

# **A New AFR Algorithm for Improving Wind Farm FRC using VSC-HVDC and IFSIC**

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**ABSTRACT:** Now a days, because of increased consumption, the quantity of non-renewable energy resources like coal, gas and crude oil is keep on diminishing at a very rapid rate, which created a remarkable essence of renewable energy based power generation systems. Wind-Farm System(WFS)s are one of the most popular renewable electrical power generation systems, which accept renewable wind energy as input. Frequent operational faults in WFS can cause a huge loss of power outage and network malfunction. In general the electrical power distribution and generation systems are extremely large and complex. 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 Ridethrough Capability (FRC) of WFS 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 collected grid upon occurrence of 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. This project is practically implemented and tested in MATLAB environment and the simulation results proved that the proposed method best in all aspects and outperforms all the existing methods and techniques.

**KEYWORDS:** WFS, FRC, IFSIC, VSC-HVDC, WF-HVGS and AFR.

## **I.INTRODUCTION**

The count and size of Wind-Farm System(WFS)s[3] and their percentage of wind power in the overall generation mix continues to rise. In countries with large-scale wind power development, onshore sites with good wind condition are mostly used up. As result, a major amount of power in generation is already coming from offshore places, and the development continues at a remarkably rapid rate well into the future. The resulting long transmission routes make the use of ac submarine cables which are problematic due to the high charging currents, and HVDC transmission is the most feasible solution. The converter stations as a result leaves a smaller footprint and, thus, the technology is more suitable for applications where the space requirement is a major consideration, such as offshore platforms. It is now generally accepted that large Wind-Farms with ratings comparable to those of conventional power plants cannot simply trip during and in the immediate aftermath of a fault[15]. Current grid codes require a Fault RideThrough (FRT) capability[15] by WFS even at zero voltage for fault durations up to 150 ms [1][2]. This requirement is particularly challenging for the VSC-based HVDC transmission system[1][2] connecting the WFS to the grid as the power flow from the WFS cannot be blocked immediately by the sending-end converter (SEC). Any fault[15] in the ac grid fed by the HVDC line obviously reduces the voltage at the connection point which, in turn, reduces the power fed into the grid by the Receiving-End Converter (REC)[4] instantaneously. The resulting imbalance between the infeed at the sending end and what is delivered at the receiving end is

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stored in the form of electric-field energy in the capacitance of the HVDC line. In the absence of suitable countermeasures, this would lead to increased dc voltage and potential equipment damage in the installation.

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. Wind Farm based High Voltage Grid System (WF-HVGS) is a best example for widely used Off-Grid Hybrid Power System (OG-HPS)[5] 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 impact the entire wind farm system, there by destructing it structure and normal operation. As a result the system must be shut-down until or unless the faulted line or faulted section is located and isolated efficiently. The line faults will occur in the VSC-HVDC transmission lines[1][15] 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 line faults that may occur in the VSC-HVDC transmission lines [1][2]. Employing an Adaptive Fault Ridethrough(AFR) algorithm for real time detection and isolation of above faults is appreciated and this will improves the operational effectiveness of the WFS[6].In this scenario we proposed an Adaptive Fault Ridethrough(AFR) algorithm for enhancing the Fault Ridethrough capability of WFS connected to the grid through VSC-HVDC transmission lines[1][2] using IFSIC modules.IFSIC controls the voltage drop in the grid upon occurrence of faults thereby reducing the resulting power wastage. IFSIC has its associated circuitry which will monitors each section of the WFS to detect operational deviation and to counteract accordingly.

## II.PROPOSED WORK

In this project we proposed, designed, developed and implemented an Adaptive Fault Ridethrough(AFR) algorithm using a most efficient and functionally effective IFSIC unit for improving the fault ridethrough capability of the WF-HVGS.The proposed IFSIC based AFR algorithm ensures the real time fault protected[15] and power quality enhanced operation of the WF-HVGS[7].We constructed a IFSIC Logic Network which will monitors the assigned VSC-HVDC[1][2] bus branch for line faults[15] and power quality deviations and acts accordingly to locate and isolate the faulted line segments and faulted sections[15]. The logical fault sensing circuitry of IFSIC unit which is organized in multiple hierarchical slices will inherently carry out these fault sensing and fault isolation activities. The proposed WF-HVGS is implemented with a 12-line ring bus architecture as shown in fig(1).The generated power from several WFSs will be routed to the HVGS through 12-line VSC-HVDC bus sections[8]. An identical bus segment is drawn to every load region surrounding the HVGS to electrify them with its power. All the HVDC bus segments will be controlled and fault monitored by an identical IFSIC module. Each IFSIC module detects, locates and isolates the segment line faults in its associated HVDC bus segment[8]. The schematic block overview of the proposed WF-HVGS[7] system is shown in figure (1).

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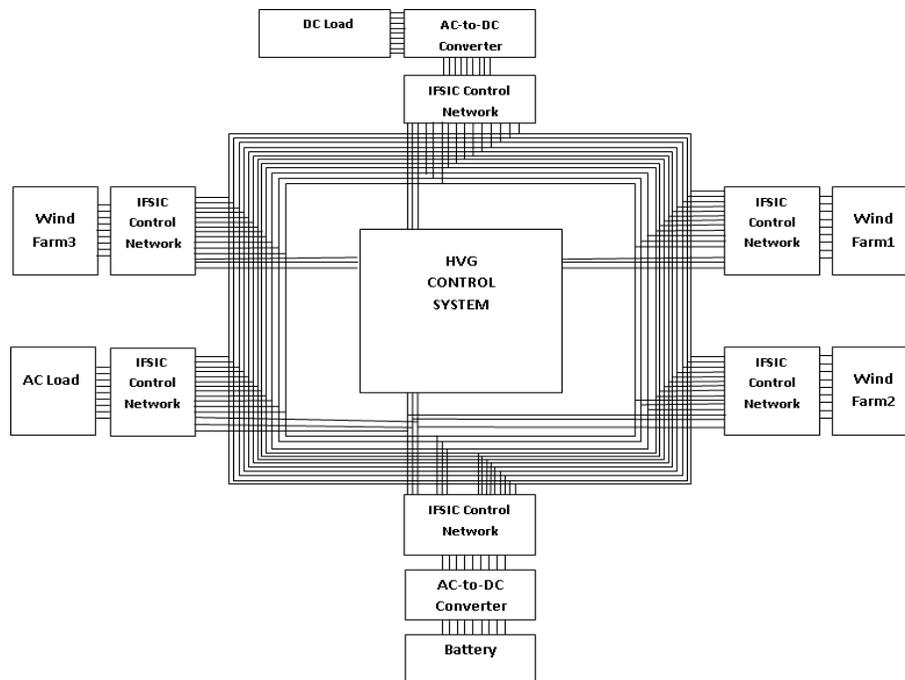


Fig (1): Schematic block diagram of the proposed WF-HVGS System.

The proposed system consists of a Distributed Generation (DG)[9][10][11][12] based WF-HVGS[7] 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[7] supplies the power to all regions or zones around it .One identical HVDC bus segment[8] is drawn to each and every region or zone. Each HVDC bus segment[8] 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 segment for faults and acts accordingly to detect, isolate the faults[15] without showing any impact on the operational power quality and effectiveness of the WF-HVGS.Individual IFSIC modules are put under the control of HVGS with an aid of three control lines. They are (i) IFSIC\_CN(IFSIC Control),whose logic high state enables the IFSIC module otherwise it is disabled;(ii)IFSIC\_S(IFSIC Status)whose logic high state indicates the perfectness of discrete components of IFSIC module, if it is logic low then an error in the internal operational components of IFSIC will be reported; and (iii)IFSIC\_ES(IFSIC Error Status),whose logic low level indicates the fault free operation[15] of IFSIC module, otherwise the corresponding line fault will be detected, located and the faulted segment will be isolated. The internal architecture of an IFSIC module is shown in fig(2).

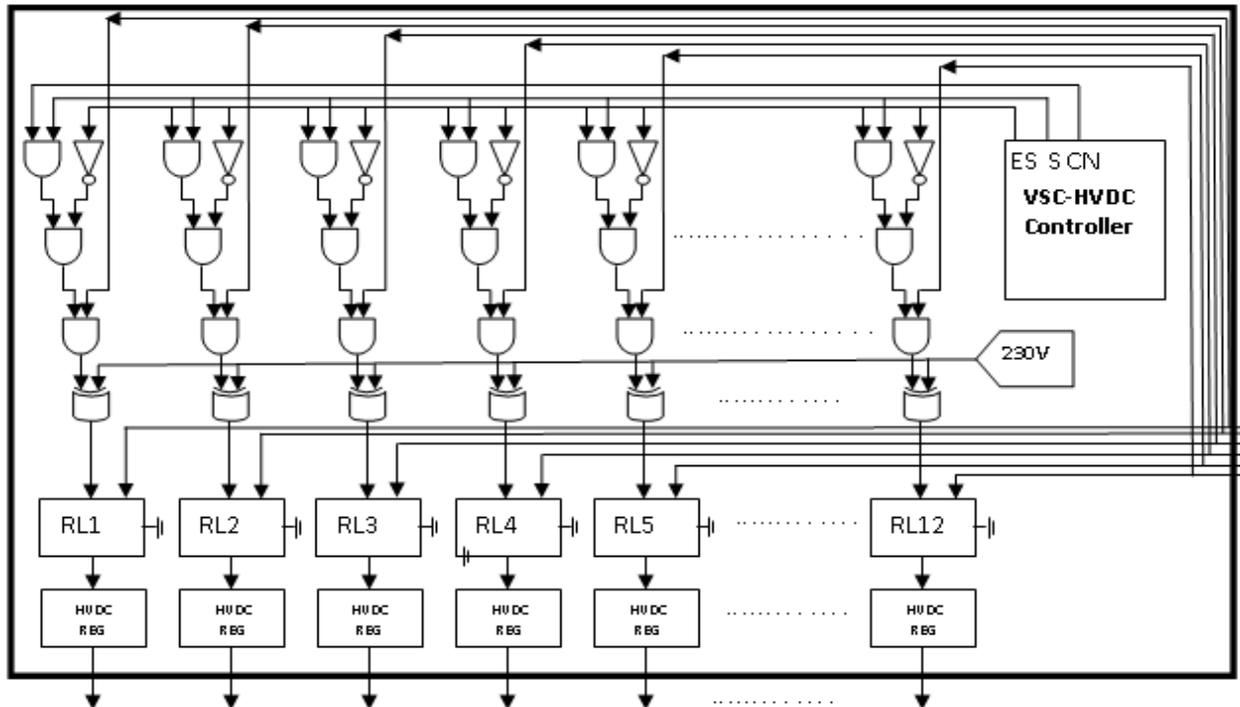


Fig (2): Internal architecture of an IFSIC module.

The internal architecture of an IFSIC module comprises a VSC-HVDC controller[1][2], hierarchical logic circuit slices, a layer of HVDC relays and a layer of HVDC regulators. All these blocks are suitably interconnected to make up the whole IFSIC module. The VSC-HVDC controller[1][2] will act as a distributed controller for the IFSIC module. It issues control signals necessary for logic slices and controls the layer of HVDC relays based on the line fault status. If a particular line is faulty, then its associated relay will be discharged, otherwise it is charged to allow the contact power flow[14]. This charging and discharging actions of relays are steered by the VSC-HVDC controller [1][2] through its control signals. The hierarchical logic circuit slices are implemented in four levels. The first level consists of the first AND slice and the first NOT slice. The first AND slice accepts the control signals such as IFSIC\_CN and IFSIC\_S and checks their status. If both are active high then it indicates the enabled and perfect operational condition of the IFSIC module, otherwise it reports a fault. The first NOT slice complements the logic level of the control signal IFSIC\_ES. If the output of the first NOT slice is logic '0', then it indicates a line fault, otherwise no fault will be detected. In level 2, a second AND slice will be used to combine the responses of the first AND slice and first NOT slice. The response of the second AND slice indicates the overall operational status of the IFSIC module. If the response of the AND slice 2 is logic high, then there is no error in the operational condition of the IFSIC module, otherwise there is an error. In level 3 the input power levels will be buffered in the third AND slice with level 2 response as its enable. The buffered input power levels will be compared with their rated counterparts in level 4 with an aid of XOR slice, whose result will be complemented by the second NOT slice. The second NOT slice response is collected by the VSC-HVDC controller[1][2] and supplies it to the layer of HVDC relays as the set relay energizing signals. Based on the logic condition of these relay energizing signals, the individual HVDC relays will be charged and discharged[13]. The output power levels of these HVDC relays[9] will be regulated by using a layer of suitable HVDC regulators[10]. In this AFR algorithm no external breakers are required to control and regulate the power levels on HVDC bus segment. A single IFSIC module will itself efficiently carry out those controlling tasks.

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## III.RESULTS AND DISCUSSION

The operational characteristics of the proposed AFR algorithm are practically verified with the help of computer simulations performed using MATLAB software. The proposed AFR algorithm is designed, programmed and simulated using Matlab.As a first task after starting its operation the WF-HVGS initializes all its IFSIC Units for fault free operation. This initialization includes loading the rated parameter values of line voltage, line currents and associated phase deviations into the individual IFSIC Units. The initialization data of the WF-HVGS is given as follows.

VSC-HVDC NETWORK STANDARD BUS PARAMETERS

SNO	HVDC_BUS_LINE	Voltage(V)	Current(A)	Phase(Deg)
1	LINE1	230.000000	50.000000	0.000000
2	LINE2	230.000000	50.000000	30.000000
3	LINE3	230.000000	50.000000	60.000000
4	LINE4	230.000000	50.000000	90.000000
5	LINE5	230.000000	50.000000	120.000000
6	LINE6	230.000000	50.000000	150.000000
7	LINE7	230.000000	50.000000	180.000000
8	LINE8	230.000000	50.000000	210.000000
9	LINE9	230.000000	50.000000	240.000000
10	LINE10	230.000000	50.000000	270.000000
11	LINE11	230.000000	50.000000	300.000000
12	LINE12	230.000000	50.000000	330.000000

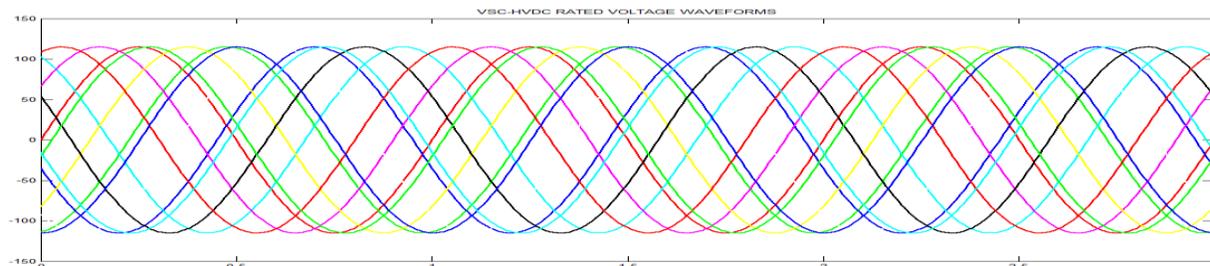
Table(1):VSC-HVDC Standard bus parameters.

VSC-HVDC NETWORK STANDARD STROBE SIGNALS

SNO	IFSIC_MODULE	Control(CN)	STATUS(S)	ERROR_STATUS(ES)
1	IFSIC1	1	1	0
2	IFSIC2	1	1	0
3	IFSIC3	1	1	0
4	IFSIC4	1	1	0
5	IFSIC5	1	1	0
6	IFSIC6	1	1	0
7	IFSIC7	1	1	0
8	IFSIC8	1	1	0

Table(2):VSC-HVDC standard strobe signals.

The above table(1) presents the VSC-HVDC network’s standard bus line parameter values,where as table(2) represents the VSC-HVDC network’s strobe signals for standard fault free operation.

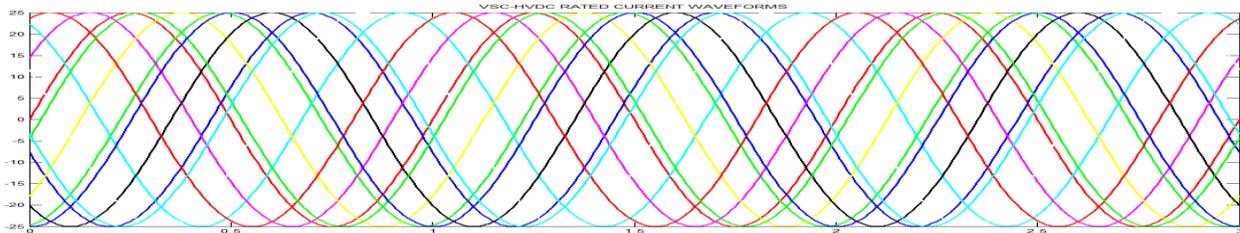


Fig(3):VSC-HVDC based Wind Farm HVGS Rated Voltage Waveforms.

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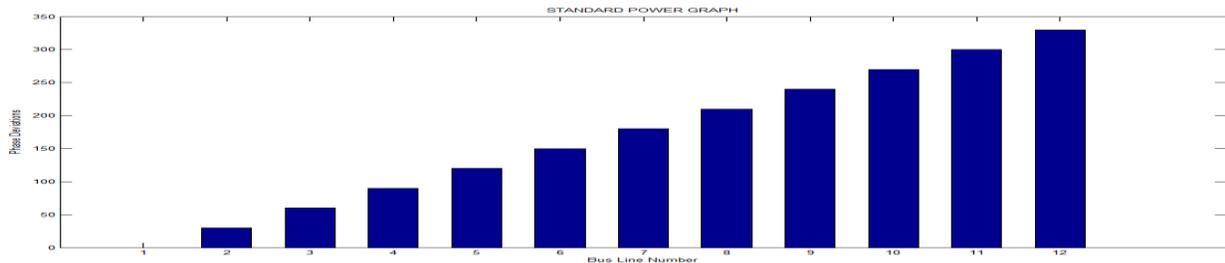
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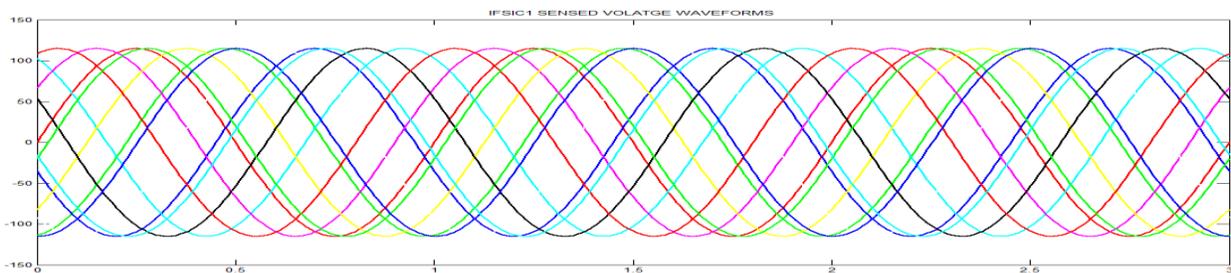


Fig(4): VSC-HVDC based Wind Farm HVGS Rated Current Waveforms.

The above figures figure(3) and figure(4) shows the rated voltage and current waveforms of VSC-HVDC based Wind Farm HVGS system.



Fig(5): VSC-HVDC based Wind Farm HVGS Rated Phase Levels.



Fig(6):IFSIC Module Sensed Voltage Waveforms.

The rated phase levels of VSC-HVDC based Wind-Farm HVGS system are shown in figure(5),where as the sensed voltage waveforms of IFSIC module are shown in figure(5).

## IV.CONCLUSION

The 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 devoted to find an appropriate means to improve the Fault Ridethrough Capability(FRC) of the Wind Farm System(WFS)s. As a result, we proposed, designed and implemented a new AFR algorithm for enhancing the FRC of wind farms connected to the grid through VSC-HVDC transmission lines using a robust IFSIC unit which will be responsible for detection and location of faults and faulted sections in the WFS. The proposed algorithm employs an IFSIC unit as the key security monitoring

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device. The proposed algorithm is implemented and tested in MATLAB 2012b environment. The simulation results adjudged that the proposed IFSIC module is very efficient in improving the Fault Ridethrough Capability (FRC) of the WF-HVGS systems and also the proposed algorithm is working well and outperforms all the existing algorithms.

## V.FUTURE SCOPE

The proposed AFR algorithm is proven to be the best in performance. In this project in order to reduce the complexity of implementation, the proposed algorithm is practically implemented with 12-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 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.

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