WELCOME GENTEL MEN

TRANSIENT STABILITY OF MULTI-TERMINAL WIND TURBINE GENERATORS SYSTEM CONNECTED TO THE GRID

What is the Objective of thesis

This thesis presents a recovery strategy that enables *HVDC* transmission systems based on voltage source converter to ride-through different position of *AC* faults with minimum current and voltage stresses on the converter switching devices. The study include control strategies for *VSC* transmission system connecting offshore wind farms to the power network.

Problem of statement

- In recent years, the increasing concerns to the environmental issues and the limited availability of conventional fossil fuels lead to rapid research and development for more sustainable and alternative electrical sources. Wind energy, as one of the most prominent renewable energy sources, is gaining increasing significance throughout the world.

- The currently worldwide installed capacity of grid connected wind generators grows rapidly; this raise of integration rate of wind energy could lead to propagation of transient stability and could potentially cause local or system wide blackout.
- In addition it is essential to ensure that the grid is capable of staying within the operation limits of frequency and voltage for all foreseen combination of wind power production and consumer load and, to keep, at the same time the grid transient stability.

Thesis contents of three important parts :

First part : discuses the wind power system. The conversion of the mechanical power of the wind turbine into the electrical power can be accomplished by any one of the following types of the electrical machines:

- The direct current (*DC*) machine.
- The synchronous machine.
- The induction machine.

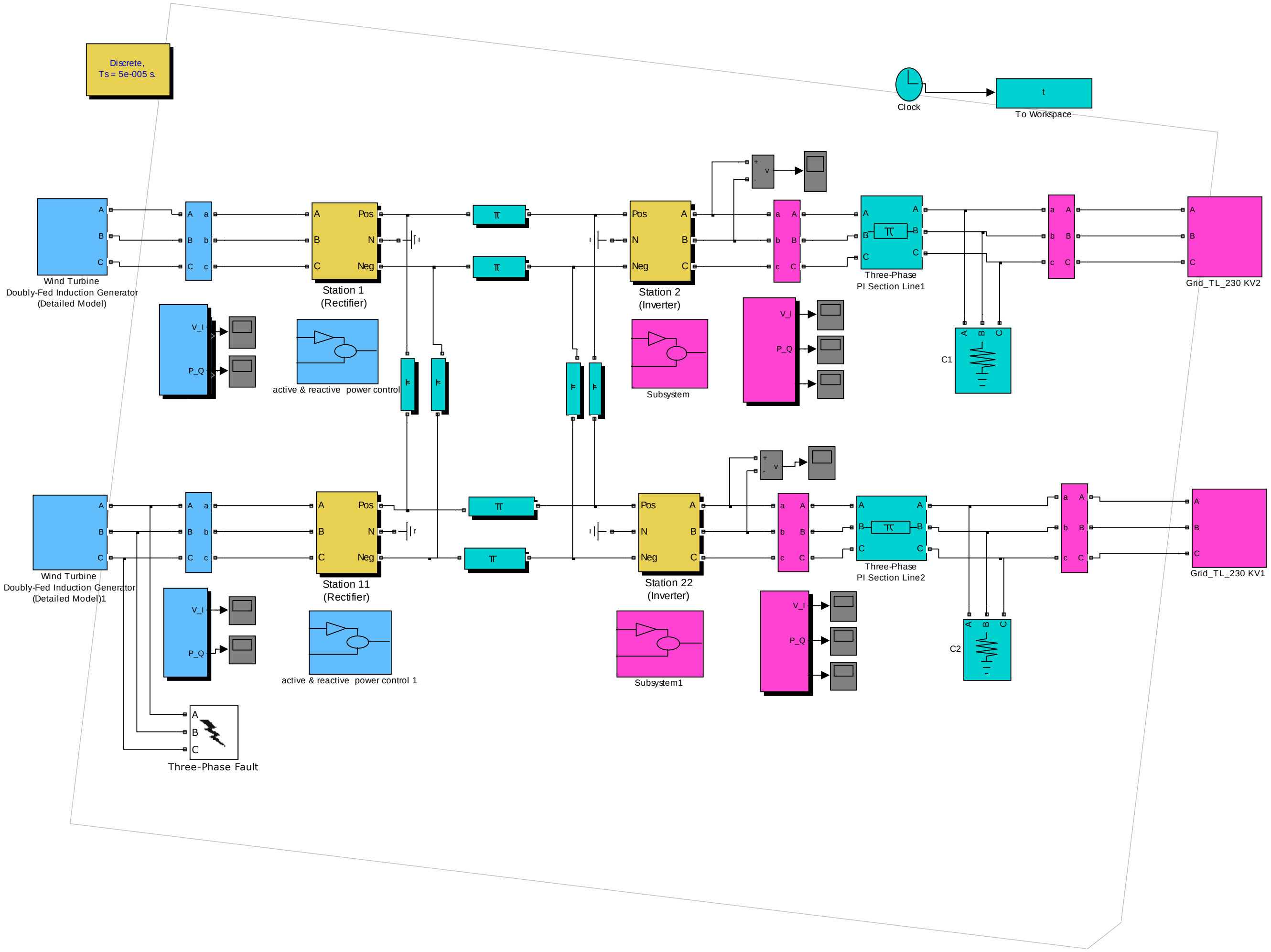
The third type uses a *DFIG* as a variable-speed wind turbine and FSIG as a fixed-speed wind turbine.

Second part : discuses the conventional power system. The interconnected in an overall network called the *power grid*, interconnection makes the energy generation and transmission more economical and reliable, since power can readily be transferred from one area to another's.

Third part : deal with the modeling and control of the VSC-HVDC,

The single line diagram of proposed test system

VSC-HVDC transmission system connecting two AC networks, wind turbines and synchronous generators



Advantages of *VSC-HVDC*

- Ability to provide voltage/reactive power support to the network.
- Decoupling of the *AC* systems which results in improved fault ride-through capability.
- Since power electronic converters are current control devices, they do not change significantly the fault level at the point of connection.
- Facilitates connection of weak systems such as wind farm, independently of the effective short circuit ratio (*ESCR*).
- Black start capability, this eliminates the need for the startup generator.

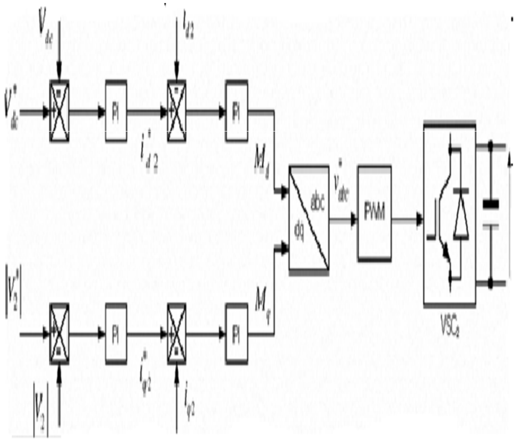
The control system of *VSC-HVDC*

- ***VSC-HVDC* grid-side converter control:**

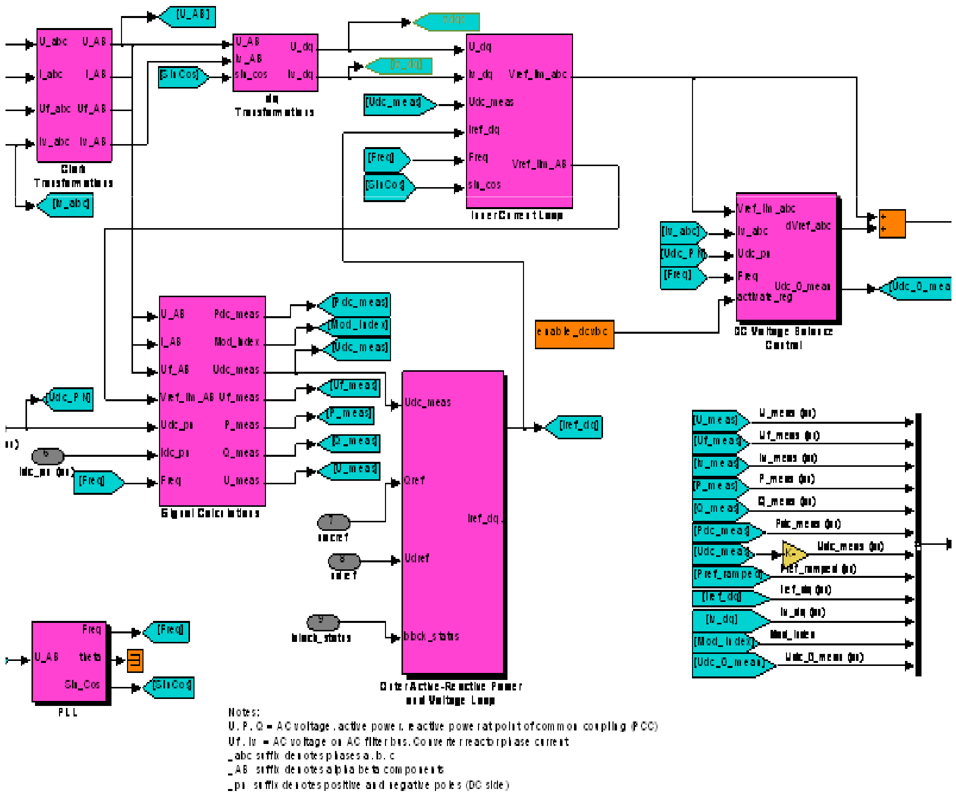
The converter here requires four independent control loops, the first and two loops are the current controllers that regulate the currents i_{d2} and i_{q2}; the third control loop is the *DC* voltage controller that regulates the *DC* link voltage ; and the fourth loop is the *AC* voltage controller that regulates the *AC* voltage magnitude at the point of common coupling.

The Controller of Grid Side Converter

For Study Case



For proposed test system



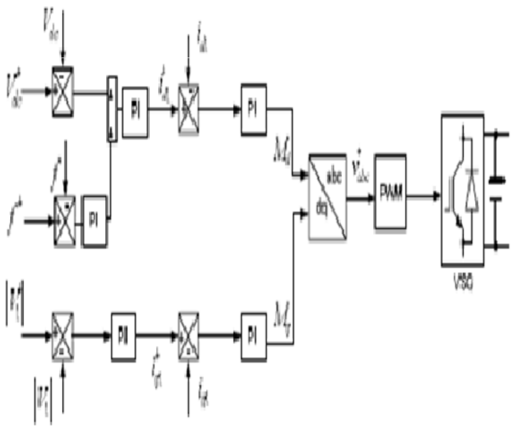
➢ ***VSC-HVDC*** **wind farm side converter :**

The control system of the wind farm side converter (*VSC*) must be modified to maintain the voltage at bus B_1 at 1.0 and guarantee the active power balance between the *AC* and *DC* sides of the converter *VSC*. Therefore, the reference active and reactive current components and are derived directly from the *AC* voltage loops.

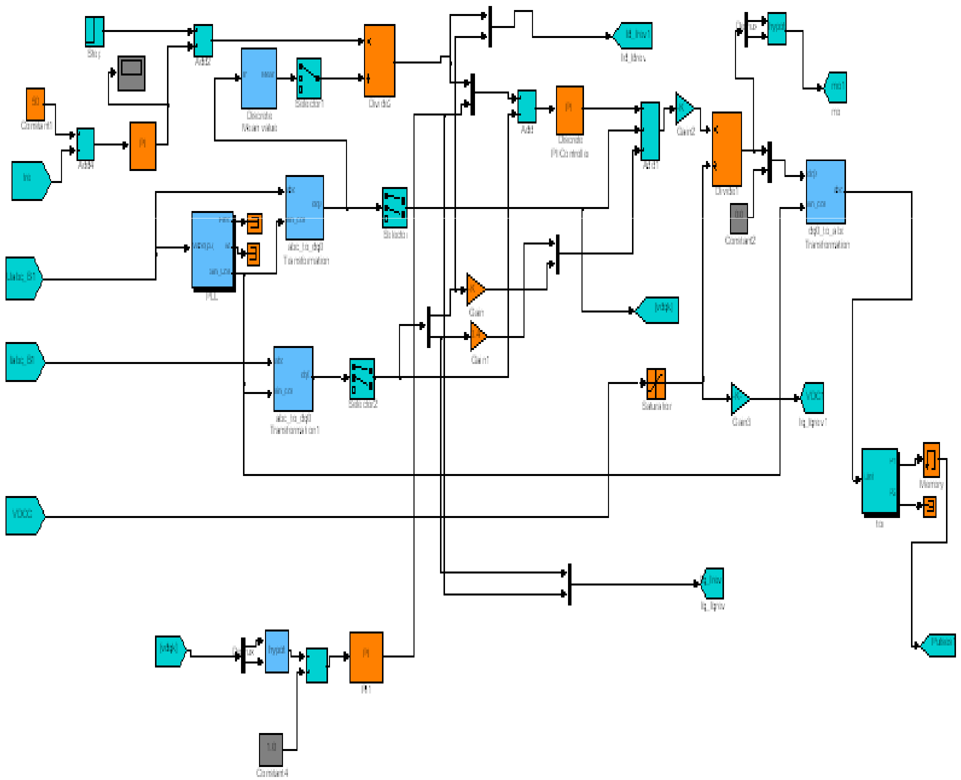
An additional frequency controller is included with active power controller to enable the wind farm side converter to respond to any changes in the grid frequency. The frequency controller used in this thesis is based on the active power-frequency characteristics.

The Controller of Wind Side Converter

For Study Case



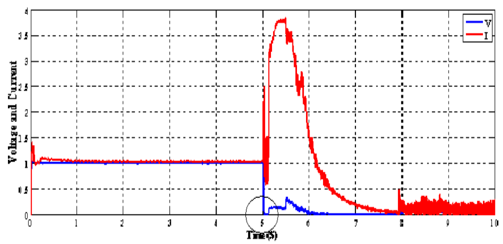
For proposed test system



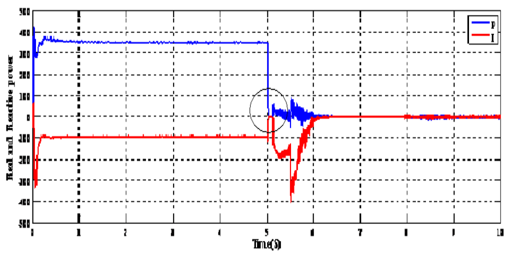
Simulation Result

A) The Fault at Wind Side at Station No. 1

- Fig 5.1(a and b) show that the active power and voltage of the wind station collapse to zero at time of fault, but anther station of wind has less sensitive as in Fig5.3.

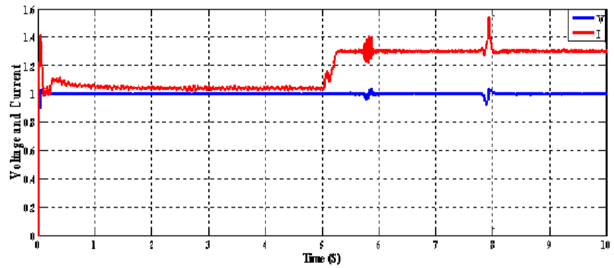


a)Voltage&Current at station No1

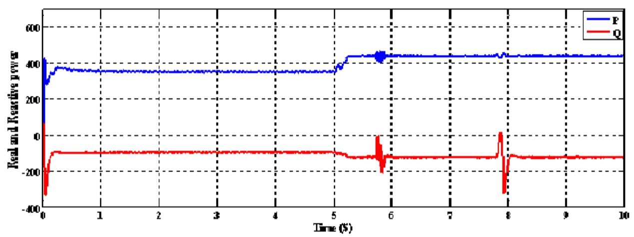


b)MW &MVA at station No1

Fig5.1 Simulation result for station No1



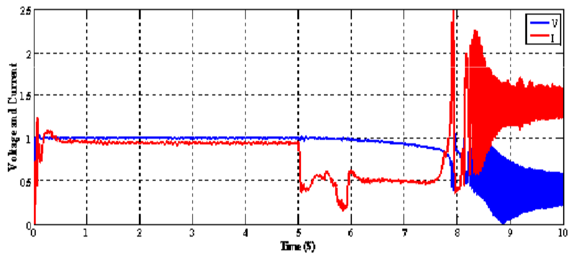
a) Voltage and current at station No3



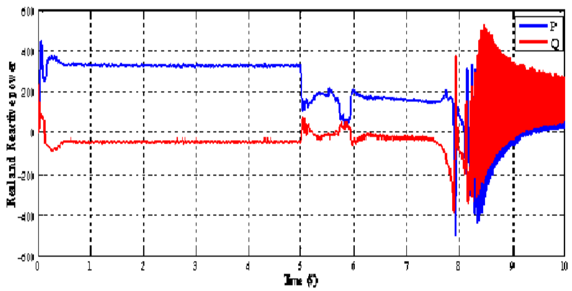
b) Real and Reactive power MW and MVA at station No 3

Fig.5.3 Simulation results for station No 3

➢Although, the AC fault on the wind side, from Fig (5.2 and 5.4) it can be notice that, at the period of steady state stability voltage and power at the side of grid very sensitive toward any small disturbance at the wind side and take long time to reach to steady state period, even with this far distance. The power and voltage curves at station 2&4 have similar behavior.

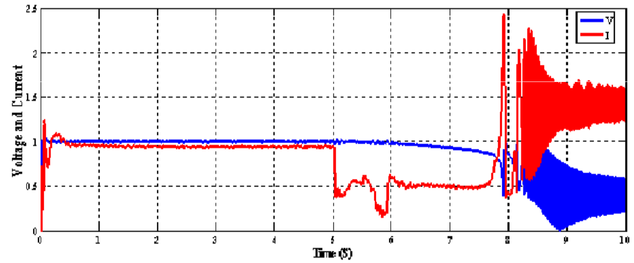


a) Voltage and current at station No2

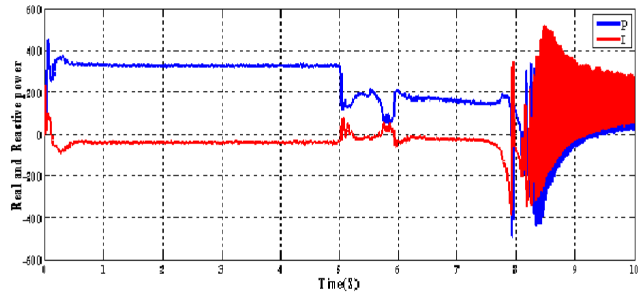


b) MW and MVA at station No 2

Fig.5.2 Simulation results for station No 2



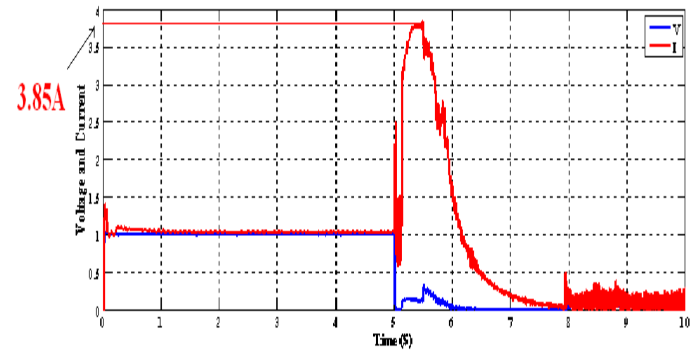
a) Voltage and current at station No 4

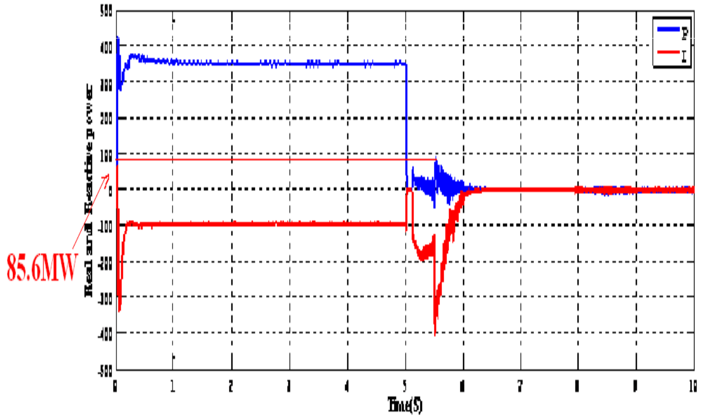


b) Real and Reactive power MW and MVA at station No 4

Fig.5.4 Simulation results for station No 4

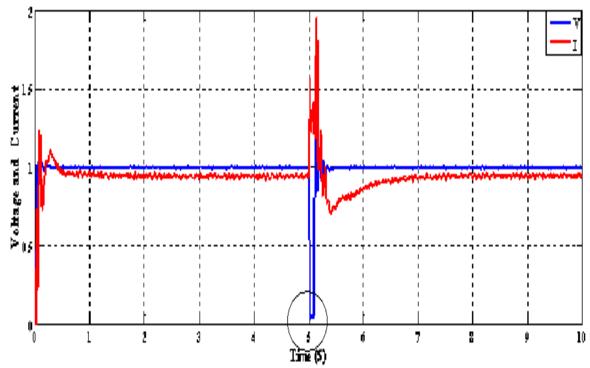
➢In addition from Fig.5.1(a and b) we notice the current at station 1 take highest value 3.85A before steady stead period, but real power take small value 85.6MW before reach to zero at steady stead period.



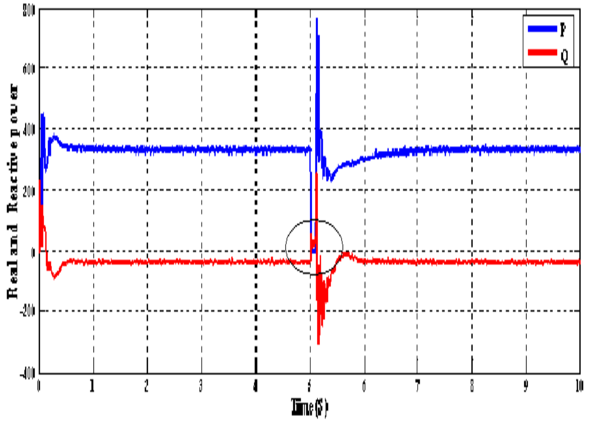


B) The Fault at Grid Side at Station No 2

- As expected at Fig.5.9(a and b) it can be notice that the voltage magnitude and active power at B2 collapses during the fault period as the reactive power capability of the converter decreases. Despite the voltage collapse at B2, the converter VSC2 contributes limited current to the fault.



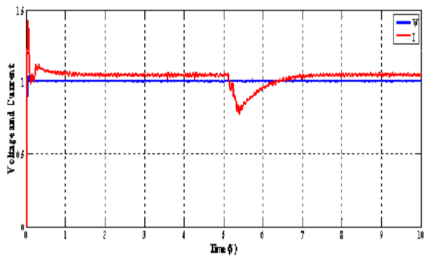
a) Voltage and current at station No 2



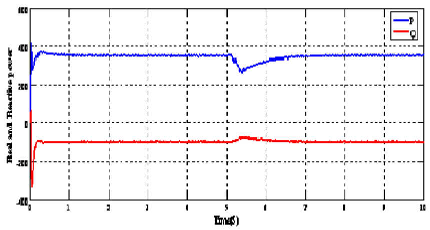
b) MW and MVA at station No 2

Fig.5.9 Simulation results for station No 2

➤ **Figures below are observed that the voltage and active power at the wind farm side (B1 and B3) remains less sensitive to the fault at the grid side, even with the wind farm side converter responding to the change in frequency in the grid.**

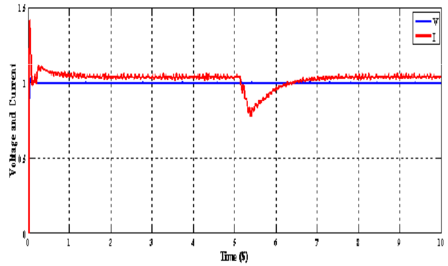


a) Voltage and current at station No 1

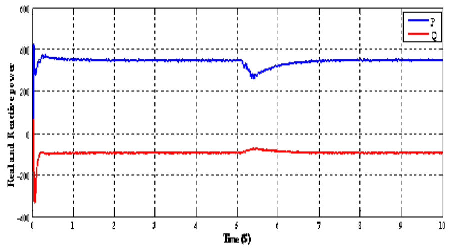


b) MW-MVA at station No 1

Fig.5.10 Simulation results for station No 1



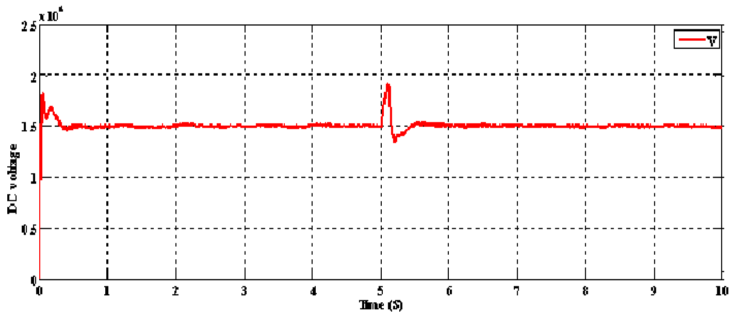
a) Voltage and current at station No 3



b) MW-MVA at station No 3

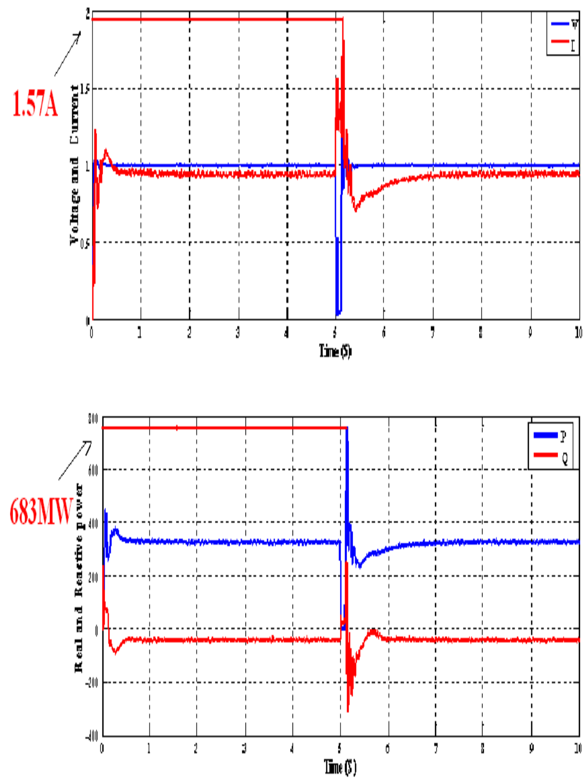
Fig.5.11 Simulation results for station No 3

➢Fig.5.9(c) show that the DC link voltage of converter VSC2 increase during the fault period as a result of the trapped energy in the DC link.



c) The DC voltage

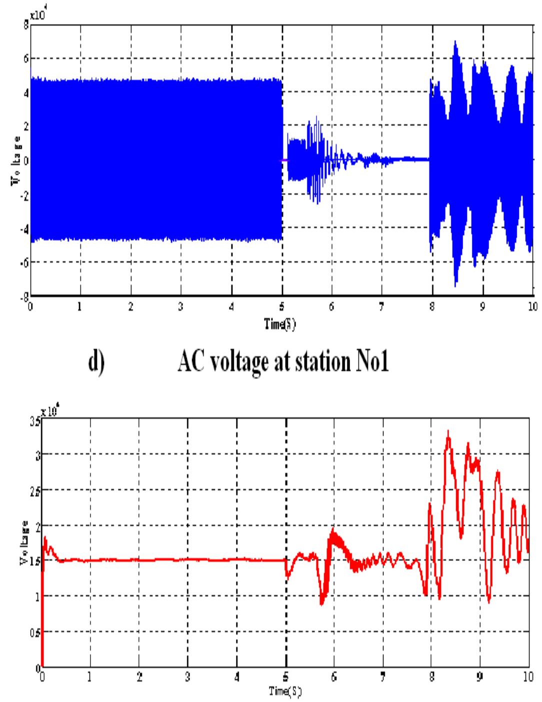
➢Moreover from Fig.5.9(a and b) we notice the real power and current at station 2 take highest values 683MW and 1.57A relatively before steady stead stability.



Conclusions

- It was demonstrated from the simulation that wind turbines must not disconnect in case of transient faults. Therefore, controllers are designed that enable the two turbine types to ride through transient faults. With these transient fault controllers the wind turbines can stay connected to the grid, such that their generation capacity is sustained, and normal grid operation can resume, after the fault is cleared.

- For the fault that at wind side stations, the whole system cannot be stable easily, the steady state period need long time to make system stable. Accordingly, we should be more careful to avoid wind fault system.



d) AC voltage at station No1

c) The DC voltage

Fig.5.1 Simulation results for station No 1

Recommendations

- The results that gotten at chapter five used tolerance : however if we need using higher tolerance for example ,to get more minuteness results or less harmonics at the waveform , we should use the newer version of MATLAB.
- Transient stability of multi-machine wind generators connected to the grid is applied with *MATLAB/ SIMULINK* , however, in practical, *ETAP* is the leader in power system analysis and management tools worldwide.

THANK YOU FOR YOUR ATTENTION