

ENHANCEMENT OF DYNAMIC STABILITY AND VOLTAGE CONTROL OF A GRID-CONNECTED OFFSHORE WIND FARM AND MARINE- CURRENT FARM USING A STATCOM

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Abstract: - This venture shows a control plot in view of a static synchronous compensator (STATCOM) to accomplish both voltage control and damping improvement of a grid-associated incorporated 80-MW offshore wind farm (OWF) and 40-MW marine-current farm (MCF). The execution of the contemplated OWF is reproduced by an equal doubly-fed induction generator (DFIG) driven by a proportional wind turbine (WT) while a comparable squirrel-confiner rotor induction generator (SCIG) driven by an equal marine-current turbine (MCT) is utilized to recreate the qualities of the MCF. A damping controller of the STATCOM is planned by utilizing modular control hypothesis to contribute powerful damping attributes to the considered system under various working conditions. A frequency-area approach in view of a changed system display utilizing Eigen esteem strategies and a period space plot in view of a nonlinear system show subject to different unsettling influences are both utilized to reenact the adequacy of the proposed control conspire. It can be finished up from the reproduced comes about that the proposed STATCOM joined with the outlined damping controller is extremely successful to settle the contemplated system under aggravation conditions. The voltage fluctuations of the AC bus subject to the dynamic power varieties of the contemplated system can likewise be viably controlled by the proposed control plot.

INTRODUCTION

A wind turbine is a device that believes kinetic energy from the wind into mechanical energy. In the event that the mechanical energy is utilized to create electricity, the device might be known as a wind generator or wind charger. In the event that the mechanical energy is utilized to drive hardware, for example, for granulating grain or pumping water, the device is known as a windmill or wind pump. Produced for over a thousand years, the present wind turbines are fabricated in a scope of vertical and even pivot sorts. The littlest turbines are utilized for applications, for example, battery charging or helper power

on cruising pontoons; while vast grid-associated varieties of turbines are turning into an inexorably extensive wellspring of business electric power.

Sustainable power source is one of the most blazing subjects in the whole world today because of the quick and gigantic utilization of non-renewable energy sources. Some scholarly scientists have dedicated to high-limit offshore wind turbine generators (WTGs) associated with coastal substations through undersea links. Currently, wind doubly-fed induction generators (DFIGs) and wind perpetual magnet synchronous generators (PMSGs) have been broadly utilized as a part of high-limit offshore wind farms (OWFs). From the authentic perspective, a direct-coupled, particular PMSG for variable-speed wind turbines was proposed and various single-stage yields were independently redressed to acquire a smooth dc connect voltage. The dynamic model in light of little flag soundness of a wind turbine (WT) utilizing an immediate drive PMSG with its power converters and controllers was proposed. Amid the most recent decades, Wind Energy Conversion System (WECS) has developed drastically. Variable-speed wind Turbines (VSWTs) draw in extensive enthusiasm around the globe, which is one of the arrangements with the most noteworthy potential to decrease wind energy cost. Essentially wind farm comprises of many wind turbines that are associated with each other to create little measure of electrical power that turns out to be powerful subsequent to interfacing with the transformer. Zones that comprises of the quantity of wind turbines for power era from wind and are associated with each other in the diverse way is called wind farm During the most recent decades. The VSWT systems are normally in view of doubly fed induction generators (DFIGs) or changeless magnet synchronous generators (PMSGs). Essentially wind farm comprises of many wind turbines that are associated with each other to create little measure of electrical power that turns out to be powerful in the wake of interfacing with the transformer. Ranges that comprises of the quantity of wind

turbines for power era from wind and are associated with each other in the diverse way is called wind farm. Fundamentally wind farm comprises of many wind turbines that are associated with each other to create little measure of electric power. Distinctive methodologies are utilized to fabricate the wind farms in various areas or range. Generators driven by marine-current turbine (MCT) consolidated with offshore generators driven by wind turbine (WT) will turn into a novel plan for energy creation later on. Since seas cover over 70% surface of the earth, a half breed power era system containing both offshore wind farm (OWF) and marine-current farm (MCF) can be broadly created at the particular areas of the world later on. One of the straightforward techniques for running an OWF is to interface the yield terminals of a few DFIGs together and after that associate with a power grid through an offshore stride up transformer and undersea links. To run a MCF may utilize a few Permanent Magnets synchronous generators (PMSGs) associated specifically to the power grid through an offshore stride up transformer and undersea links

Both wind energy and sea energy have been coordinated together in the U.K. Sea energy may incorporate warm energy, wave energy, offshore wind energy, tidal energy, sea current energy, and so forth. Generators driven by marine-current turbine (MCT) consolidated with offshore generators driven by wind turbine (WT) will turn into a novel plan for energy creation later on. Since seas cover over 70% surface of the earth, a cross breed power era system containing both offshore wind farm (OWF) and marine-current farm (MCF) can be widely created at the particular areas of the world later on. One of the basic strategies for running an OWF is to interface the yield terminals of a few DFIGs together and after that associate with a power grid through an offshore stride up transformer and undersea links. To run a MCF may utilize a few squirrel-confine induction generators (SCIGs) associated specifically to the power grid through an offshore stride up transformer and undersea links. Both WTs and MCTs have fundamentally the same as working attributes yet a SCIG-based MCF requires receptive power for polarization while a DFIG-based OWF with two bi-directional power converters can control its yield power factor to be near solidarity. At the point when the produced dynamic power of a SCIG-based MCF is shifted because of marine-current fluctuations, the consumed responsive power and the terminal voltage of the MCF can be altogether influenced. In case of expanding grid unsettling influences, e.g., grid blames, an energy stockpiling system

or a control device for a substantial scale highcapacity power era system is by and large required to repay fluctuating segments when associating with a power grid. An extensive scale OWF may join with various FACTS devices or energy-stockpiling systems, for example, a STATCOM, and so on. The broke down consequences of security change of power systems utilizing STATCOMs and the damping controller outline of STATCOMs were displayed. The outline of a yield input straight quadratic controller for a STATCOM and a variable-sharp edge pitch of a wind energy transformation system to perform both voltage control and mechanical power control under grid-association or islanding conditions. System displaying and controller outline for quick load voltage direction and alleviation of voltage flash utilizing a STATCOM were illustrated. Another D-STATCOM control calculation empowering separate control of positive-and negative-sequence currents was proposed, and the calculation depended on the created numerical model in the directions for a DSTATCOM working under uneven conditions

DOUBLE FED INDUCTION GENERATOR (DFIG)

DFIG is an abbreviation for Double Fed Induction Generator, a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly, but there are problems with efficiency, cost and size.

PERMANENT MAGNET SYNCHRONOUS MACHINE

A synchronous machine is an air conditioner pivoting machine whose speed under relentless state condition is corresponding to the frequency of the current in its armature. Figure 3 demonstrates the PMSM Cylindrical rotor and Salient rotor structures. The attractive field made by the armature currents pivots at an indistinguishable speed from that made by the field current on the rotor, which is turning at the synchronous speed, and a consistent torque comes about. Synchronous machines are normally utilized as generators particularly for substantial power systems, for example, turbine generators and hydroelectric generators in the grid power supply. Since the rotor speed is corresponding to the frequency of excitation, synchronous engines can be utilized as a part of circumstances where steady speed drive is required. Since the receptive power created by a synchronous machine can be balanced by controlling the magnitude of the rotor field current, emptied synchronous machines are likewise

frequently introduced in power systems exclusively for power factor remedy. The armature winding of a customary synchronous machine [3] is perpetually on the stator and is generally a three stage winding. The field winding is for the most part on rotor and energized by dc current, or changeless magnets. The dc power supply required for excitation for the most part is provided through a dc generator known as exciter, machine which is frequently mounted on an indistinguishable shaft from the synchronous.

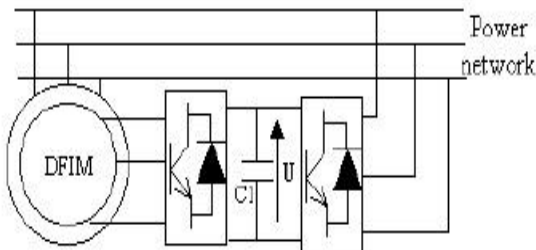


Fig1: Doubly fed induction generator

The dynamic crowbar can evacuate the rotor short controlledly and in this way the rotor side converter can be begun simply after 20-60 ms from the begin of the grid unsettling influence. Along these lines it is conceivable to produce responsive current to the grid amid whatever remains of the voltage plunge and thusly help the grid to recuperate from the blame. A doubly fed induction machine is an injury rotor doubly-fed electric machine and has a few preferences over a traditional induction machine in wind power applications. Initially, as the rotor circuit is controlled by a power hardware converter, the induction generator can both import and fare responsive power. This has critical consequences for power system steadiness and enables the machine to help the grid amid serious voltage unsettling influences (low voltage ride through, LVRT). Second, the control of the rotor voltages and currents empowers the induction machine to stay synchronized with the grid while the wind turbine speed changes. A variable speed wind turbine uses the accessible wind asset more effectively than a settled speed wind turbine, particularly amid light wind conditions. Third, the cost of the converter is low when contrasted and other variable speed arrangements in light of the fact that lone a small amount of the mechanical power, ordinarily 25-30 %, is fed to the grid through the converter, the rest being fed to grid straightforwardly from the stator. The productivity of the DFIG is useful for a similar reason.

MODELS OF THE OFF SHORE WIND FARM AND MARINE CURRENT FARM

Figure demonstrates the structure of the concentrated coordinated DFIG based OWF and PMSG based MCF with the proposed STATCOM. The 80MW OWF is spoken to by a huge equal collected DFIG driven by an identical amassed variable speed WT through an equal accumulated gearbox. The 40MW MCF is spoken to by an expansive proportionate accumulated PMSG driven by an equal collected variable speed MCT through an identical totaled gearbox. The OWF, the MCF, the STATCOM and a neighborhood stack are associated with an AC bus that is fed to the coastal power grid through an offshore stride up transformer and undersea links [9]. The utilized numerical models of the contemplated system are depicted as beneath.

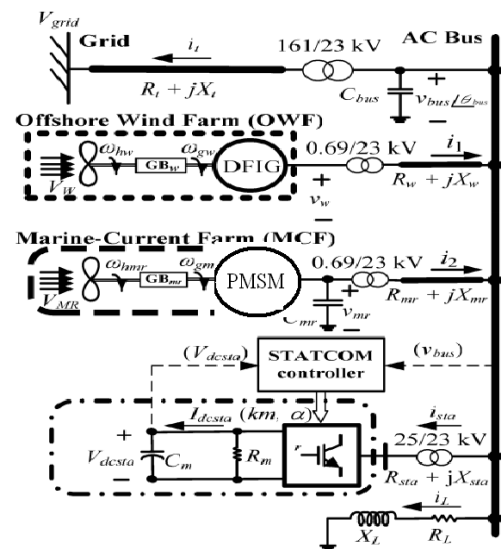


Fig2 Composition of the integrated OWF and MCF with STATCOM

Figure demonstrates the structure of the concentrated coordinated DFIG based OWF and PMSG based MCF with the proposed STATCOM. The 80MW OWF is spoken to by an extensive proportionate accumulated DFIG driven by an equal collected variable speed WT through an equal amassed gearbox. The 40MW MCF is spoken to by an expansive equal totaled PMSG driven by an identical accumulated variable speed MCT through a comparable amassed gearbox. The OWF, the MCF, the STATCOM and a nearby load are associated with an AC bus that is fed to the inland power grid through an offshore stride up transformer and undersea links [9]. The utilized scientific models of the examined system are depicted as underneath.

MARINE-CURRENT SPEED AND MARINE-CURRENT TURBINE MODEL

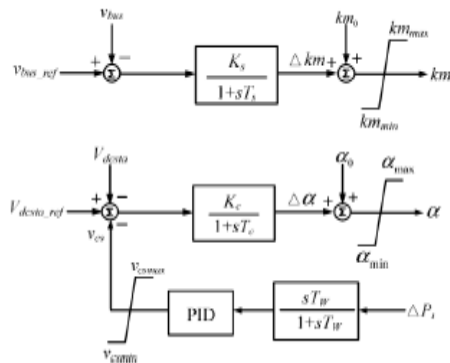


Fig.3. Control block diagram of the proposed STATCOM including the designed PID damping controller

STRUCTURE OF STATCOM

Basically, STATCOM is contained three basic parts (as seen from Figure underneath): a voltage source converter (VSC), a phase up coupling transformer, and a controller. In a high-voltage system, the spillage inductances of the movement up power transformers can fill in as coupling reactors. The major inspiration driving the coupling inductors is to filter through the current consonant parts that are created mainly by the throbbing yield voltage of the power converters

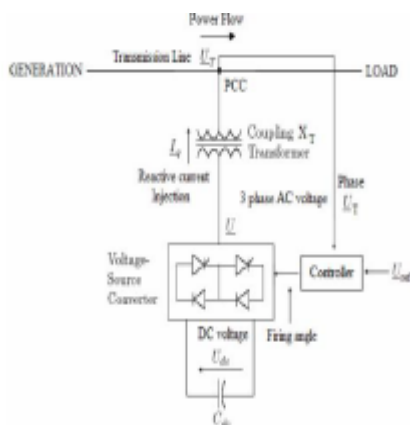


Fig 4 structure of STATCOM

The controller of a STATCOM works the converter especially that the stage edge between the converter voltage and the transmission line voltage is powerfully balanced and synchronized so that the STATCOM creates or retains fancied VAR at the purpose of coupling association. Figure demonstrates an improved graph of the STATCOM with a converter voltage source

DESIGN OF A PID DAMPING CONTROLLER FOR STATCOM USING MODAL CONTROL THEORY

This section presents a unified approach based on modal control theory to design the PID damping controller of the proposed STATCOM shown in Figure. For dynamic stability improvement of the studied system. The nonlinear system equations developed in Section II are first linearized around a nominal operating point to obtain a set of linearized system equations in matrix form of

$$PX = AX + BU + VW$$

$$Y = CX + DU$$

STATCOM is a controlled receptive power source. It gives voltage bolster by producing or engrossing responsive power at the purpose of normal coupling without the need of extensive outer reactors or capacitor banks. Utilizing the controller, the VSC and the coupling transformer, the STATCOM operation is delineated in Figure 8. The one-line chart of the contemplated STATCOM was appeared in Figure 8. The per unit q-pivot and - hub yield voltages of STATCOM can be communicated by, separately

$$V_{qsta} = V_{dcsta} \cdot K_m \cdot \cos(\text{bus} \angle + \alpha)$$

$$V_{dsta} = V_{dcsta} \cdot K_m \cdot \sin(\text{bus} \angle + \alpha)$$

Two Modes of Operation There are two techniques for operation for a STATCOM, inductive mode and the capacitive mode. The STATCOM regards an inductive reactance related at its terminal when the converter voltage is higher than the transmission line voltage. Along these lines, from the framework's point of view, it sees the STATCOM as a capacitive reactance and the STATCOM is believed to be working in a capacitive mode. So likewise, when the framework voltage is higher than the converter voltage, the framework regards an inductive reactance related at its terminal. Thus, the STATCOM sees the framework as a capacitive reactance and the STATCOM is believed to be working in an inductive mode

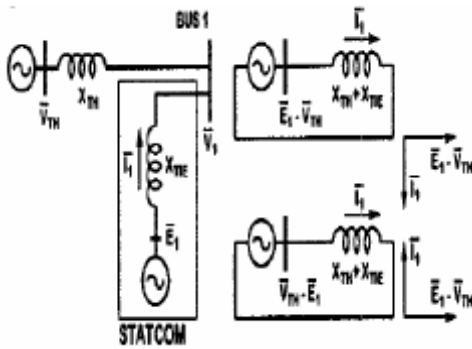


Fig 5 STATCOM operating in inductive or capacitive modes

STATCOM operating in inductive or capacitive modes In other words, looking at the phasor diagrams on the right of Figure 3.4, when I_1 , the reactive current component of the STATCOM, leads $(V_{TH}-V_1)$ by 90° , it is in inductive mode and when it lags by 90° , it is in capacitive mode. This double mode ability empowers the STATCOM to give inductive pay and capacitive remuneration to a system. Inductive remuneration of the STATCOM makes it exceptional. This inductive remuneration is to give inductive reactance when overcompensation because of capacitors banks happens. This occurs amid the night, when a regular inductive load is around 20% of the full load, and the capacitor banks along the transmission line give inordinate capacitive reactance because of the lower stack. Essentially the control system for a STATCOM comprises of a current control and a voltage control.

STEADY-STATE ANALYSIS UNDER VARIOUS OPERATING CONDITIONS

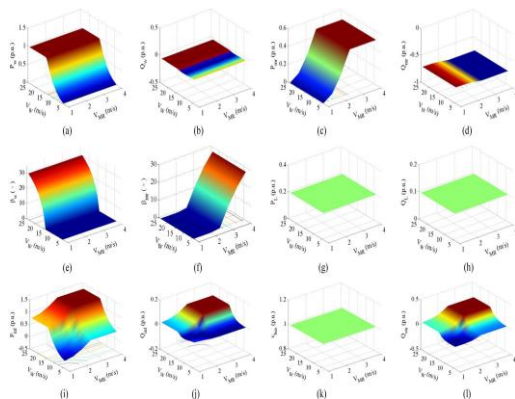


Fig.6: Steady-state operating conditions of the studied system under various values of wind speed and marine-current

SIMULATION RESULTS

In this area, to demonstrate the standard of power control of PMSG-based variable-speed wind turbine associated with the grid, it is controlled keeping in mind the end goal to catch the most extreme wind energy and its conduct subjected to a variable speed wind will be shown utilizing numerical recreations conveyed under the Matlab - SIMULINK. The damping attributes contributed by the proposed STATCOM joined with the planned PID damping controller to showing signs of improvement dynamic soundness change of the contemplated system

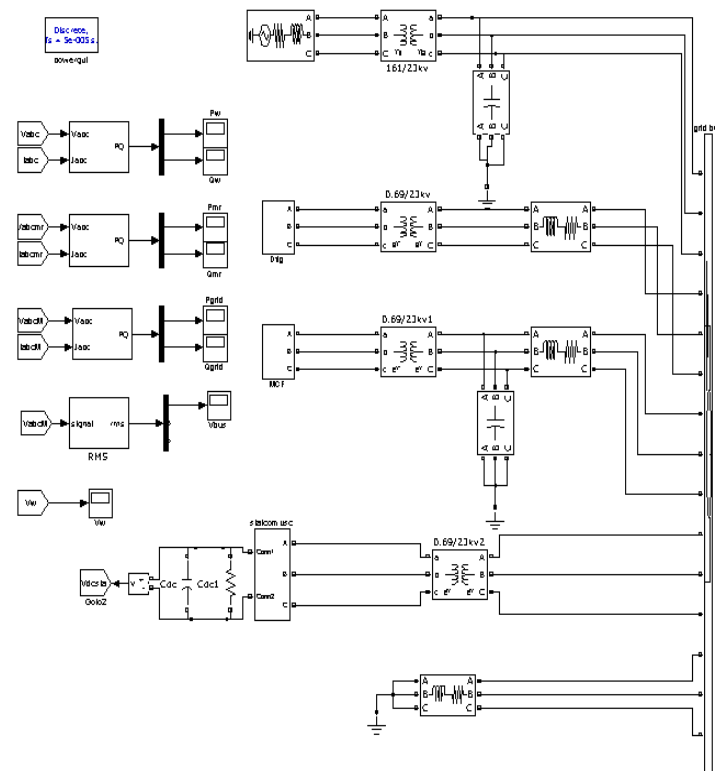
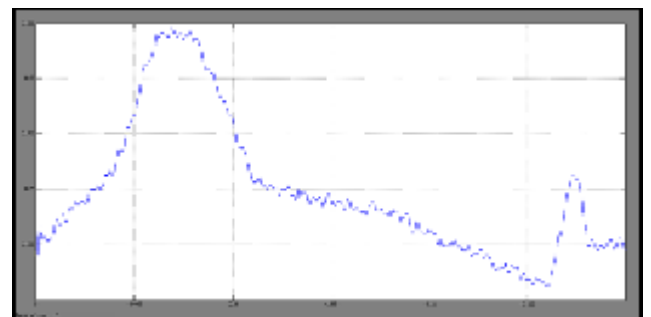


Fig7: MATLAB simulation circuit for Dynamic responses of the studied system under wind speed disturbance



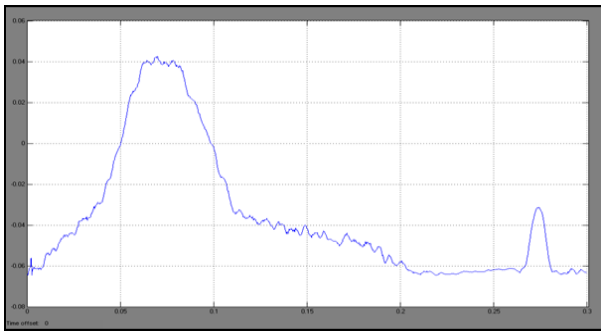


Fig. 8 Dynamic responses of the studied system without the STATCOM damping controller under a noise wind speed disturbance

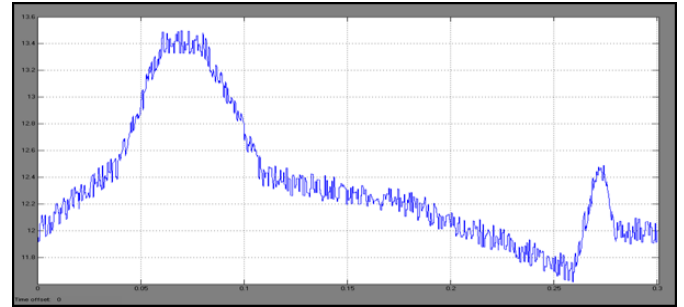
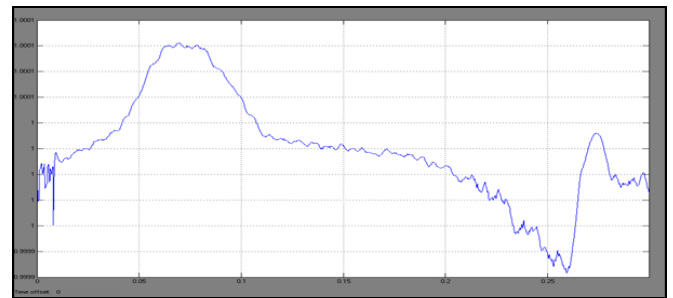
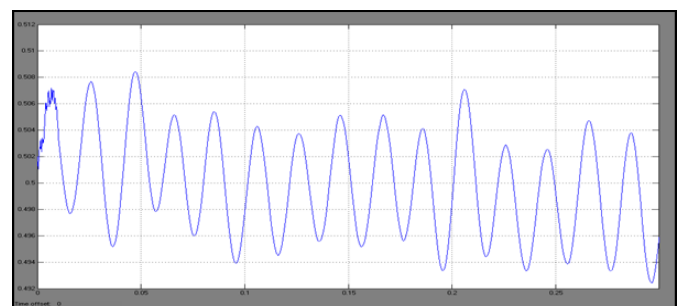
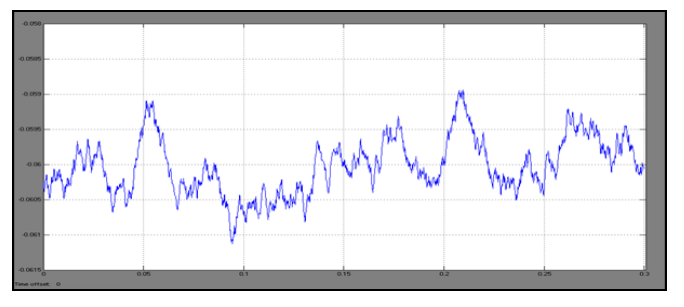
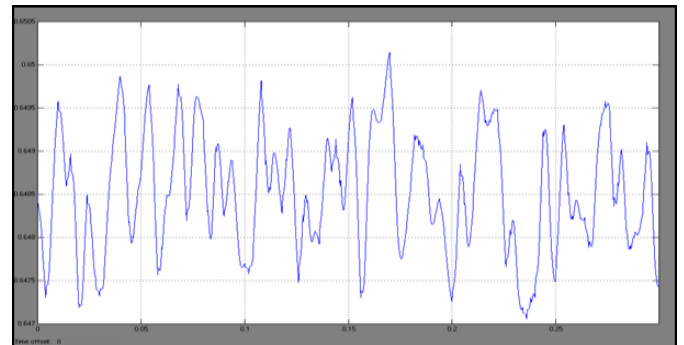
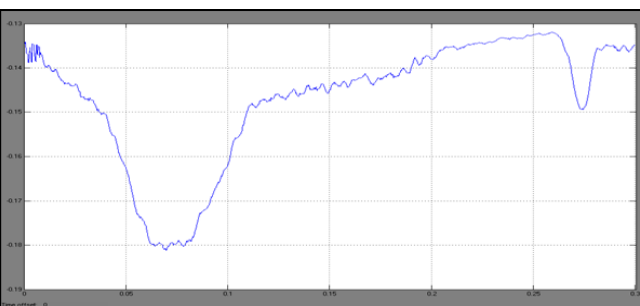
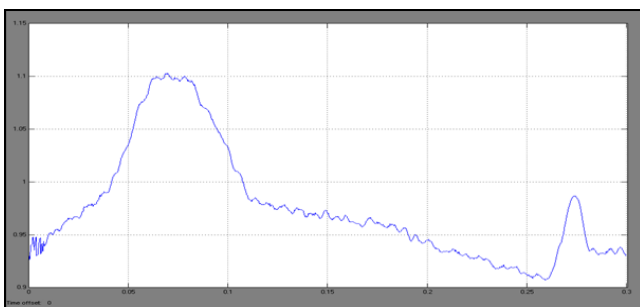
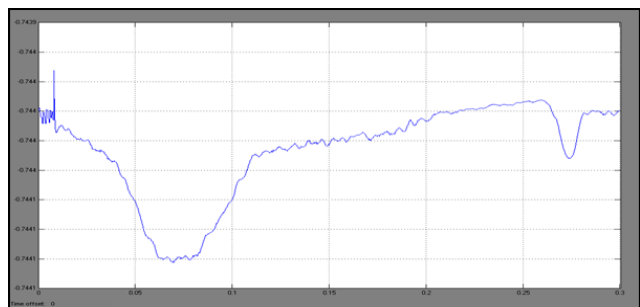
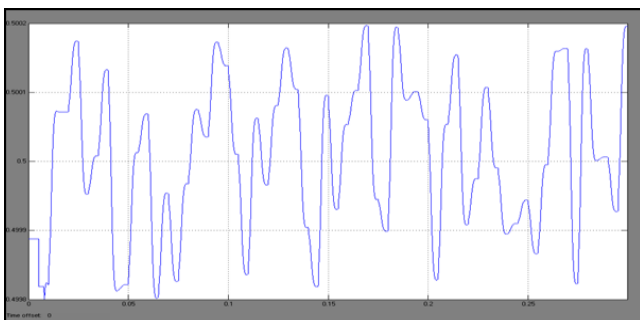


Fig.9 Dynamic responses of the studied system with and without the designed PID STATCOM damping controller under a noise wind speed disturbance



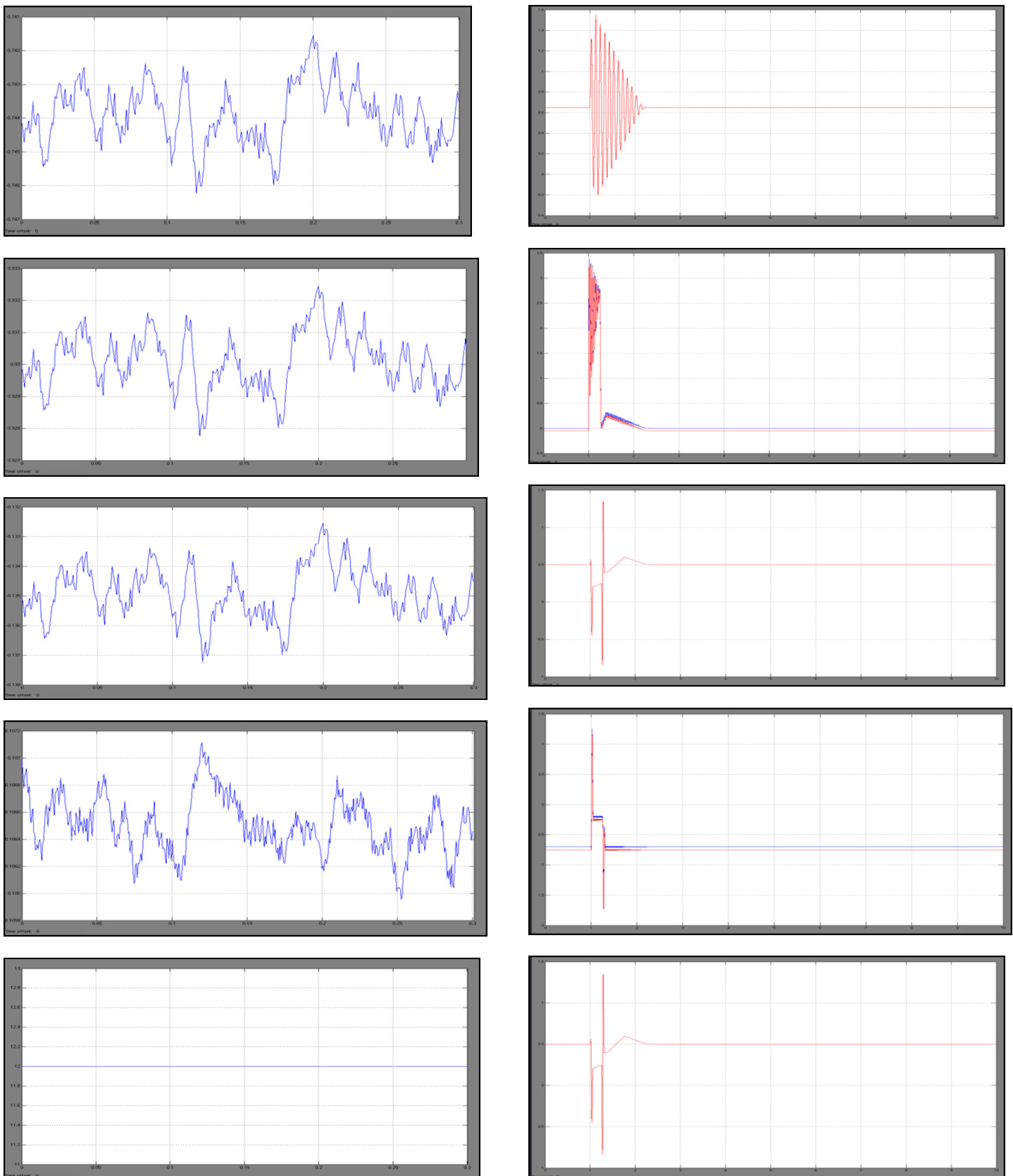


Fig:10 Dynamic responses of the studied system with and without the PID STATCOM damping controller under a marine-current speed disturbance.

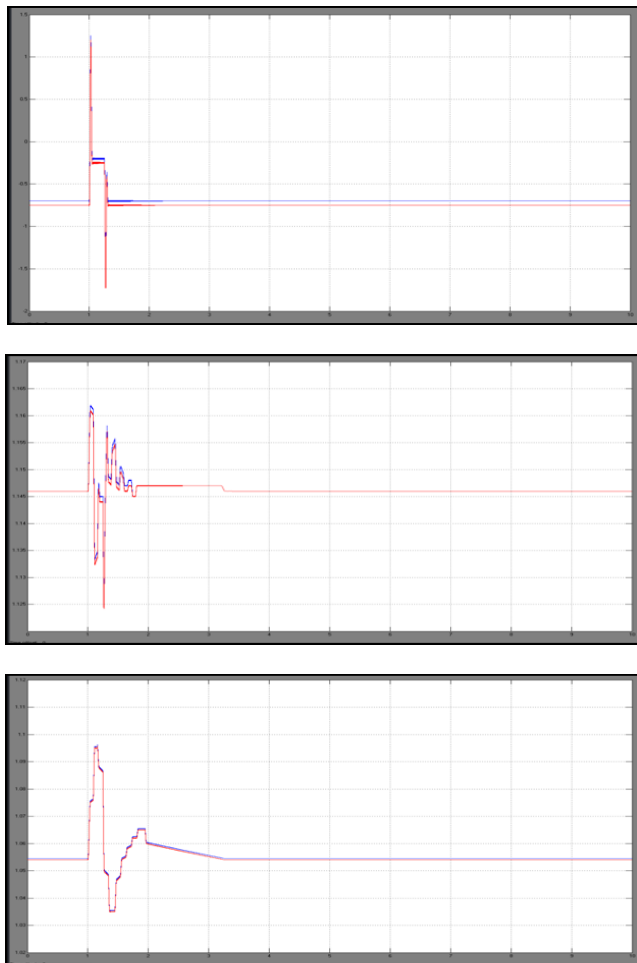


Fig.11. Transient responses of the studied system with and without the designed PID STATCOM damping controller under a three-phase fault at power grid.

CONCLUSION

This venture has displayed the dynamic security change of an incorporated OWF and MCF utilizing a STATCOM. A PID damping controller has been intended for the STATCOM by utilizing a unified approach in light of post task approach. Eigen esteem computations and time-space reproductions of the contemplated framework subject to a clamor wind-speed unsettling influence, a marine-current speed aggravation, and a three-stage impede at the grid have been methodically performed to show the viability of the proposed STATCOM joined with the composed PID damping controller on smothering voltage fluctuation of the examined framework and enhancing framework dynamic strength under various working conditions. It can be finished up from the reproduction comes about that the proposed STATCOM joined with the composed PID damping controller is equipped for enhancing the

execution of the concentrated incorporated OWF and MCF under various working conditions.

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