Hybrid Energy System of Offshore Wind and Tidal Energy with Power Quality Improvement

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***Abstract* —** This paper represents hybrid energy system of renewable energy sources are such as offshore wind and tidal energy for electrical power generation and delivered to the required grid connected or integrated power system. The power quality problems are frequency variation, voltage dips which are due to fault on dynamic load conditions can be reduced by the hybrid energy system. The proposed system of offshore wind and tidal generator consist of two different bridge rectifiers connected and through DC link along with the (proportional and integral) PI controller. The sinusoidal pulse with modulation technique (PWM) is used to design an inverter for grid connected load system which controls/maintains the voltage profile and the power factor of the system. In order to communicate and synchronize between of tidal and wind energy conversions system is implemented by using MATLAB/SIMULINK.

***Keywords*—** *DFIG-Double Fed Induction Generator, SCIG-Squirrel Cage Induction Generator, Wind Energy Conversion System, Tidal Energy Conversion System*

I. INTRODUCTION

Renewable energy power generation has been noted as the most growing technology. The limited resources are coal, fossil fuel, nuclear, for producing electricity and cost of fuels are increased so, and we need of renewable energy. 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. [1]

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. Then the rated capacity of the wind generator were 1.5MW and those of the tidal generator were 1.0MW. 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. Wind turbine generates ac power is converted to dc power through machine side converter as a diode rectifier. The diode rectifier gives a fixed output voltage for a given ac supply from variable speed generating system of offshore wind and tidal.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.[5]

Then the induction generators are connected to load (grid) through the back to back converter type 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 width 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. [3] The control strategy and feasibility of hybrid wind and tidal turbine energy system model has been implemented by using MATLAB/Simulink.

II. PROPOSED SYSTEM

A. SYSTEM OVERVIEW:

In this proposed an improved system of hybrid wind and tidal energy to compensate generated power. Then the both machine side converter diode based three phase bridge rectifier and grid side converter IGBT based three phase inverter with PWM technique. The inverter output can be connected the filter arrangement to reduce the harmonic distortion and to improve the power quality. An offshore wind and tidal energy systems generated AC power is converted into DC power using three phase bridge rectifier. The DC power is transmitted through underground cable or overhead cable with IGBT based DC link. And DC link output has been connected to grid side converter after the AC power transmitted through the transmission lines.

B.WIND GENERATION SYSTEM:

The wind generating system consists of DFIG with wind turbine rotates according consider to available wind almost constant. The stator directly connected to the three phase rectifier unit and rotor connected through the AC/DC/AC converter setup.

C.TIDAL GENERATION SYSTEM:

The wind generating system consists of SCIG with tidal turbine rotates according consider to available wave almost constant. The stator connected reactive power source to the three phase rectifier unit.

D.DC LINK:

The inverter output maintain constant bus voltage in the power system required by providing of line reactor and capacitor with IGBT power switch. It's used to adjust the duty ratio of gate trigger pulse of switching device by using of PI controller with feedback system. Fig. 1 shows below block diagram of the proposed hybrid energy system.

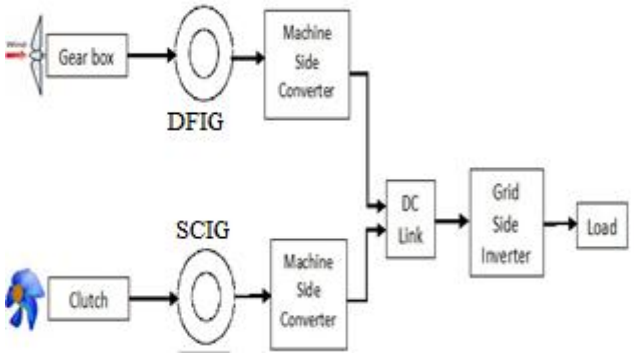

Fig 1: block diagram of proposed system

III. MODELLING OF PROPOSED SYSTEM

A.WIND GENERATION MODEL:

The wind velocity (V_w) can be written as,

$$V_w = V_{wB} + V_{wG} + V_{wR} \quad \ldots (1)$$

Where, V_w is the Total Wind Velocity, V_{wB} is the Base Wind Velocity, V_{wG} is the Gust wind component and V_{wR} is the Ramp wind component.

Wind turbine works on the principle of extracting kinetic energy form the air that across the blade swept area. The power in air (Pair) is as follows,

$$P_{air} = 0.5\,\rho\, AV\infty \quad \ldots\ldots\ldots (2)$$

Where P air is the power contained in wind, ρ is the air density (1.225 kg/m3), A is the swept area, and V∞ is the wind velocity.

The power extracted from the air stream by the turbine blades, (P),

$$P = 0.5C_p\rho\upsilon^3\pi R^2 \quad \ldots\ldots\ldots\ldots (3)$$

Where, ρ = air density (1.22 kg/m3), R = radius of swept area by the turbine blades, υ = speed of moving air flow, Cp =power coefficient.

The turbine torque Tm (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).

$$T_m - T_{s1} = J_m \frac{d\omega b}{dt} \quad \ldots\ldots\ldots (4)$$

Where, ω_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.

$$T_{s2} - T_e = J_r \frac{d\omega b}{dt} \quad \ldots\ldots\ldots (5)$$

Where, ω_r = Angular velocity of the rotor and Jr = Moment of inertia of the rotor.

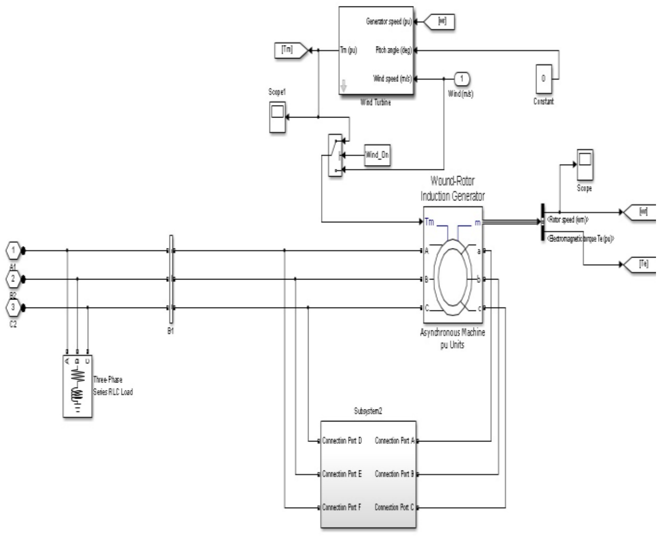

Fig 2: Simulation of Wind System

B.TIDAL GENERATION MODEL:

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.

$$Vi_{(t)} = \Sigma Vi.\sin(2\pi fit+Pi) \quad \ldots\ldots\ldots\ldots (5)$$

Where, Vi is the amplitude, is the t period and Pi is the phase for i-th harmonic constituents.

The potential energy of a tidal turbine can be calculated.

$$E = 0.5C_p(\lambda)\, gpAh^2 \quad \ldots\ldots\ldots (6)$$

Where, Ep is Potential Energy (J), Cp is power coefficient
λ is tip speed ratio, g is acceleration due to gravity (ms-2)
ρ is density of the water (seawater is 1025 kgm-3), A is the sweep area of the turbine (m3), H is tide amplitude (m)

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

$$P_{act} = 0.5\rho C_p(\lambda)\, Av^3 \quad \ldots (7)$$

Where, ρ 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.

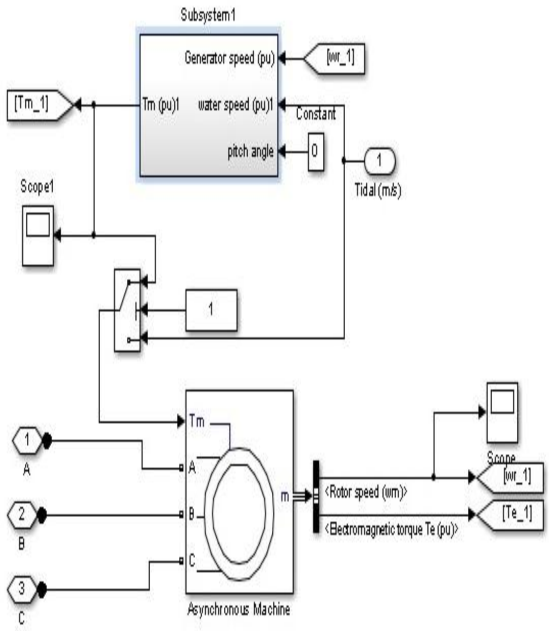

Fig 3: Simulation of Tidal System

C.DC LINK & PI controller:

Each converter has to produce an AC voltage at least equal to the AC-side nominal voltage in order to properly control the injected AC-side current. Assuming an ideal converter with large frequency modulation ratio, naturally sampled sinusoidal PWM and a balanced system, the AC-side line-to-line output voltage is a function of the DC-link voltage V_{dc} and of the amplitude modulation ratio m,

$$VLL = \frac{\sqrt{3}\, mVdc}{2\sqrt{2}} \qquad \text{............ (10)}$$

But accounting for grid fluctuations, line reactor voltage drop and operation reliability, the reference DC-link voltage Vdc* is chosen as,

$$Vdc *= \frac{x2\sqrt{2}mVLL}{\sqrt{3}} \qquad \text{............. (11)}$$

Where x is an overvoltage factor.

The selection of the DC-link capacitor of a back-to-back converter is a trade-off between voltage ripple, lifetime and fast control of the DC-link voltage.

$$C = \frac{S}{4\pi fmin\ Vdc * \Delta Vdc} \qquad \text{........... (12)}$$

Considering this, the DC link capacitance C is chosen a where S is the apparent converter power, $f$min is the minimum between the grid and the generator nominal electrical frequency, and ΔVdc is the allowed steady-state peak-to-peak voltage ripple in the DC-link.

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.

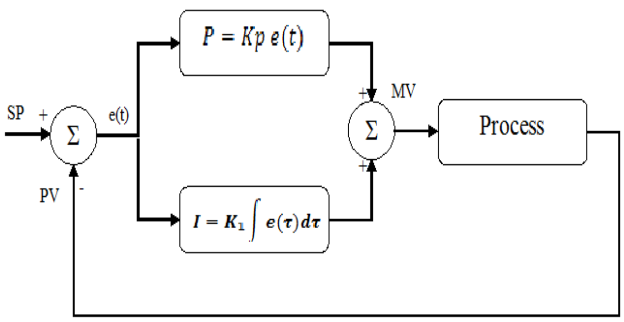

Fig 4: PI controller

Where Δ is the error or deviation of actual measured value (*PV*) from the set point (*SP*),

$$\Delta = SP - PV \qquad \text{................. (18)}$$

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

$$C = \frac{G(1+\tau S)}{\tau S} \qquad \text{............. (19)}$$

Where,

$G=K_P$ = proportional gain

$G/\tau=K_I$= 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.

$$Vo = \frac{Vi}{1-D} \qquad \text{................ (13)}$$

The value of D (duty ratio) varies in the range of 0 < D < 1 and it can be seen above the equation the output voltage is greater than the sources voltage and their circuit acts as boost converter. The output voltage has lowest value D=0 and then the output voltages equal to the source voltage. When D approaches output voltage tends to varied 0.1 < D < 0.9 to maintain the DC link output voltage.

D.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.

The expression of inverting mode of output voltage and current,

$$Vo = \frac{3\sqrt{2}\ VL\ cos\alpha}{\pi} \qquad \text{......... (14)}$$

$$Ia = \frac{2\sqrt{3}\ Io\ \cos(\omega t - \alpha)}{\pi} \qquad \text{......... (15)}$$

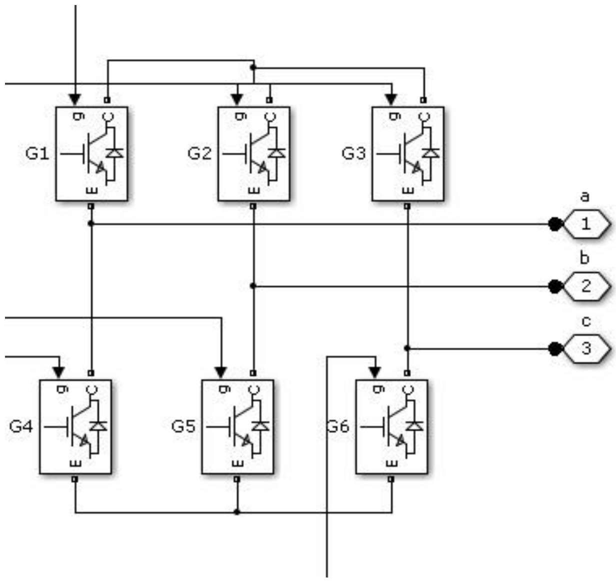

Fig 5: PWM inverter

IV SIMULATION RESULTS

The hybrid system consists of induction generators having of 1.5 MW, 25KV to connect with three phase bridge rectifier (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.

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.

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.

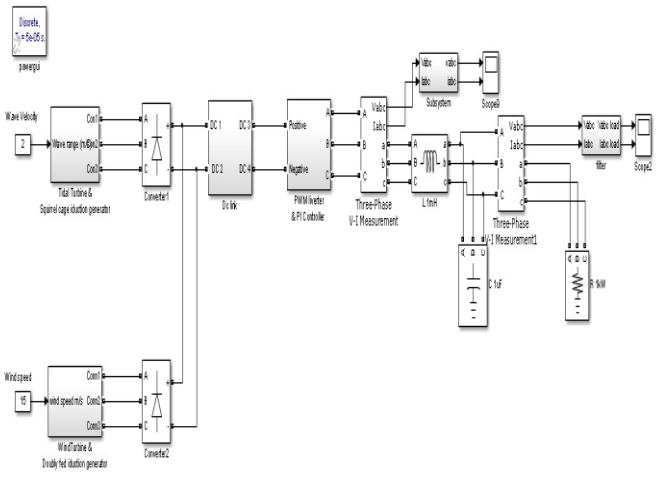

Fig 6: Output Voltage of DC Link

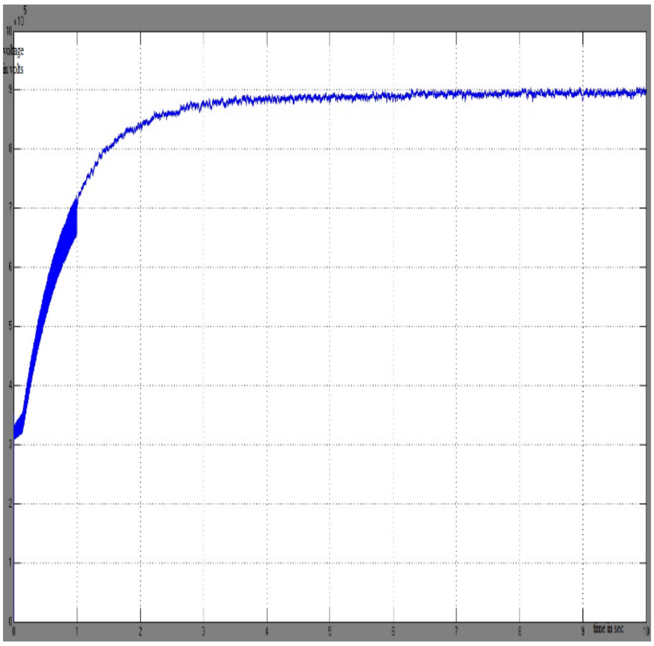

Fig 7: Output Voltage of DC Link

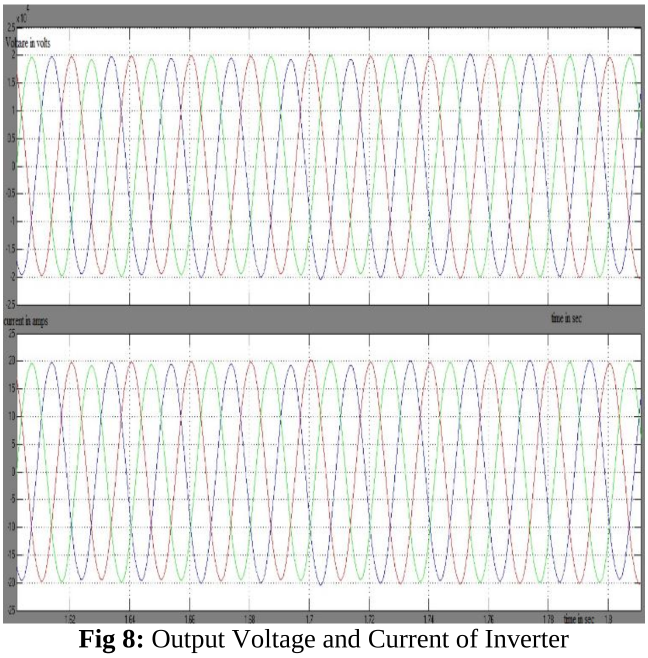

Fig 8: Output Voltage and Current of Inverter

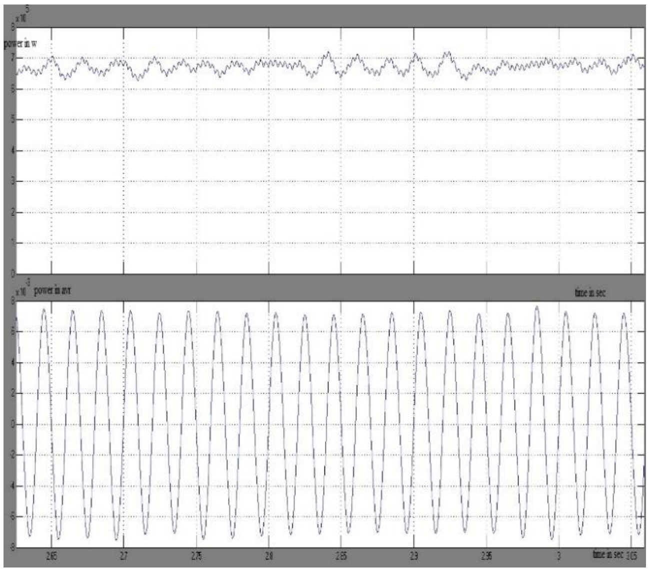

Fig 9: Output of Real and Reactive Power

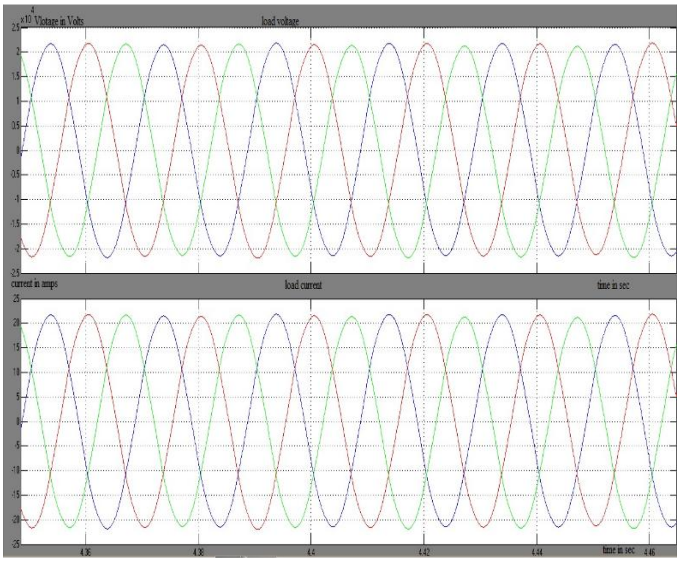

Fig 18: Output Voltage and Current of R Load

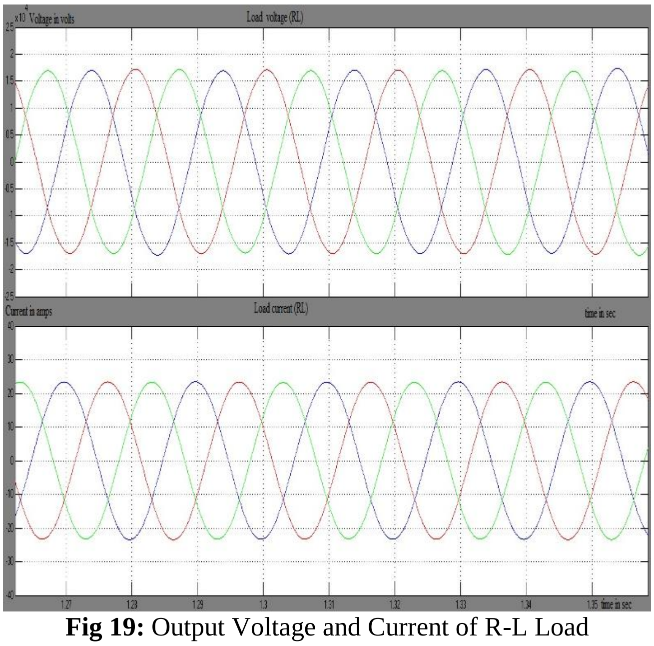

Fig 19: Output Voltage and Current of R-L Load

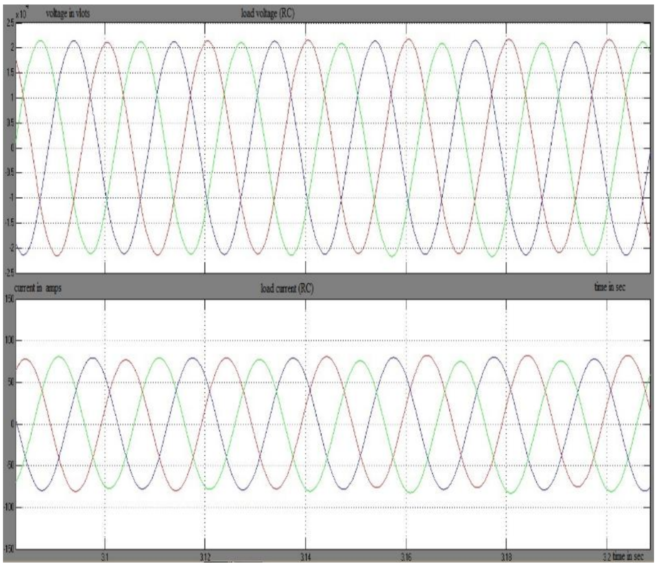

Fig 20: Output Voltage and Current of R-C Load

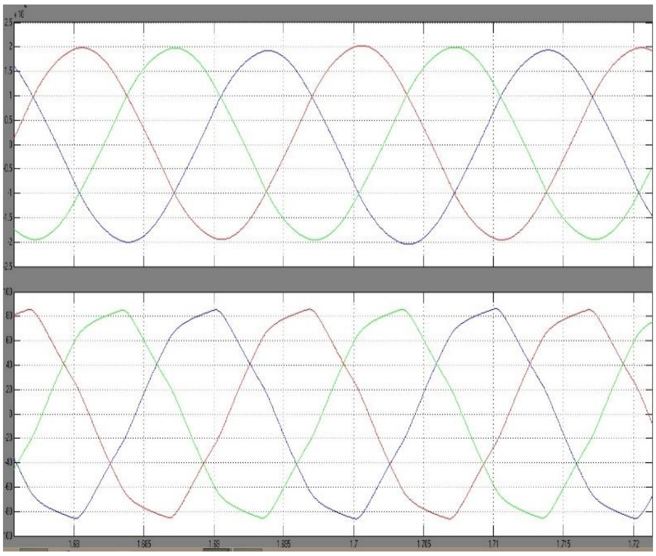
Fig 21: Output Voltage and Current of R-L-C Load

CONCLUSION

Thus the proposed system wind and tidal 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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