

## **Power Quality Improvement Hybrid Energy System of Offshore Wind and Tidal Energy**

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**Abstract:** This paper represents the integrated of power extracted from two different renewable energy sources are off-shore wind and tidal energy. In those combination of two different renewable energy sources non-pollutants to the atmosphere. Then the sources are integrated by using hybrid energy system and its uses power quality problems are reduced in integrated power system. The power quality problems are such as voltage variation and frequency changes due to dynamic load conditions. In the proposed system consists of wind and tidal generator connected to the individual bridge rectifier. Then the rectified output connected to PWM (Pulse Width Modulation) inverter through common DC link along with PI (Propositional Integral) controller. Therefore finally the inverter connected to the required grid system which control the voltage profile and power factor of the system. In order to communicate and synchronise between of wind and tidal energy conversion system has been implemented by using MATLAB/SIMULINK.

**Keyword:** DFIG-Double Fed Induction Generator, SCIG-Squirrel Cage Induction Generator, WECS-Wind Energy Conversion System, TECS-Tidal Energy Conversion System.

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### **I. Introduction**

Renewable energy power generation has been noted as the most growing technology. Then the most cost effective ways to generate electricity from renewable energy sources of wind and tidal energy. A combination of two or more types of energy sources might provide a good chance of optimizing power generating system. However still a lot of researches needed to make wind and tidal energy harvesting systems co-operate efficiently and reliably. The hybrid system electrical energy extracted from off shore wind and tidal turbine hybrid systems is outline represented in this paper.

Off shore wind and tidal energy conversion systems to operate as variable speed of the generator is required for depend upon the wind and tidal flow. Then the DFIG-Double Fed Induction Generator for wind energy conversion and SCIG-Squirrel Cage Induction Generator for tidal energy conversion has been commonly used. Wind power is the conversion of wind energy into a suitable form of energy such as using wind turbine to generate electricity from wind blades rotational mechanical energy. The induction machine works on the principle of according to mutual induction and Lenz law.so, the generator converting mechanical power from wind turbine into electrical power. Generally the tidal flow is more stable than to wind flow. The tidal produced by the moon and sun, in combination with earth rotation are responsible for the generation on the tides. On the walled dam there are low head turbines hat allow the water to flow from one side of the barrage to inside the tidal basin, this difference on the elevation of the water level creates rotational force applied to the generator it's depend upon water density.

Then the induction generators are connected to load (grid) through the back to back connected system. The generated power from two types of power generation system is initially coupled to the three phase bridge rectifier which convert from AC into DC. On the DC side to provide converter with DC link for to maintain the DC bus voltage level for system stable at AC side. Then the sinusoidal pulse with modulation technique using bidirectional inverter connected after the DC link. So, the inverter output were connected to the grid connected load system. The generator power the inverter controls the DC link voltage and the power factor of the system. The control strategy and feasibility of hybrid wind and tidal turbine energy system model has been implemented by using MATLAB/Simulink.

### **II. Proposed System**

#### **2.1 System Overview**

The limited resources are coal, fossil fuel, nuclear, for producing electricity and cost of fuels are increased so, and we need of renewable energy. In this proposed an improved system of hybrid wind and tidal to compensate generated power.

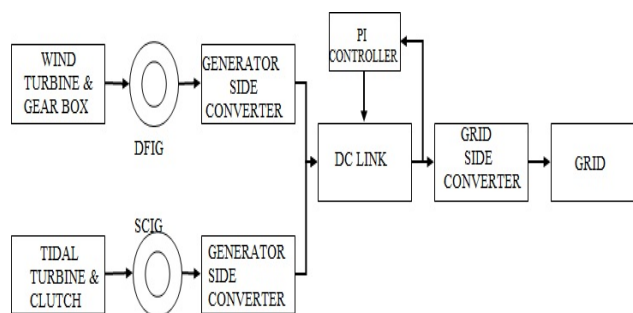


Fig 1: block diagram of proposed system

An offshore wind and tidal generated variable speed variable voltage AC power output is converted by machine side three phase bridge rectifier and using of PI controller to maintain DC power. The DC power is transmitted through underground cable to grid side DC/AC inverter station. Thus the generated power connected to the grid system before connect setup of the above mentioned (AC/DC/AC).

### 2.2 Wind Energy Conversion System

The basic principle used in DFIG is to interpose a frequency converter between the variable frequency of induction generator (it is mainly for injecting the current in the rotor circuitry for frequency the compensation) and fixed frequency grid. The speed of machine can be controlled from either rotor side or stator side. Converter acts in both super and sub synchronous speed. Since the slip power can flow in both directions such as from the rotor side to the supply and from the supply to the rotor side.

### 2.3 Tidal Energy Conversion System

Turbines are used to extract energy from the rise and fall of tides, located in water passages in the barrage. The potential energy is developed due to the difference in water level across the barrage and is converted to kinetic energy. This in turn is converted into rotational kinetic energy by the blades of turbine.

The amount by which the rotating flux produced by the stator exceeds the rotor speed is called the slip. In generator mode the slip is negative as the rotor runs faster than the flux produced by the stator.

### 2.4 Dc Link

An intermediate circuit capacitor (DC-Link) as used in the intermediate circuit of converters of different kinds where it couples different electrical grids to one DC voltage level. Due to its high capacitance and its ability to supply power quickly the DC voltage intermediate circuit is supported, and a constant DC voltage value can be realized even high current peaks are generated by the system. DC-Link capacitors are used in the DC voltage intermediate circuit of wind power units for voltage stabilization.

### 2.5 Grid Side Converter

The main tasks of the inverter is the grid connection and current control that can be performed only if the conditions regarding the grid voltage are satisfied. Moreover, in order to control the grid current, the DC Link voltage must be above the peak of the grid voltage

A three phase fully controlled converter is obtained by replacing all the six diodes replaced three phase diode rectifier by six IGBT (Insulated Gate Bipolar Transistor). Now the semiconductor switches having six conduction mode operation of the correct sequence with 60° interval between each firing angle. If the inverter firing angle α has been assumed that larger than 90° direction of power flow reverse provided there exists a power source in the dc side of DC link provided. The grid-connected converter must inject power with unity power factor, but the recent penetration of renewable energy systems into the mains has caused some problems regarding the grid voltage stability.

## III. Simulation Model Of Proposed System

### 3.1 Wind Turbine and Generator Model

Wind turbines convert the kinetic energy represent in the wind energy into mechanical energy by means of producing rotating torque. Since the energy contained by the wind is in the form of kinetic energy, its magnitude depends on the air density and the wind velocity as shown in fig 2. The wind power developed by the turbine is given by the equation

$$P = 0.5C_p\rho AV^3 \dots\dots\dots (1)$$

Where  $C_p$  is the Power Co-efficient,  $\rho$  is the air density in kg/m<sup>3</sup>, A is the area of the turbine blades in m<sup>2</sup> and V is the wind velocity in m/sec.

The power coefficient  $C_p$  gives the fraction of the kinetic energy that is converted into mechanical energy by the wind turbine. It is a function of the tip speed ratio  $\lambda$  and depends on the blade pitch angle for pitch-controlled turbines. The tip speed ratio may be defined as the ratio of turbine blade linear speed and the wind speed.

$$\lambda = \frac{R\omega}{V} \dots\dots\dots (2)$$

$$P = 0.5 C_p(\lambda) \rho A(R/\lambda)^3 \omega^3 \dots\dots\dots (3)$$

The output torque of the wind turbine  $T_{\text{turbine}}$  is calculated by the following equation

$$T_{\text{turbine}} = 0.5 C_p \rho A V / \lambda \dots\dots\dots (4)$$

Where  $R$  is the radius of the wind turbine rotor (m) There is a value of the tip speed ratio at which the power coefficient is maximum [2]. Variable speed turbines can be made to capture this maximum energy in the wind by operating them at a blade speed that gives the optimum tip speed ratio. This may be done by changing the speed of the turbine in proportion to the change in wind speed.

The gearbox is used to step up the low angular speeds of the turbine (normally about 25-30 rpm) to the high rotational speeds of the generator (normally around 1800 rpm). The turbine torque  $T_m$  (produced by the wind), accelerates the turbine inertia and is counter balanced by the shaft torque  $T_{s1}$  (produced by the torsional oscillation action of the low speed shaft).

$$T_m - T_{s1} = J_m (d\omega_b/dt) \dots\dots\dots (5)$$

Where,  $\omega_r$  is the Angular velocity of the turbine and  $J_m$  is the Moment of inertia of the turbine.

Similarly, the shaft produced torque by the high-speed shaft ( $T_{s2}$ ) accelerates the rotor and is counterbalanced by the electromagnetic torque ( $T_e$ ) produced by the generator.

$$T_{s2} - T_e = J_r (d\omega_r/dt) \dots\dots\dots (6)$$

Where,  $\omega_r$  = Angular velocity of the rotor and  $J_r$  = Moment of inertia of the rotor.

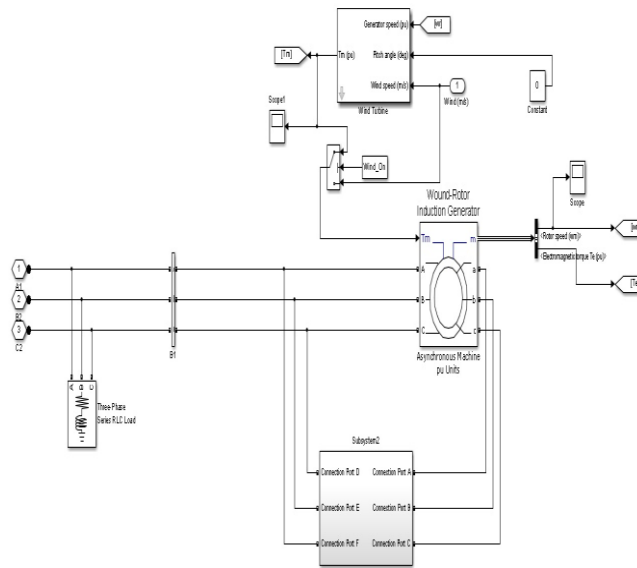


Fig 2: Wind Generation Dfig Model

**3.2 Tidal Turbine and Generator Model**

Tidal current devices seek to extract energy from the kinetic movement of water much as wind turbines extract energy from movement of air; these tidal currents are often enlarged where water is forced to flow through narrow channels. As tidal currents are a periodic horizontal flow of water accompany to the rise and fall of the tide they can be modelled as a stream of harmonics,

$$V(t) = \sum V_i \sin(2\pi f_i t + P_i) \dots\dots\dots (7)$$

Where,  $V_i$  is the amplitude, is the  $t$  period and  $P_i$  is the phase for  $i$ -th harmonic constituents

The potential energy of a tidal turbine given by below

$$E_p = 0.5 C_p(\lambda) g \rho A h^2 \dots\dots\dots (8)$$

Where,  $E_p$  is Potential Energy (J),  $C_p$  is power coefficient

$\lambda$  is tip speed ratio,  $g$  is acceleration due to gravity ( $ms^{-2}$ )

$\rho$  is density of the water (seawater is  $1025 \text{ kgm}^{-3}$ ),  $A$  is the sweep area of the turbine ( $m^2$ ),  $H$  is tide amplitude (m)

Actual power can be harnessed as follows by  $P_{\text{act}}$

$$P_{act} = 0.5 \rho C_P (\lambda, \beta) AV^3 \dots\dots\dots (9)$$

Where,  $\rho$  is the seawater density =1025, A is the rotor blade area and V is the water current speed,  $C_p$  power coefficient that is a function in tip speed ratio TSR.

Drive train is the connector that deliver the turbine rotor mechanical motion to the generator. It generally consists of low-speed shaft with connected to the turbine hub, speed multiplier and high-speed shaft, motivating the electrical generator model shown in fig 3.

$$J(dW_g/dt) = T_m - T_e - V_f W_g \dots\dots\dots(10)$$

$$T_m = P_{act} / W_r$$

$$T_m = (0.5 \rho C_P (\lambda, \beta) AV^3) / W_r \dots\dots\dots(11)$$

Where, j is the summation of rotor and generator inertia,  $T_m$  is the turbine mechanical torque,  $T_e$  is the generator electromagnetic torque,  $V_f$  is the viscous friction coefficient or damping ratio,  $W_g$  is the generator angular speed and  $W_r$  is the rotor angular speed.

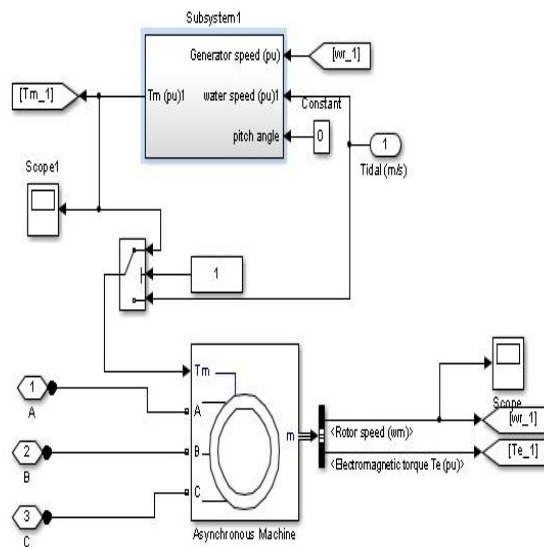


FIG 3: Tidal Generation SCIG Model

**3.3 Dc Link**

An intermediate circuit capacitor (DC-Link) as used in the intermediate circuit of converters of different kinds where it couples different electrical grids to one DC voltage level. Due to its high capacitance and its ability to supply power quickly the DC voltage intermediate circuit is supported, and a constant DC voltage value can be realized even high current peaks are generated by the system. DC-Link capacitors are used in the DC voltage intermediate circuit of wind power units for voltage stabilization.

The DFIG based WECS and SCIG based TECS combined by using of DC-DC converter (DC\_Link) can be provided to overcome the problems are mentioned below,

- To maintain dc bus voltage due any variation speed of wind and tidal generator.
- To maintain grid side inverter output.

The output voltage equation of the DC-DC converter,

$$\frac{V_o}{V_i} = \frac{1}{1 - D} \dots\dots\dots (10)$$

Where,

$V_o$  - Output voltage of converter

$V_i$  - Input voltage of converter

D - Duty ratio of converter

If any variations in input voltage then the duty ratio of converter varied to maintain the output dc voltage. Therefore the ratio between ranges of (0-1).The control strategy closed loop control of using PI controller as shown in fig 4. To sense the voltage variation at output side compare to the reference voltage. The error is proceed to controller output has been modulated by changing the firing pulse that drives the IGBT by PWM technique.

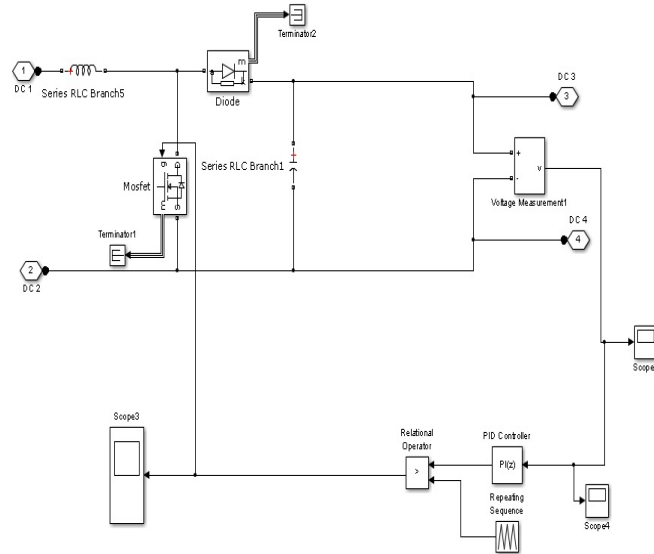


Fig 4: DC Link Model

### 3.4 Grid Side Inverter

The PWM inverter along with APF used to interface to the grid system modelled as shown in fig 5. The inverter contains necessity conditions satisfied of inverter mentioned below,

- To transfer real power from generator to grid.
- To support reactive power demand
- To limits the odd harmonics

The utility grid voltage as

$$V_a = \sin \theta \quad \dots\dots (11)$$

$$V_b = \sin (\theta - 2\pi/3) \quad \dots\dots (12)$$

$$V_c = \sin (\theta + 2\pi/3) \quad \dots\dots (13)$$

The DC link voltage maintain constant by using PI regulator according to the reference voltage as utility grid voltage of above. The instantaneous values of reference grid current as

$$I_a = I_m * V_a \quad \dots\dots (14)$$

$$I_b = I_m * V_b \quad \dots\dots (15)$$

$$I_c = I_m * V_c \quad \dots\dots (16)$$

According to the reference of utility grid voltage and current to PI controller to generated switching pattern for gate terminal of the IGBT grid side inverter.

Now the semiconductor switches having six conduction mode operation of the correct sequence with  $60^\circ$  interval between each firing angle. If the inverter firing angle  $\alpha$  has been assumed that larger than  $90^\circ$  direction of power flow reverse provided there exists a power source in the dc side of DC link provided. The grid-connected converter must inject power with unity power factor, but the recent penetration of renewable energy systems into the mains has caused some problems regarding the grid voltage stability.

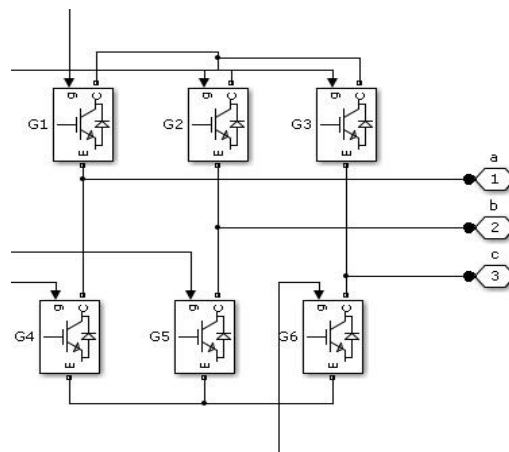


Fig 5: Grid Side Inverter Model

### 3.5 P-I Controller

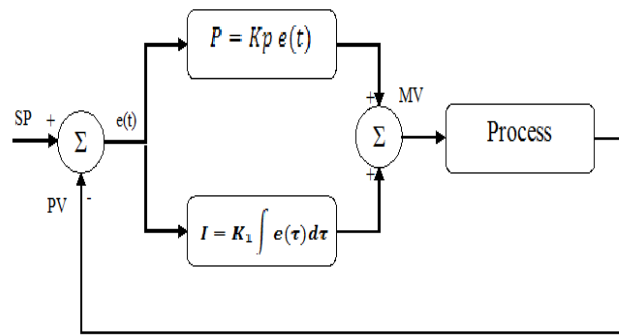


Fig 6: PI controller

A PI Controller (proportional-integral controller) is a special case of the PID controller in which the derivative (D) of the error is not used.

The controller output is given by,

$$Kp + Ki \int \Delta dt \dots\dots\dots(17)$$

Where  $\Delta$  is the error or deviation of actual measured value (PV) from the set point (SP),

$$\Delta = SP - PV \dots\dots\dots (18)$$

A PI controller can be modelled in fig 6 easily in software such as Simulink or Xcos using a "flow chart" box involving Laplace operators,

$$C = \frac{G(1 + \tau S)}{\tau S} \dots\dots\dots (19)$$

Where

G = Kp = proportional gain

G = Ki = integral gain

Setting a value for G is often a trade-off between decreasing overshoot and increasing settling time. This is because derivative action is more sensitive to higher-frequency terms in the inputs.

## IV. Simulation Results

The hybrid system consists of induction generators having of 1.5 MW, 25KV to connect with three phase bridge converter (MSC) and connected to three phase bidirectional inverter (GSC) through DC link. The inverter AC output connected to the assumed as local center having of (11 or 20 KV line) used for distribution electricity to the consumer end.

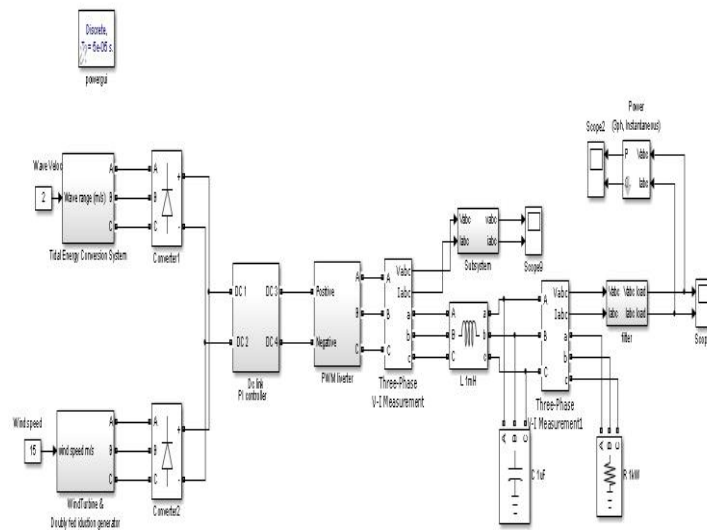
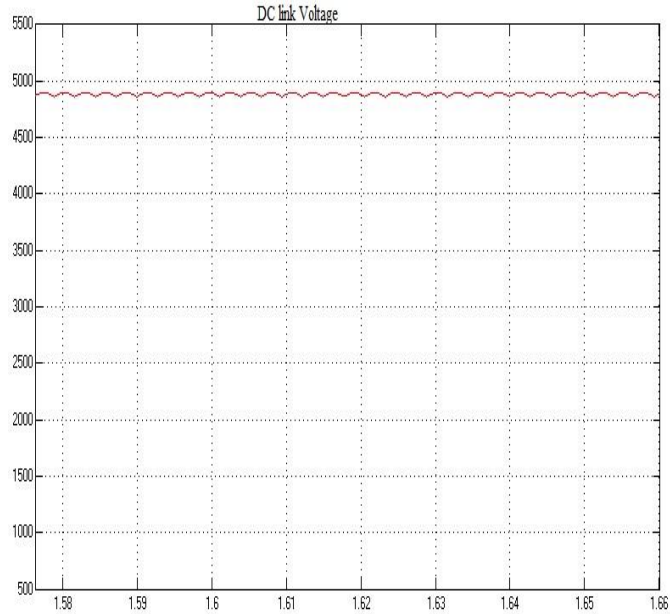


Fig 14: Simulation of Hybrid Wind and Tidal System

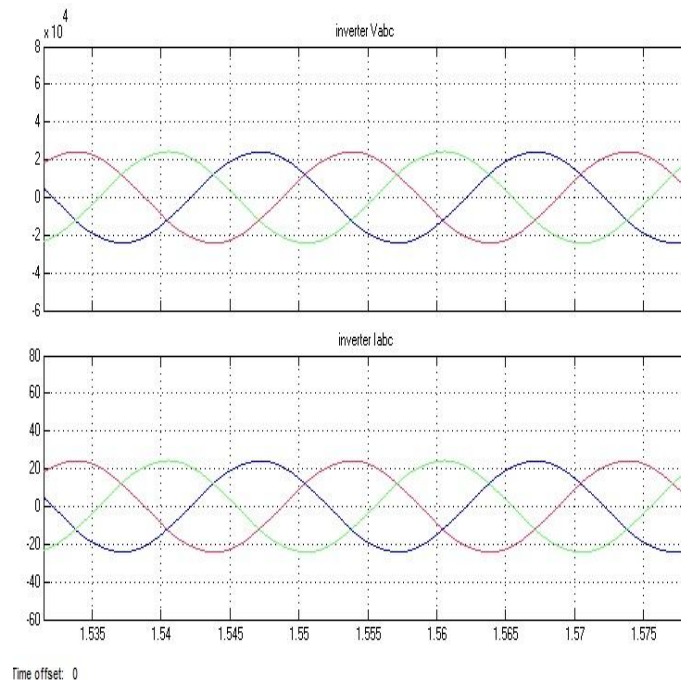




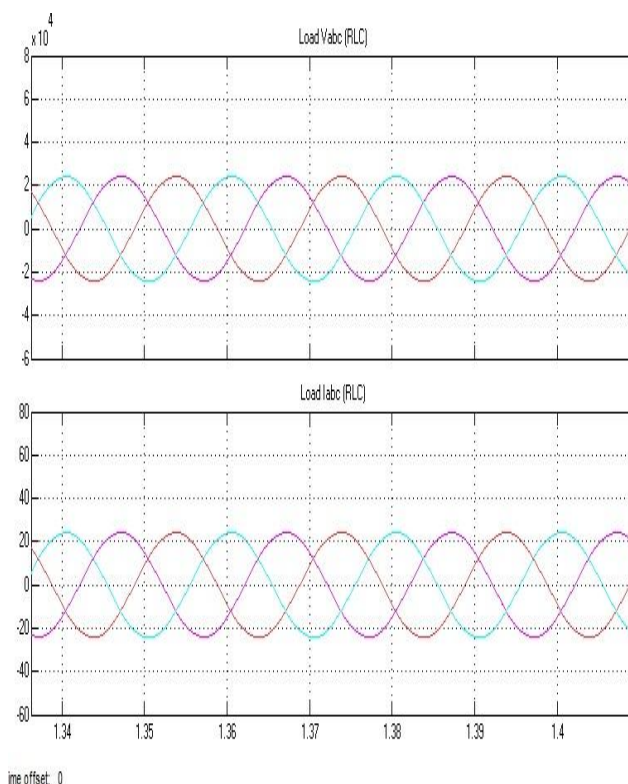
**Fig 14:** Simulation of Hybrid Wind and Tidal System

Then the tidal turbine according to water velocity range let us assumed as (1to 5m/sec) as shown below fig 7.2 applied to induction generator states that variable so, it's connected to grid system by providing similar to the AC-DC-AC converter.. The generator initially connected to three phase diode rectifier arrangement as shown in diagram above fig 15.

The wind velocity varies in each every second depend upon earth rotation let us assumed as in between (10 to 15m/sec). In which the wind generation similar to the tidal turbine generator as show in fig 16. The generator initially connected to three phase diode rectifier arrangement as shown in diagram above fig 17.



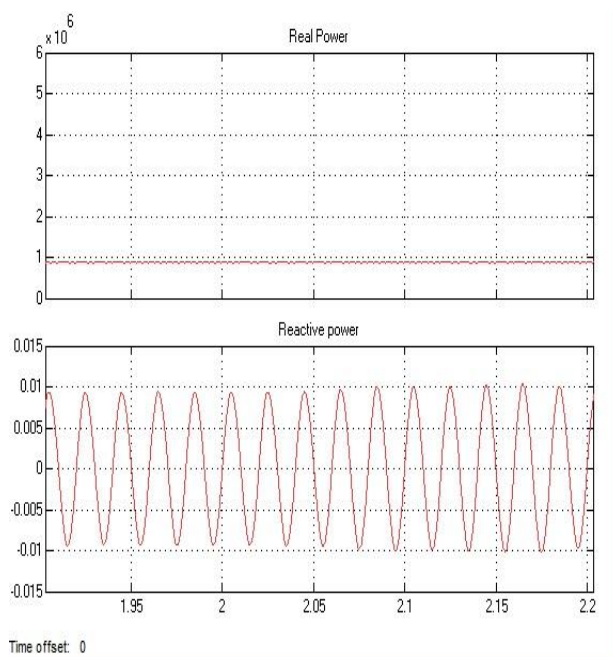
**Fig 14:** Simulation of Hybrid Wind and Tidal System



**Fig 14:** Simulation of Hybrid Wind and Tidal System

**Table 1:** Hybrid Wind and Tidal System

Quantity	Values
Vdc	4800 Volts
Vinverter	25kVolts
Iinverter	20Amps
Vload	25kVolts
Iload	20 Amps
Real power	0.9 MW
Reactive power	0.01 Mvar



**Fig 14:** Simulation of Hybrid Wind and Tidal System



## V. Conclusion

The proposed wind and tidal energy hybrid generation system model linked by use of dc link capacitor and the bidirectional grid inverter showed good performances and stable operation. The techniques of offshore-wind and the tidal power hybrid system are a design, an electric transmission, a system and a stability operation, a system investigation, a reactive power and voltage frequency control strategy, and the interaction between offshore-wind and tidal generation systems.

As the frequency of the rotating magnetic field of the induction machine increases, the output power and phase difference of the tidal turbine generation system increase. The automatic power fluctuation compensation simulation shows that the output power of offshore wind turbine generation system is compensated and hybrid power is integrated by the tidal turbine generation system. Implemented for the grid side control ensures a decoupling strategy of the stator side. A simulation model is proving that the dc link voltage is maintained constant using a PI controller. Overall, this system provides an alternative for future sustainable energy harvesting systems.

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