farm Fault Ridethrough Capability using VSC-HVDC and IFSIC.

T.Kavitha[1], P.Nagarjuna[2]
P.G. Student, Department of Electrical and Electronics Engineering, CBIT, Proddutur, Kadapa, India[1].
Associate Professor, Department of Electrical and Electronics Engineering, CBIT, Proddutur, Kadapa, India[2]

Abstract--Faults and device failures in wind farm electrical power generation systems can interrupt their performance causing a huge loss of power and network destruction. Generally the electrical power distribution and generation systems are extremely large and very complex. Due to their inherent complex architecture a small fault in a corner part of the wind farm power generation and distribution system can disturb the entire wind farm system, there by destructing its structure and normal operation. As a result the system should be shut-down until or unless the faulted line or faulted section is located and isolated efficiently. In a Solution to this ever teasing problem a new control approach is proposed for enhancing the fault Ride through capability of wind farms connected to the grid through a Voltage-Source-Converter-based High-Voltage DC(VSC-HVDC) transmission line using an Intelligent Fault Sensing and Isolation Circuit(IFSIC) which will detect and locates the faults and faulted sections in Wind Farm System(WFS) by sensing the spurious fluctuations in line voltage and currents .IFSIC controls the voltage drop in the wind farm connected grid upon occurrence of the fault in the high voltage grid to achieve faster power reduction to decrease the resulting power wastage due to the occurrence of fault. IFSIC has its associated circuitry which will monitors each section of the WFS to detect operational deviation and to counteract accordingly .IFSIC not only acts as a unit which provides the Fault Ride through Capability but also performs the job as a DG unit to integrate the WFS with High Voltage Grid System(HVGS). This project is practically implemented and tested in MATLAB environment and the simulation results proved that the proposed method is the best in all aspects and outperforms all the existing methods and techniques.

Key words-- Wind Farm System, VSC-HVDC, Fault Ridethrough, DG, HVGS and HPS

INTRODUCTION

The growth of any power system grid in the world is and always has been on an accelerating pace, feeding the almost insatiable demand for electrical power for the past century or so [1, 2]. This in turn forces a certain level of intricacy on the power system and that intricacy compounds with time; to the point where the power systems face the inability to progress with ease due to introductions of new transmission systems and construction of generating plants near load centers. As the system grows more complex and burdened with increasing load; various issues regarding cost, pollution, power quality and voltage stability takes centre stage [2].

Distributed Generation (DG) is an electrical power generation unit that is directly connected to a distribution network or placed as nearly as possible to its consumer. The technologies adopted in distributed generation vary in methods of generation including small-scaled gas turbines, wind, fuel cells, solar energy and hydro, etc [1].But in this project we focused on the methods and techniques used to generate the power using the reliable and fault free operation of the Wind Farm System(WFS)s which will consumes the natural renewable energy resource as the raw input and generate the power proportional to the WFS generator rotation speed. Generally all the WFS systems are Hybrid Power System(HPS)s which will generates the hybrid power from the natural renewable energy resources. These HPS will find their extensive use in forest,hilly,terrain and geographically remote areas to where the power from the conventional grid systems cannot reach due to geographical irregularities and discontinuities. The Domestic grids are constructed in such remote areas to distribute the power to all power consumption units and utilities. Such domestic grids are called Off-Grids or Hybrid Grids. From these Off-Grid systems an identical dedicated branch is drawn to several regions surrounding it. To control and monitor the power supply and faults on each line of the Power Distribution Bus (PDB) branch, an identical fault isolation and controlling module is assigned to each bus branch drawn from the Off-Grid System. Wind Farm based High Voltage Grid System (WF-HVGS)is a best example for widely used Off-Grid Hybrid Power System (OG-HPS) in hilly, terrain and geographically irregular and discontinuous remote areas. Generally the electrical power distribution and generation systems are extremely large and very complex. Due to their inherent complex architecture a small fault in a corner part of the wind farm power generation and distribution system can disturb the entire wind farm system, there by destructing it structure and normal operation. As a result the system should be shut-down until or unless the faulted line or faulted section is located and isolated efficiently. Wind Farm Systems are hybrid power generation systems which will generate the power using natural resources. Hence these Hybrid WFS systems can generate and transmit the power grid uninterruptedly until or unless there is no fault occurred. Faults which are very frequent to occur in the WFS are classified into two categories; they are (i) Power generation faults and (ii) Power distribution faults. Power generation faults include the faults which are caused due to the imperfections and ageing of wind farm generator and its associated circuit components such as stator, rotor, slip-rings and commutators. Power distribution faults are the faults which will occur in the VSC-HVDC transmission lines which are used to route the power from WFS to the power grid. The Line-to-Line and Line-to-Ground faults are the two major categories of faults that may occur in the VSC-HVDC transmission lines. Employing an efficient algorithm for real time detection and isolation of above faults is appreciated and this will improves the operational effectiveness of the WFS. Faults and device failures in wind farm electrical power generation systems can interrupt their performance causing a huge loss of power and network destruction. As a result the system should be shut-down until or unless the faulted line or faulted section is located and isolated efficiently. Generally the detection and location of faults in Wind Farm System (WFS)s is a very complex and time consuming task which requires a huge man power. In a Solution to this ever teasing problem and to ensure the fault security of WFS,a new control approach is proposed for enhancing the fault Ride through capability of wind farms connected to the grid through a Voltage-Source-Converter-based High-Voltage DC(VSC-HVDC) transmission line using an Intelligent Fault Sensing and Isolation Circuit(IFSIC) which will detect and locates the faults and faulted sections in Wind Farm System(WFS) by sensing the spurious fluctuations in line voltage and currents.IFSIC which is being used as a DG unit controls the voltage drop in the wind farm connected grid upon occurrence of the fault in the high voltage grid to achieve faster power reduction to decrease the resulting power wastage due to the occurrence of fault. IFSIC has its associated circuitry which will monitors each section of the WFS to detect operational deviation and to counteract accordingly.

Distribution Generation (DG) plays an important role in delivering the power into the distribution system. However, power losses and voltage magnitude must be taken into consideration in order to produce reliable power to consumer. Non-optimal location and sizing of DG units may lead to losses increase together with bad effect on power losses and voltage magnitude. Many optimization techniques that are used to minimize the losses and improve voltage magnitude by considering the optimal sizing and location of DG.In this project a new control approach is proposed for enhancing the fault Ride through capability of wind farms connected to the grid through a Voltage-Source-Converter-based High-Voltage DC(VSC-HVDC) transmission line using an Intelligent Fault Sensing and Isolation Circuit(IFSIC) which will detect and locates the faults and faulted sections in Wind Farm System(WFS) by sensing the spurious fluctuations in line voltage and currents.IFSIC which is being used as a DG unit controls the voltage drop in the wind farm connected grid upon occurrence of the fault in the high voltage grid to achieve faster power reduction to decrease the resulting power wastage due to the occurrence of fault. IFSIC has its associated circuitry which will monitors each section of the WFS to detect operational deviation and to counteract accordingly.

PROPOSED METHOD

In this project we proposed and developed a novel approach for improving fault ride through capability of the Wind-Farm based High Voltage Grid System using the Voltage Source Converter based High Voltage Direct Current(VSC-HVDC) transmission line network and an Intelligent Fault Sensing and Isolation Circuit(IFSIC) .Generally Wind-Farm based power generation systems are the subset of a Distribution Generation (DG) based power generation and distribution systems which can reduce the power loss and improve the voltage profile. Generally the Wind-Farm Systems (WFS) are a small scale power generation and distribution units in located in the remote geographic regions to where the conventional grid electricity cannot reach. Distributed Generation is a renewable energy in small scale located near to the load in the DPS.Generally a Micro –Grid system is a large scale power distribution system which is employed to cover a relatively a large geographic area with its power. In this project we intended centrally to develop a novel method to design and implement an efficient fault protection algorithm for fault security of the Wind-Farm based High Voltage Grid System(WF-HVGS) using an IFSIC and VSC-HVDC transmission line network for effective Observability[3], detection and isolation of faults that occur frequently in the WF-HVDS and to improve the voltage profile and to reduce the power loss. As a matter of fact the Wind Farm Systems (WFS) are the Hybrid Power System (HPS)s which will generates the power from the natural renewable energy resources. These HPS are generally used for Distribution Generation (DG) in Hybrid Power Grid Systems (HPGS) which are especially meant to electrify the geographically remote villages and areas to where the conventional grid electricity cannot reach. At remote areas the HPS are considered as a reliable and viable option for electrification of rural villages and geographically remote areas, where there is a huge scarce for Grid Power. In such remote areas the renewable energy resources such as solar energy, water resources and wind energy are the most dependable means. These renewable energy resources are employed as raw inputs to generate the power using the power generation units such as Photo-Voltaic Cells, Hydro-Power Plants and Wind Farms which are of prime concern in this project. Thus the generated power is distributed to the rural village and geographic remote areas using the power distribution network such as a High Voltage Grid System (HVGS) employing power distribution units. The Generated Power of the renewable energy driven power generation units is called a hybrid power which is not coming from conventional grid system. The Generated Hybrid Power is routed efficiently from generation units to the distribution units using a highly efficient loss less IFSIC along with VSC-HVDC power coupling circuit. The IFSIC will act as a DG unit to maintain the perfect impedance matching between the power generation and distribution units which are being connected to the IFSIC using an efficient VSC-HVDC transmission network. The WFS generates the hybrid power using the power generation units and couples it to the power distribution units using IFSIC module which matches the load impedance of generation unit with the source impedance of distribution unit. Normally these DG units will act as an interconnection circuit between the power generation and distribution units. The DG units will perform the function of the distributed generation along with the power generation and distribution units. The overall arrangement including the power generation units, DG units and power distribution units are collectively named as a Hybrid Power System (HPS) which is aimed at generation and distribution of the hybrid power in remote areas using the renewable energy resources based on the principle of Distributed Generation. Hence the WF-HVGS can also be called as WF-HVGS.The WF-HVGS is also called as Off-Grid Hybrid Power System (OG-HPS). Many of such OG-HPS working mostly in India are generating power which is not at par with grid power. Due to high penetration of Distributed Generation (DG) in the WF-HVGS, the transmission networks are no longer responsible for security issues in WF-HVGS.All the control of power among different renewable sources while maintaining the power quality oriented supply is very important for the reliable and sustainable Operation of WF-HVGS.DG units may also participate in security as well as power generation and distribution activities depending on their locations . Installation of DG in power system can reduce the power loss and improve the voltage profile. Generally Power Grids are large scale distribution power networks of very complex architecture, construction and structure. These huge complex Power Grid Networks will be employed to serve a relatively large area with its power. Hence these are considered as the giant class distributed power systems which will cover a large area. All the times these huge complex networks cannot spread their branches to the remote areas due to the geographical conditions and discontinuities of these areas. The unfair geographic conditions oppose the extension of the conventional grid branches to remote areas. Generally a distributed power system is a huge network which distributes the power over a large areas surrounding it .It becomes a gigantic power distribution source for all the major regions surrounding the network. The most practical example of the distributed power system is the Power Grid which supplies the power over the large extent in the regions surrounding it. Some grids will supply the power to several districts surrounding it by treating them as their operational zones. Some big distributed power systems can have several states around it as their zones of operation. Under the situation that distribution system consisting of a number of radial feeders are always subject to the various types of fault caused by storms, lightning, snow, freezing, rain, insulation breakdown, and short circuits caused by birds and other external objects, desired reliability cannot be achieved very easily.

In traditional methods, customers' calls are the base of outage troubleshooting. That is, usually the utility starts to identify faults when they are informed by consumers about a fallen electric pole, broken cable, or when they receive complaints about the cut in power supply [3]. In order to specify the exact location of the fault there has to be a precise overlap between the geographic location of the caller and the connectivity of the distribution network. In addition, if the fault occurs during the night-time, the utility might not receive any calls, which poses a problem for the operator in locating the fault. Also, barriers such as practical difficulties to install the measurement devices at each distribution system bus or problems such as communication failures limit the possibility of measuring currents in the lines and voltages at the distribution transformers.

Also, since the WF-HVGS is a huge and very complex network, which carries the power transmission operation over large areas surrounding it. The quality and uninterrupted HVGS is achieved with the robust and fault free operation of it. Reliability of the WF-HVGS can be improved with its fault free operation. But in general in any HVGS the faults and device failures are very frequent to occur. These faults can affect the power quality in HVGS and cause losses to both electric utilities and customers by causing an undesirable deviation in their operational condition there by leading to their malfunction. Any unexpected deviation in the normal operational condition of the device is treated as a fault. The possible types of faults that have the probability to occur in the HVGS are discussed earlier in this thesis. Naturally in any distributed network, safety and secure operation of the system highly rely on the level of power system operating condition monitoring.

Due to its huge and complex networking structure of the HVGS, a small fault occurred at one remote corner of the network, will cause a large deviation in the operational conditions of the network. For instance, let us consider that the WF-HVGS is being operated with a ring bus like architecture. The power from the generation stations will reach to the power distribution source from where it is given to excite the power distribution bus(ring bus).From this bus the branches are derived in all directions to supply the power to all the regions surrounding it. For each region in one particular direction an unique branch will be derived. All the bus branches are supplied with power by the power distribution bus (which is of loop structure). A small fault in the corner part of the network due to environmental changes like snow, rain fall, storms,thunders,birds and animals not only the associated remote branch of the network but also entire power distribution network will get disturbed and creates an essence to primarily shut-down the entire network until the fault and the faulted line is traced and isolated. It takes a huge time to test each and every line to detect the fault and the faulted line. During this time the network will be in an idle (shut-down) state. This will cause a remarkable loss to both production industries, business organizations and other consumers of electricity.

In order to improve the reliability, utility should be able to detect and recognize the fault location and type immediately after fault occurs. The faster the fault location is identified or at least estimated with reasonable accuracy, the more accelerated the maintenance time to restore normal energy supply. Since the Distributed Generation –Hybrid Power Systems(WF-HVGS)are the only possible means to electrify the remote villages and regions of irregular geometric structures and unfair atmospheric conditions, the reliable and sustainable operation of these WF-HVGS systems are of great importance to ensure uninterrupted renewable power generation and distribution to the remote geographic areas to where the grid electricity cannot fulfill the need of their electrification. The most sophisticated and effective algorithms are required for practical realization of the aforementioned task. Real time fault protection without operational disturbance of the WF-HVGS is challengeous and almost impossible task we developed a new

Distribution Generation (DG)unit using the novel most efficient and widely accepted techniques called the IFSIC and VSC-HVDC.The IFSIC module senses the faults and fault conditions with the knowledge of the power level deviations on the individual power distribution lines from their rated counterparts and isolates them accordingly to avoid their effect on and to protect the rest of the power distribution network from being destroyed by the resultant faults. The technique exploits the close relationships between the voltage and current phasors of power lines using the mesh voltage and node current analysis and uses these universally accepted relationships to detect the deviations in the line parameter values such as line amplitude, impedance and admittance levels. Using this analysis as the core processing unit an IFSIC module performs the real time fault detection and isolation without causing any disturbance to the normal operation of the WF-HVGS.A detailed implementation procedure and operational structure of IFSIC based WF-HVGS is provided in the proposed work.

PROPOSED WORK

In this project we designed, developed and implemented a most efficient and functionally effective IFSIC unit to employ as a DG unit in the emerging VSC-HVDC based WF-HVGS system to ensure the real time fault protected and power quality enhanced operation of the WF-HVGS.We constructed a IFSIC Control Network to act as an efficient DG units for fault free operation of WF-HVGS.The schematic block overview of the proposed WF- HVGS system is shown in figure (1).

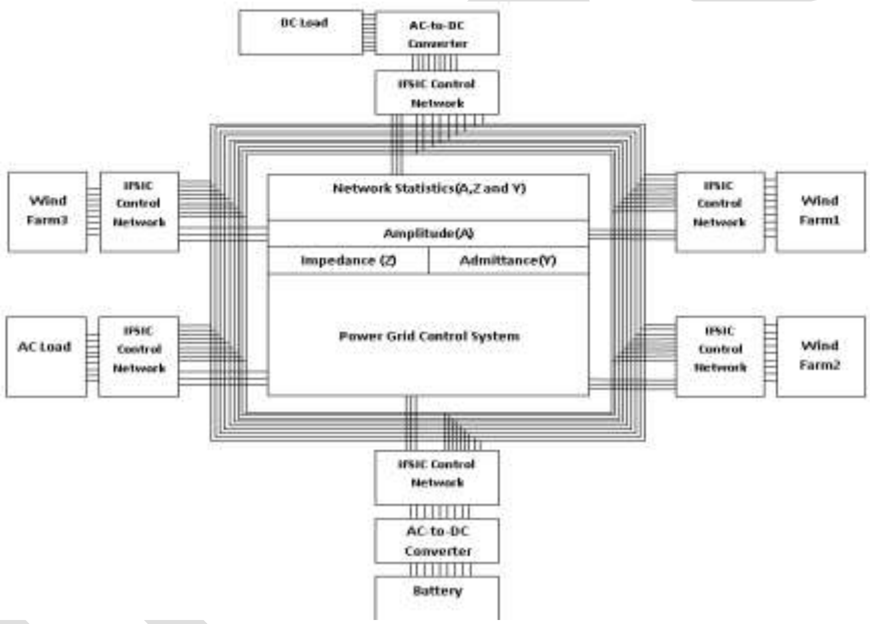


Fig (1): Schematic block diagram of the proposed WF-HVGS System.

The proposed system consists of a Distributed Generation(DG) based WF-HVGS which is implemented using a ring bus like architecture as shown in figure(1).The ring bus architecture enables the WF-HVGS to serve the regions surrounding it with its power. WF-HVGS supplies the power to all regions or zones around it .One identical bus branch is drawn to each and every region or zone. Each power distribution bus branch is put under the control of an unique IFSIC Control Network as shown in the figure(1).Each IFSIC Control Network will control and monitors the assigned bus branch for faults and acts accordingly to detect, isolate the faults without showing any impact on the operational power quality and effectiveness of the WF-HVGS.The WF-HVGS maintains the data base of rated values of line parameters of individual lines of Power Distribution Bus(PDB) and Power Generation Bus(PGB) of the WF-HVGS.The rated line parameter values are used as the basis for fault detection, isolation and power quality correction in a WF-HVGS.WF-HVGS also consists of a Power Grid Control System(PGCS),which will control and regulates all operational activities of WF-HVGS.PGCS simply serves as a control system for WF-HVGS.All the IFSIC Control Networks are put under the control and direction of DPGCS.The PGCS controls all the IFSIC Control Networks through three control signals. The internal architecture of the IFSIC Control Network based DG unit is shown in figure (2).The IFSIC Control Network based DG unit will consists of an IFSIC Module and its associated bi-directional breakers. An identical set of breakers are used on both distribution and generation sides. The breakers on distribution side are identified with a prefix ‘D’ in their terminology to indicate the distribution side, where as the breakers on the power generation side are added with a prefix ‘G’ in their terminology to indicate the power generation side. The internal architecture of the IFSIC Module consists of a ROM unit, two dedicated RAM units one for each side(i.e., one for generation side and one for distribution side) ,two mini processes(Line Amplitude Sensors(LAS),each for both PDB and PGB) and a Fault Sensing and Decision Making Device(FS-DMD) units. The time switched checking and comparing operations are adopted by the FS-DMD, so as to check the line faults in both PDB and PGB.A fixed time slot is set to switch the operational status check between the power generation and distribution buses. Required time duration is provided by the Astable multi-vibrator circuit as shown in below figure(2).

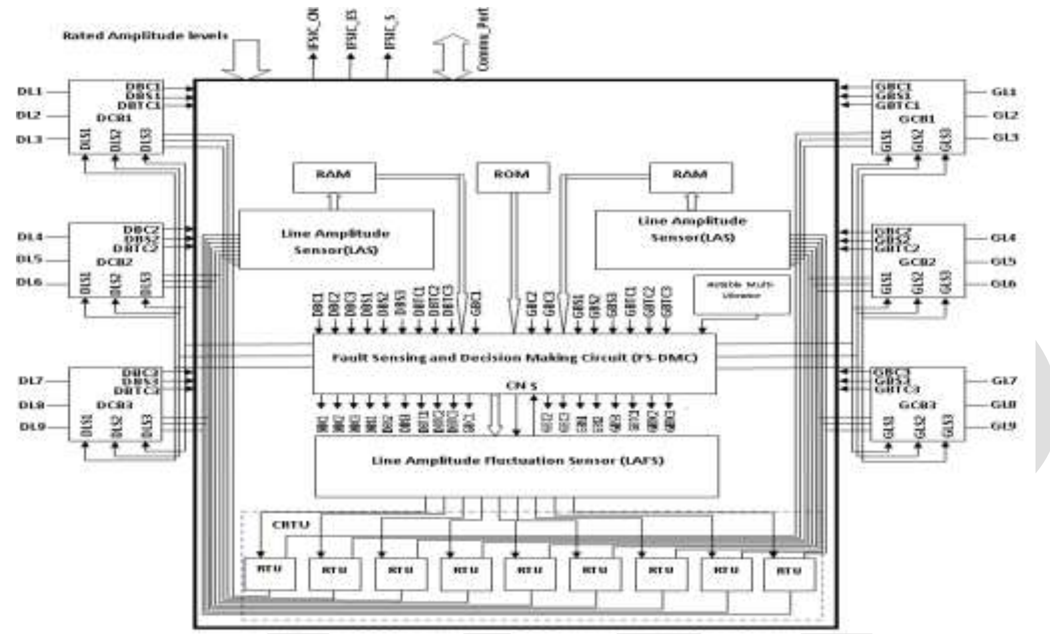
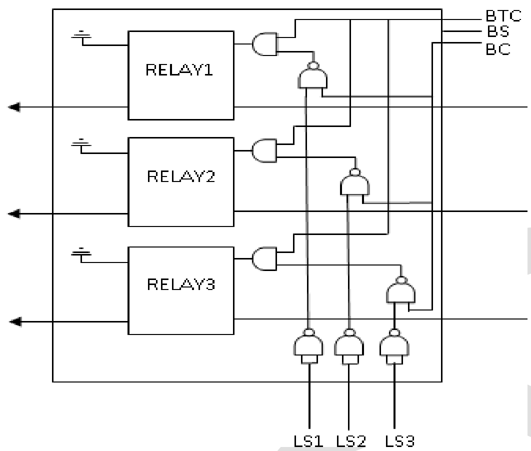


Fig (2): Schematic block diagram of the proposed IFSIC Control Network

A devoted mini-processor (Line Parameter Calculation Circuit) is assigned for both Power Generation and Distribution Bus units to calculate the instantaneous line parameter values of PDB and PGB.The objective of RAM unit is to store the rated parameter values from data base unit of WF-HVGS.The Time Switched Comparator and Decision Making Device accepts the instantaneous line parameter values and rated line parameter values along with the control, status and trip signals of the individual breakers as input and processes them accordingly to issue the necessary control signals to all breakers to ensure the fault free and regulated operation of the proposed WF-HVGS.A single IFSIC Module inside the DG unit controls all the breakers on both power generation and distribution sides. Each DG unit is put under the control of the PGCS unit which will control them with a specialized set of three control signals they are: IFSICCN (IFSIC Control),IFSICS(IFSIC Status) and IFSIC Error Status(IFSICES).Whose direct implementation. The Control signal logical definitions are given as

IFSICCN→IFSIC based DG unit control signal; If IFSICCN=1;DG unit is enabled, otherwise disabled.IFSICS→ IFSIC based DG unit Operational Status. If IFSICS=1; All the internal components of DG unit are working perfectly and the DG unit is active at this instance of operation, otherwise there is an error in the operational condition of internal components of the DG unit.IFSICES→IFSIC based DG unit Error Status. If IFSICES=1; there is a fault in the lines of the bus branch being monitored by this DG unit. Otherwise there is no fault in the lines of the bus branch being monitored by this IFSIC based DG unit.

At every instant of its operation, the instantaneous operational status of the DG unit is informed in terms of a detailed text message format to the PGCS unit. The PGCS unit receives the operational status messages from all the DG units to examine their operational condition and to act accordingly. If the PGCS unit receives a message stating an error in the operational condition of a particular DG unit, the PGCS unit passes the messages received from the corresponding DG unit which is monitoring the faulted bus branch for faults to the technical department. Since this message from the DG unit consists of a detailed information about the operational conditions of the region to which it is assigned as an independent region monitoring device, if any line fault is occurred in a region, then that fault condition is precisely identified by its type, location and number of the line suffering from the fault and the same information is informed to the technical department so as enable faster recovery of faults with negligible amount of delay and man power. The internal architecture of the breaker circuit is shown in below figure (3), which consists of three relay circuits to control three lines one for each line and the associated control circuitry. Each relay will control and monitor the close or open status of one particular line. Each breaker has three control pins such as BC,BS and BTC with access of which the associated IFSIC controls its operation..If a fault is occurred in a particular breaker lines, then it will get tripped by making its BTC=1 and based on the logic levels on Line Status(LS)pins such as LS1,LS2 and LS3,the relay of the particular faulted line will get discharged there by isolating the corresponding faulted line. When LS1=0, then first line of the breaker will faulty and hence isolated from the network. Similarly, if LS2=0, second line of the breaker will be isolated and if LS3=0 then the third line of the breaker will be isolated.



Fig(3):Internal architecture of the breaker circuit.

RESULTS AND DISCUSSION

To verify the operational effectiveness of the proposed WF-HVGS, the computer simulations have been performed using MATLAB.The algorithm is designed, programmed with six operational zones and simulated using Matlab.As a first task after starting its operation the WF-HVGS initializes all its IFSIC based DG Units for rated fault free operation. This initialization includes loading the rated parameter values of line voltage, line currents and associated phase deviations by individual IFSIC Units from the WF-HVGS as given in table (1), table (2) and table (3).The initialization data of the WF-HVGS is given as follows.

Initializing The WF-HVGS Rated Line Currents..........

SNO	BUS LINE	RATED CURRENT LEVELS(in A)
1	LINE1	50
2	LINE2	50
3	LINE3	50
4	LINE4	50
5	LINE5	50
6	LINE6	50
7	LINE7	50
8	LINE8	50
9	LINE9	50

Table (1): Line Current Initialization.

Intializing The Network Rated Line Voltages..........

SNO	BUS LINE	RATED VOLTAGE LEVELS(in V)
1	LINE1	400
2	LINE2	400
3	LINE3	400
4	LINE4	400
5	LINE5	400
6	LINE6	400
7	LINE7	400
8	LINE8	400
9	LINE9	400

Table (2): Line Voltage Initialization.

Intializing The Network Rated Line Phases..........

SNO	BUS LINE	RATED PHASE LEVELS(in Deg)
1	LINE1	0
2	LINE2	40
3	LINE3	80
4	LINE4	120
5	LINE5	160
6	LINE6	200
7	LINE7	240
8	LINE8	280
9	LINE9	320

Table (3): Line Phase Initialization.

Intializing The Network Rated PHASE Voltages..........

SNO	BUS LINE	RATED PHASE VOLTAGE LEVELS(in V)
1	LINE1	230
2	LINE2	230
3	LINE3	230
4	LINE4	230
5	LINE5	230
6	LINE6	230
7	LINE7	230
8	LINE8	230
9	LINE9	230

Table (4): Network Rated Phase Voltages.

The operational results of the proposed algorithm under fault free conditions of the WF-HVGS are presented primarily as follows. Under fault free condition the operational status of the IFSIC unit on both Generation and Distribution sides are given in table(5) and table(6).

IFSIC GENERATION UNIT OPERATIONAL SUMMARY

SNO	Control Variable	Operational Status
1	IFSIC Control	Enabled
2	IFSIC Status	Active
3	IFSIC Error Status	No Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC1 Status	Untrip
11	BTC2 Status	Untrip
12	BTC3 Status	Untrip

Table (5): IFSIC Unit Operational Summary on Generation Side.

IFSIC DISTRIBUTION UNIT OPERATIONAL SUMMARY

SNO	Control Variable	Operational Status
1	IFSIC Control	Enabled
2	IFSIC Status	Active
3	IFSIC Error Status	No Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC1 Status	Untrip
11	BTC2 Status	Untrip
12	BTC3 Status	Untrip

Table (6): IFSIC Unit Operational Summary on Distribution Side.

If there is no error in the IFSIC Unit of a particular branch, then its control, status and error status are in enabled, active and no error conditions. Ultimately all the breakers will work perfectly and doesn't cause any line trip problem. The IFSIC Unit's operational performance summary on both Generation and Distribution sides are given in table (7) and table (8).

IFSIC GENERATION UNIT PERFORMANCE SUMMARY

SNO	IFSIC_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Closed	Rated	Rated	Rated
3	LINE3	Closed	Rated	Rated	Rated
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Closed	Rated	Rated	Rated
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (7): IFSIC Unit's performance summary on Generation side under fault free conditions.

IFSIC DISTRIBUTION UNIT PERFORMANCE SUMMARY

SNO	IFSIC_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Closed	Rated	Rated	Rated
3	LINE3	Closed	Rated	Rated	Rated
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Closed	Rated	Rated	Rated
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (8): IFSIC Unit's performance summary on Distribution side under fault free conditions.

The status and variational characteristics of breaker currents of the IFSIC Unit breakers with respect to the operational conditions for fault free operation on both Generation and Distribution sides are illustrated in fig(4) and fig(5) respectively. When a particular breaker of the IFSIC Unit is working according to the normal fault free operational condition, then its current variation is also normal and is logic high, otherwise the current variation is abnormal and logic low.

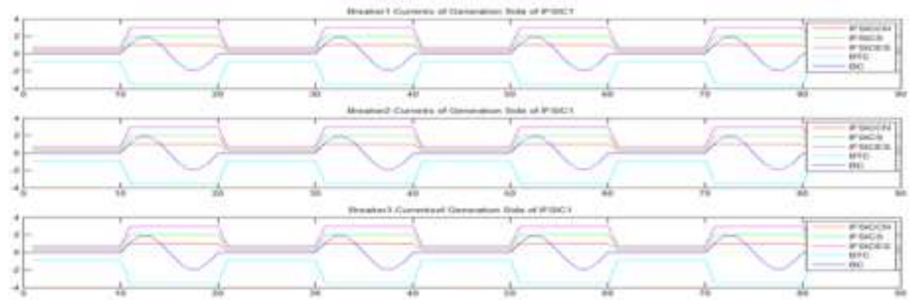


Fig (4): Breaker currents of the IFSIC Unit breakers on Generation unit under fault free condition.

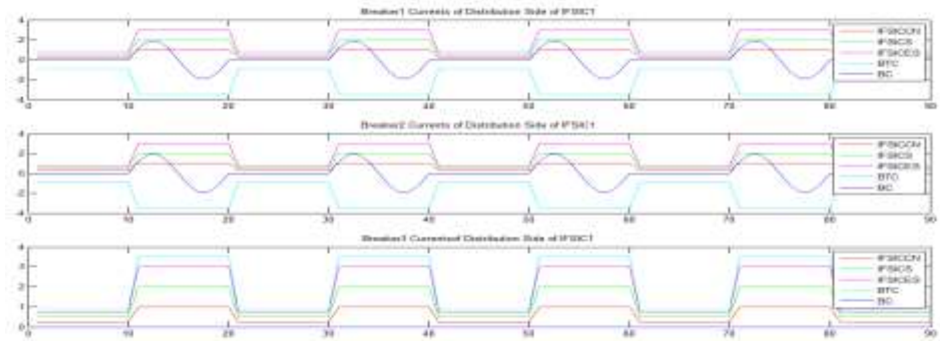
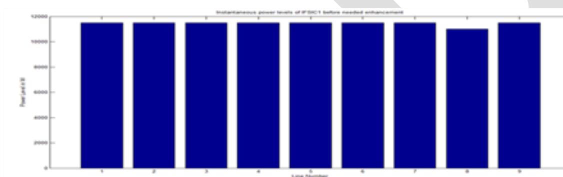
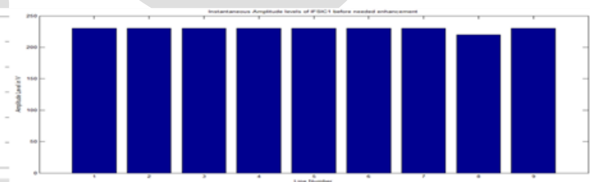


Fig (5): Breaker currents of the IFSIC Unit breakers on Distribution side under fault free condition.

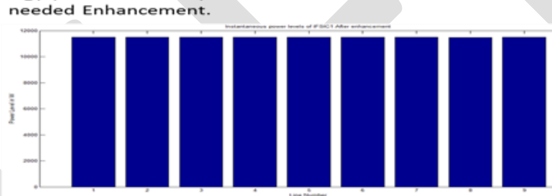
The power quality enhancement results of the proposed IFSIC under fault free operational conditions are presented in fig(6)-fig(9).



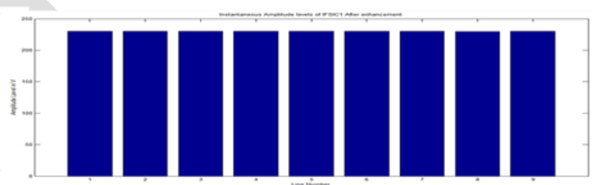
Fig(6):Instantaneous power levels of an IFSIC before the needed Enhancement.



Fig(7):Instantaneous amplitude levels of an IFSIC before the needed Enhancement.



Fig(8):Instantaneous power levels of an IFSIC after the needed Enhancement.



Fig(9):Instantaneous amplitude levels of an IFSIC after the needed Enhancement.

The line amplitude levels of the discrete HVDC lines on both generation and distribution sides of IFSIC unit under fault free operation of WF-HVGS are shown in fig (10) and fig (11) respectively.

Fig (10): Line Amplitude Levels of Discrete HVDC Lines on Generation Side of IFSIC.

Fig (11): Line Amplitude Levels of Discrete HVDC Lines on Distribution Side of IFSIC.

If any fault is occurred in the IFSIC based WF-HVGS.The the operational conditions and results may get deviated from the rated fault free operational conditions and results. The simulation results of the proposed algorithm under faulty operational conditions of the WF-HVGS are presented as follows. Under faulty condition the operational status of the IFSIC unit on both Generation and Distribution sides are given in table (9) and table (10).

IFSIC GENERATION UNIT OPERATIONAL SUMMARY

SNO	Control Variable	Operational Status
1	IFSIC Control	Enabled
2	IFSIC Status	Active
3	IFSIC Error Status	Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC2 Status	Untrip
11	BTC2 Status	Trip
12	BTC3 Status	Untrip

Table (9): Operational Summary of an IFSIC Generation Unit under faulty condition.

IFSIC DISTRIBUTION UNIT OPERATIONAL SUMMARY

SNO	Control Variable	Operational Status
1	IFSIC Control	Enabled
2	IFSIC Status	Active
3	IFSIC Error Status	Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC2 Status	Untrip
11	BTC2 Status	Trip
12	BTC3 Status	Untrip

Table (10): Operational Summary of an IFSIC Distribution Unit under faulty condition.

If there is an error in the IFSIC Unit of a particular branch, then its control, status and error status are in disabled, inactive and error conditions. Ultimately all the faulty breakers will get tripped. The IFSIC Unit's operational performance summary on both Generation and Distribution sides are given in table (11) and table (12).

IFSIC GENERATION UNIT PERFORMANCE SUMMARY

SNO	IFSIC_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Closed	Rated	Rated	Rated
3	LINE3	Closed	Rated	Rated	Rated
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Opened	Change	Change	Change
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (11): Performance Summary of an IFSIC Generation Unit under faulty condition.

IFSIC DISTRIBUTION UNIT PERFORMANCE SUMMARY

SNO	IFSIC_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Closed	Rated	Rated	Rated
3	LINE3	Closed	Rated	Rated	Rated
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Opened	Change	Change	Change
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (12): Performance Summary of an IFSIC Distribution Unit under faulty condition.

The status and variational characteristics of breaker currents of the IFSIC Unit breakers with respect to the operational conditions for faulty operation on both Generation and Distribution sides are illustrated in fig (12) and fig (13) respectively.

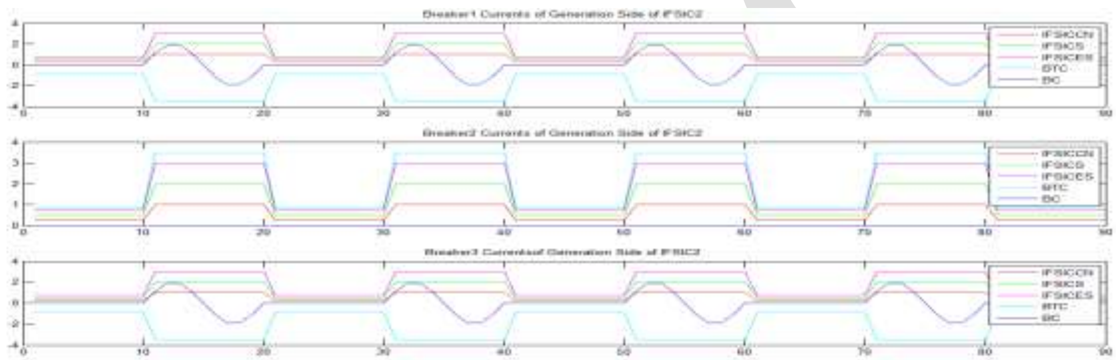


Fig (12): Breaker Currents of an IFSIC Generation Unit under faulty operation.

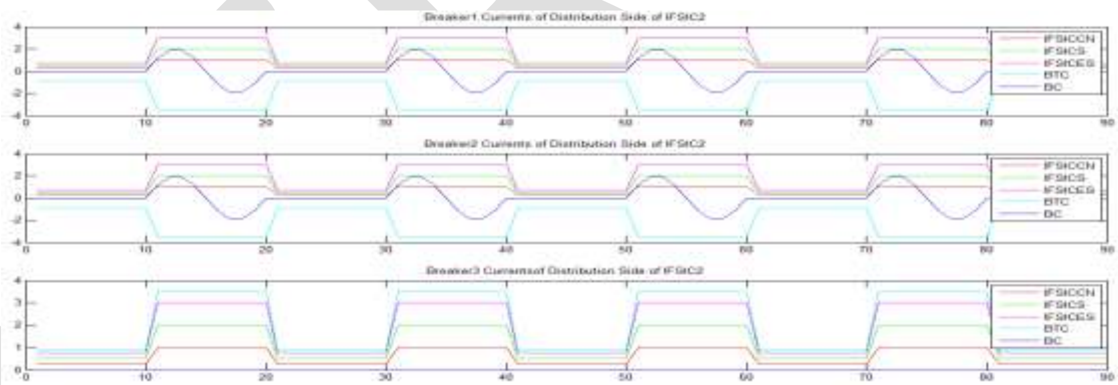
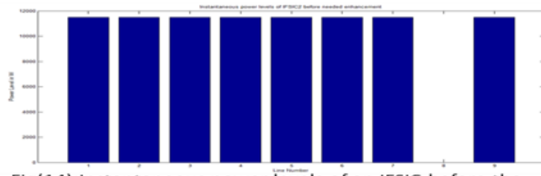
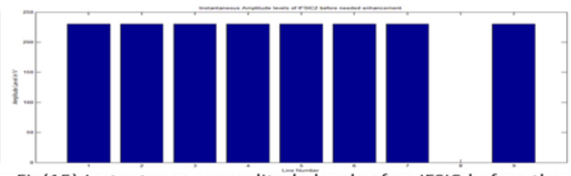


Fig (13): Breaker Currents of an IFSIC Distribution Unit under faulty operation.

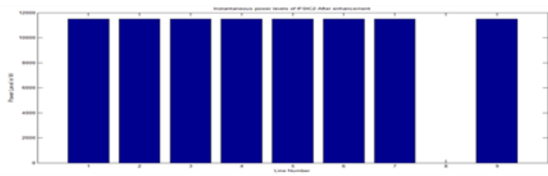
The power quality regulation results of the proposed IFSIC unit under fault free operational conditions are presented in fig (14)-fig (17).



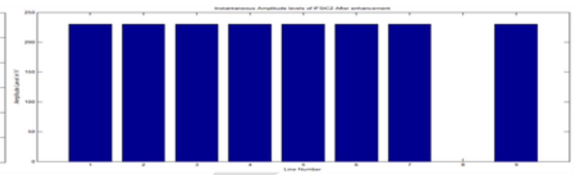
Fig(14):Instantaneous power levels of an IFSIC before the needed Enhancement.



Fig(15):Instantaneous amplitude levels of an IFSIC before the needed Enhancement.



Fig(16):Instantaneous power levels of an IFSIC after the needed Enhancement.



Fig(17):Instantaneous amplitude levels of an IFSIC after the needed Enhancement.

The line amplitude levels of the discrete HVDC lines on both generation and distribution sides of the IFSIC unit under faulty operation of the WF-HVGS are shown in fig (18) and fig (19) respectively.

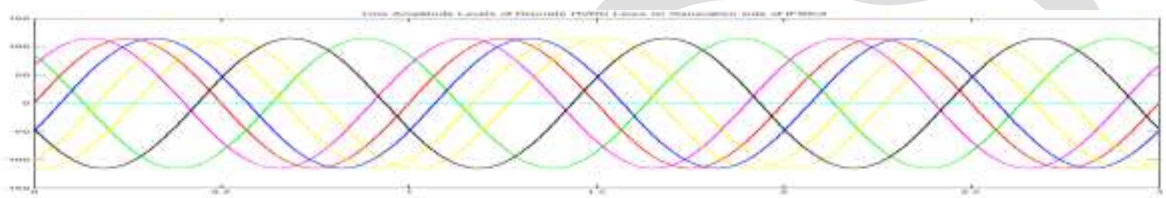


Fig (18): Line Amplitude Levels of Discrete HVDC Lines on Generation Side of IFSIC.

Fig(19):Line Amplitude Levels of Discrete HVDC Lines on Distribution Side of IFSIC.

CONCLUSION

The importance to maintain the reliable WF-HVGS operation demands an efficient fault detection and location algorithms on both power generation and distribution sides which reduces the time and cost of fault identification and isolation. Robust and fault free operation of a Wind-Farm based High Voltage Grid Systems(WF-HVGS) can benefit the power distribution company, network and also the consumers. Some years of research was dedicated to find an appropriate means to improve the fault ride through capability of Wind Farm System(WFS)s for. As a result, several algorithms were proposed in the literature at an incremental stage of research, but still a rapid improvement in the algorithm and techniques used for adaptive security of WF-HVGS is demanded by the today's huge, deeply routed and very complex distributed power systems.

In this project in order to counteract to the challenges in the adaptive security of the WF-HVGS, we proposed ,designed and implemented a new fault monitoring and isolation algorithm for enhancing the fault Ride through capability of wind farms connected to the grid through a Voltage-Source-Converter-based High-Voltage DC(VSC-HVDC) transmission line using a robust Intelligent Fault Sensing and Isolation Circuit(IFSIC) which will detect and locates the faults and faulted sections in Wind Farm System(WFS) by sensing the spurious fluctuations in line voltage and currents. The proposed algorithm employs an IFSIC units as the key security monitoring devices on both Power Generation and Distribution Sides. The proposed algorithm is implemented and tested in MATLAB 2012b environment. The simulation results of the proposed algorithm have proven that the proposed IFSIC Control Network is very efficient in providing the robust fault security of the WF-HVGS systems. The testing results adjudged that the proposed algorithm is working well and outperforms all the existing algorithms.

FUTURE WORK

This algorithm is proven to be the best in performance in all aspects by its performance. In this project in order to reduce the complexity of implementation, the proposed algorithm is practically implemented with 9-line ring bus architecture. But there are no practical constraints on the size of the network and hence it can be extended to any large size WF-HVGS with increased number of operational zones and any higher order bus. Increase in the physical size of the WF-HVGS network doesn't cause any performance dissimilarities and extra limitations. As a consequence the physical size and processing capability of the internal components has to be justified with the proper selection of the internal components of matched capacity and efficiency.

REFERENCES:

[1] Mirzai, M.A.; Afzalian, A.A., "A Novel Fault-Locator System; Algorithm, Principle and Practical Implementation," Power Delivery, IEEE Transactions on , vol.25, no.1, pp.35,46, Jan. 2010.
[2] Faradonbeh, M.A.; Bin Mokhlis, H., "Unbalance fault location in electrical distribution system," Electrical Power Distribution Networks (EPDC), 2011 16th Conference on , vol., no., pp.1,8, 19-20 April 2011.
[3] Thukaram, D.; Khincha, H. P.; Vijaynarasimha, H. P., "Artificial neural network and support vector Machine approach for locating faults in radial distribution systems," Power Delivery, IEEE Transactions on , vol.20, no.2, pp.710,721, April 2005.
[4] Javadian, S. A M; Nasrabadi, A.M.; Haghifam, M.-R.; Rezvantalab, J., "Determining fault's type and accurate location in distribution systems with DG using MLP Neural networks," Clean Electrical Power, 2009 International Conference on , vol., no., pp.284,289, 9-11 June 2009.
[5] Barker, P . P . ; de Mello, R . W. " Determining the impact of distributed generation on power systems: part1-radial distribution systems," IEEE Trans. Power Delivery, vol. 15,pp. 486–493, Apr. 2000.
[6] Dugan, R. C.; McDermott, T. E. "Operating conflicts for Distributed Generation interconnected with Utility Distribution Systems, " IEEE Industry Applications Magazines, 19-25, Mar/Apr. 2002.
[7] Yimai Dong; Kezunovic, M., "Fault location algorithm for radial distribution systems capable of handling insufficient and inaccurate field data," North American Power Symposium (NAPS), 2009 , vol., no., pp.1,6, 4-6 Oct. 2009.
[8] Senger, E.C.; Manassero, G.; Goldemberg, C.; Pellini, E.L., "Automated fault location system for primary distribution networks," Power Delivery, IEEE Transactions on , vol.20, no.2, pp.1332,1340, April 2005.
[9] Salim, R.H.; Resener, M.; Filomena, A.D.; Rezende Caino de Oliveira, K.; Bretas, A.S., "Extended Fault-Location Formulation for Power Distribution Systems," Power Delivery, IEEE Transactions on , vol.24, no.2, pp.508,516, April 2009.
[10] R.M. Cuzner and G. Venkataramanan. The status of dc micro-grid protection. pages 1 {8, oct. 2008.
[11] Fairley P. Edison vindicated. IEEE Spectrum, N/A:14{16, February 2011.
[12] X Fu, K Zhou, and M Cheng. Predictive current control of the VSC-HVDC system. International Conference on Electrical Machines and Systems, pages 3892{3896, 2008.
[13] H Chen. Research on the control strategy of VSC based HVDC systems supplying passive network. Power & Energy Society General Meeting, pages 1{4, October 2009.
[14] L Tang and B.T. Ooi. Protection of VSC-multi-terminal HVDC against DC faults. 33rd Annual IEEE Power Electronics Specialist Conference,2:719{724, November 2002.
[15] N Flourentzou, V Agelidis, and G Demetriades. VSC-based HVDC power transmission systems: An overview. Power Electronics Transaction, 24(3):592{602, April 2009.
[16] M.E. Baran and N.R. Mahajan. Overcurrent protection on voltage sourced converter based multiterminal DC distribution systems. IEEE Transactions on Power Delivery, 22(1):406{412, January 2007.
[17] J.L. Blackburn and T.J. Domin. Protective Relaying:Priniples and Applications. CRC Press, 2007.
[18] J Yang, J Zheng, G Tang, and Z He. Characteristics and recovery performance of VSC-HVDC DC transmission line fault. Power and Energy Engineering Conference (APPEEC), pages 1{4, April 2010.
[19] IEEE application guide for "ac high-voltage circuit breakers rated on a symmetrical current basis". 1999.
[20] P.M. Anderson. Power systems protection. 1998.
[21] N.R. Mahajan. Systems Protection for Power Electronic Building Block Based DC Distribution Systems. PhD thesis