ELECTRICITY GENERATION BY USING WIND AND TIDAL TURBINE FOR POWER FLUCTUATION COMPENSATION

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Abstract:- The innovative renewable energy conversion system called "Hybrid Offshore wind and Tidal Turbine (HOTT) Generation System" is proposed. "Offshore-wind and Tidal Turbine" hybrid and autonomous power system research will demonstrate the feasibility of using hybrid wind and tidal current power to provide reliable electrical energy, and to create a push toward the development of a sustainable commercial market for this technology. This paper describes the control system for a small laboratory based hybrid power system that uses two types of power generation, offshore-wind and tidal turbines, connected on the DC side. HOTT generation system energy can have numerous benefits from both the environmental and socioeconomic perspectives. An unenclosed HOTT generation system can avoid many of the detrimental environmental effects, including CO2 emission, which is becoming a key issue, while providing significant amounts of distributed renewable energy.

Keywords: Offshore-Wind Turbine, Tidal Turbine, Flywheel, Hybrid System.

Introduction

Wind energy is the energy produced from the simple air in motion and this motion is caused by the uneven heating of the earth's surface by the sun. The air over the sea absorbs the heats faster than the land and so the air moves from the sea to the land causing the wind but in the night the air motion is changed from the land to the sea because the air over the sea cools faster than the air over the land. This wind is hardly predictable source of energy. Tidal energy is due to the gravitational influence of the moon and the sun on the earth due to the rotation of the earth relative to the moon and the sun which produces two high and two low waters each day (12.4 h cycle). This rotation makes the rise and fall of the tides and these tides are predictable. These tides run approximately six hours in one direction and then reverse for another six hour in the opposite direction [1, 2]. Tidal in-stream energy has various advantages such as high energy density, hence cheap rotors for power output, predictable energy; hence its integration is easy, low environmental impact and low bird disturbance [3]. The main difference between the wind and tidal is the high density of the seawater (800 times greater than air) if it is compared to wind and this helps to use a smaller system for tidal and obtaining the same energy [4, 5].

While wind turbines have negative issues such as audio noise, visual impacts, erosion, birds and bats killed and radio interference, it is useful in rural area applications where access to transmission facilities is limited. Moreover, wind energy helps to reduce the environmental damage (Green house Gas emissions) and climate change due to fossil fuel replacement [6]. The wind power resource is intermittent and challenging to predict, and requires using some form of storage to integrate it in the electric grid. New control techniques and improved forecasting methods help establish operating practices which will increase reliability of wind energy supply to the grid.

The problems of wind and tidal-stream may be overcome by the advanced technology in the near future and will become from the preferred ways for obtaining electrical energy.

Offshore wind energy is not really a marine energy form.

Nevertheless, exploitation of wind turbine in the marine environment presents some advantages compared to onshore specially[7]:

- Wind at sea is more powerful and more constant than that of onshore. This assures a greater energy production.
- The sea offers lager open spaces. Then, they can install wind turbines lager than onshore.

A tidal turbine has the role to extract energy from marine current. Its principle is the same than wind turbine. As offshore wind and tidal turbines are both installed at the sea, it will be interested to conceive and run together an offshore wind and tidal power system.

The purpose of this paper is to present a possibility of wind and tidal power systems coupling and treat especially the modeling and wind turbine control that is supposed to be used in the hybrid system.

This paper deals with a conversion system concept based on the real time simulation of a hybrid offshore wind and tidal current system. In order to provide reliable, environmental, and cost effective electrical energy we present a simulation research device composed by two real time emulators:, one for each type of energy: a wind turbine emulator and a tidal turbine emulator. The wind turbine emulator based on a permanent magnet synchronous machine, is used to simulate the characteristics of a working turbine and an electrical generator. The tidal turbine emulator has in its composition 3 electrical drives: an asynchronous drive with vector control used to simulate the behavior of a tidal turbine, a double feed asynchronous generator and an active break. Both of them are using the "hardware-in the-loop" techniques.

Hybrid System

To reduce their CO2 emissions, many countries are now opting for renewable energy in electricity generation. That is why this sector is clearly growing. Until now, we denote six renewable energy sources to generate electricity: hydroelectricity, the biomass, geothermal, solar, wind energy, marine energy. Because of their diversity, marine energies begin to be considered promising. We find: ocean thermal energy (MTE), the potential energy of the tide (tidal energy), wave energy (wave), the offshore wind, marine current energy (tidal). A tidal turbine approaches a wind. Tidal technology is expected to arrive more quickly at maturity because it is possible to rely on a number of techniques developed for wind. Since their merger, we assume that it is possible to realize the connection hybrid offshore wind-tidal.

The principle of hybrid connection is that the machines compensate each other to produce energy in a continuous regime. However, the problem is that renewable energy does not produce a continuous basis. That is why we often use another source such as a diesel generator to compensate for periods of non-productivity. In our system, the tidal turbine will fill this role and can be considered as a continuous source because the resource (the ocean current) is mostly constant and predictable. In addition, the presence of offshore wind is more common than onshore. This gives the offshore wind regime almost continuous production.
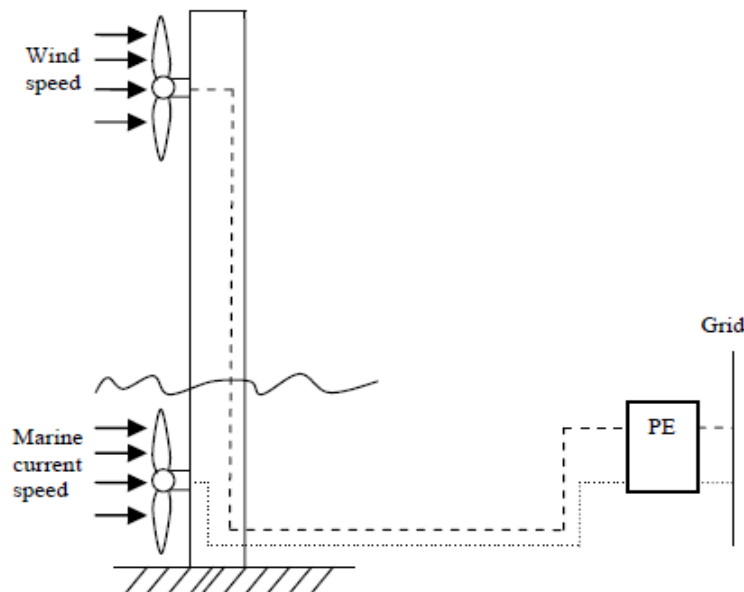

Fig. 1: General structure of the hybrid structure of energy conversion

SYSTEM DEVELOPMENT

3.1 Model Setup

A number of system make up an offshore-wind/tidal generation farm and the ac generation power is converted and gathered to dc power. The dc power is transmitted through a dc under-sea transmission cable to a grid dc/ac converter station.

In order to investigate the system performances and the control strategies, a small laboratory base hybrid power system model, whose photograph and schematic view are shown in Fig. 4(b) and (c), were designed and made. The system has two types of generators, the tidal motor/generator and the offshore wind turbine generator. The tidal turbine (induction machine) can act as a motor or as a generator depending on the need. The tidal generator provides smooth total output power, whereas the output power of a wind turbine depends on the wind velocity [8].

Fig. 4(a) : HOT-PC actual image

Fig 4 (b): Photography of laboratory scale prototype model of hybrid offshore-wind and tidal turbine with fly-wheel.
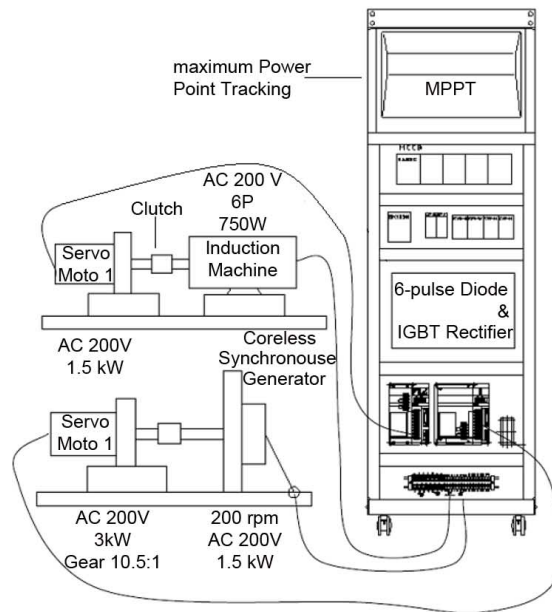
Fig 4 (c): Schematic of prototype model of hybrid offshore-wind and tidal turbine with fly-wheel.

3.2 Offshore wind turbine Generation System:

Fig.5 shows an experimental model of the offshore-wind turbine generator system. It consists of a coreless synchronous generator and a servo-motor. The offshore-wind turbine is simulated by the servo-motor. To make the model system with the small servo-motor, the rated rotating speed is 2500 rpm and the gear ratio is 10.5: 1. In a real system, the wind turbine would be of lower rotating speed without the step-down gear. The rotating speed or the torque of the servo-motor is controlled by a computer. The electrical energy depends on the rounds per minute (rpm) of servo-motor which drives the coreless generator. Wind turbine generated ac power is converted to dc power through a six-pulse diode rectifier. The parameters of the servo-motor and the coreless synchronous generator are listed in Tables I and II, respectively.

Fig:5: offshore wind generator experimental turbine model

TABLE I
RATING OF MAIN COMPONENTS (OFFSHORE-WIND SERVO MOTOR)

Parameter	Value
Rated output	3.0kW
Rated voltage	200V
Rated frequency	60Hz
Rated speed	2500 rpm
Gear ratio	10.5:1

TABLE II
RATING OF MAIN COMPONENTS (CORELESS SYNCHRONOUS GENERATOR)

Parameter	Value
Rated output	1.5kW
Rated voltage	200V
Rated frequency	60Hz
Rated speed	200rpm

3.3 Tidal turbine generator/storage (fly wheel) system:

Fig. 6 shows the experimental model of a tidal turbine induction generator/motor. A rotating shaft of the servo-motor, which simulates the tidal turbine, is connected to that of the induction machine (generator/motor) through a one-way clutch. Normally, the servo-motor (tidal turbine) drives the induction generator to produce the electric energy. On the other hand, the induction machine is also driven by a bidirectional IGBT inverter/converter. The generation power can be controlled quickly by the frequency control of the inverter.

Additionally, when the induction machine is accelerated by the inverter control up to higher rotation speed than that of the servo-motor (turbine), the servo-motor clutch turns to the OFF-state and the induction machine works as a motor. The rotational kinetic energy is stored as a function of the square of the rotation speed like a fly-wheel energy storage system. The stored energy can be extracted by decelerating with the inverter control. This generation system has the ability and flexibility to compensate the power fluctuations with proper control scheme. The design parameters of the servo-motor and the induction machine are listed in Tables III and IV, respectively. The rated speed of the induction machine was selected as 1110 rpm in order to store the rotating kinetic energy. To meet this speed, the rated speed of the servo-motor (turbine) was 2500 rpm; how-ever, the tidal turbine rotation speed would be much lower than that of the servo-motor and so the step-up gear would be necessary in the real system.

Fig.6: The experimental model of a tidal turbine induction generator/motor.

3.4 Inverter circuit configuration

Figure 7 shows the HOTT inverter circuit for this method. The output of the inverter is a single-phase three-wire system. A general domestic power supply is often a single-phase three-wire system. The inverter has a circuit configuration that combines two half bridges The input can share one line with the output by using the half bridge type inverter[9]. In order to meet the grid voltage (200V), the boost up chopper circuit is adopted in figure 5 to increase the voltage of the DC side.
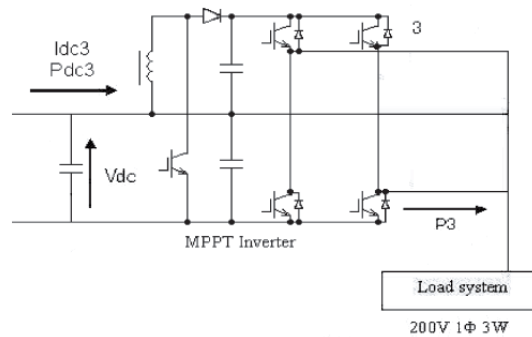

Fig. 7: Boost up chopper with a half-bridge inverter circuit

2.4 Maximum Power Point Tracking

There is an optimum operating point such that the PV delivers the maximum possible power to the load. This unique point is the maximum power point (MPP) of solar panel. Because of the photovoltaic nature of solar panels, their current-voltage, or IV, curves depend on temperature and irradiance levels. Therefore, the operating current and voltage which maximize power output will change with environmental conditions. As the optimum point changes with the natural conditions so it is very important to track the maximum power point (MPP) for a successful PV system. So in PV systems a maximum power point tracker (MPPT) is very much needed. In most PV systems a control algorithm, namely maximum power point tracking algorithm is utilized to have the full advantage of the PV systems.

For any given set of operational conditions, cells have a single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular load resistance, R= V/I, as specified by Ohm's Law. The power P is given by P = V*I. From basic circuit theory, the power delivered from or to a device is optimized where the derivative of the I-V curve is equal and opposite the I/V ratio. This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve. The load with resistance R=V/I, which is equal to the reciprocal of this value and draws the maximum power from the device is sometimes called the characteristic resistance of the cell. This is a dynamic quantity which changes depending on the level of illumination, as well as other factors such as temperature and the age of the cell. If the resistance is lower or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.

3.6 Fly-Wheel Operation

The fundamental test results showed that the proposed HOT-PC systems have an ability to cope with the power fluctuation compensation with a proper control strategy. Additionally, with proper frequency control of the bidirectional inverter, the kinetic energy of the tidal induction machine can be used to assist in compensating fluctuation in the total generation power. Even when the tidal flow is too weak to produce any electric power, the induction machine plays as the fly-wheel energy storage system and compensates the power fluctuation to some extent.
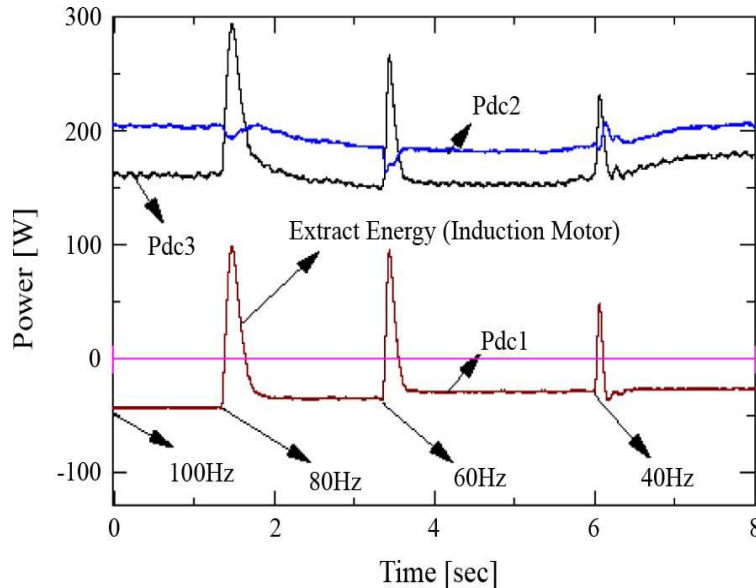
Fig. 10:. Powers in dc side in the fly-wheel operation of the induction machine.

The induction machine was driven by the inverter whose voltage frequency was stepped down from 100 to 40 Hz. The kinetic (rotating) energy was extracted at each decelerating condition and converted to Pdc1 which is summed up to the total output power Pdc3.

Hybrid System connection: offshore wind turbine emulator-tidal turbine emulator:

The hybrid energy system is based on the connection of two sources of renewable energy, and for this research there will be used real time emulators. The wind turbine emulator is a controlled synchronous motor, which reproduces at its shaft the same characteristics as the real turbine and the electrical generator produces electrical power.

In the other part, the tidal turbine emulator reproduces the behavior of the real turbine, using an asynchronous motor driving a double feed induction generator.

This connection involves many problems, because perturbations appear from each side, making it hard to control.

In figure 11 is the presented the schematic hybrid connection of this two types of turbines. The Control and Supervision Device (CSD) has the task to ensure the possibility to connect into a single AC Bus line the power lines. This is the major target of our researches. This is a new development into the hybrid connection filed of research, because mainly it is simpler to use AC/DC converters and to have at the point of connection the same type of electrical energy.

The main objective of using the real time emulators is to interconnect two energy resources in AS environment, offering a lower price for the electrical energy and help develop a new direction of research.

Another characteristic of the CSD is to decide where and how to use the produced energy. It has multiple choices and taking into consideration the demand and the priority criteria's it decides where to send the produced energy. So, in this way this system will have the possibility to be implemented into local grid network.
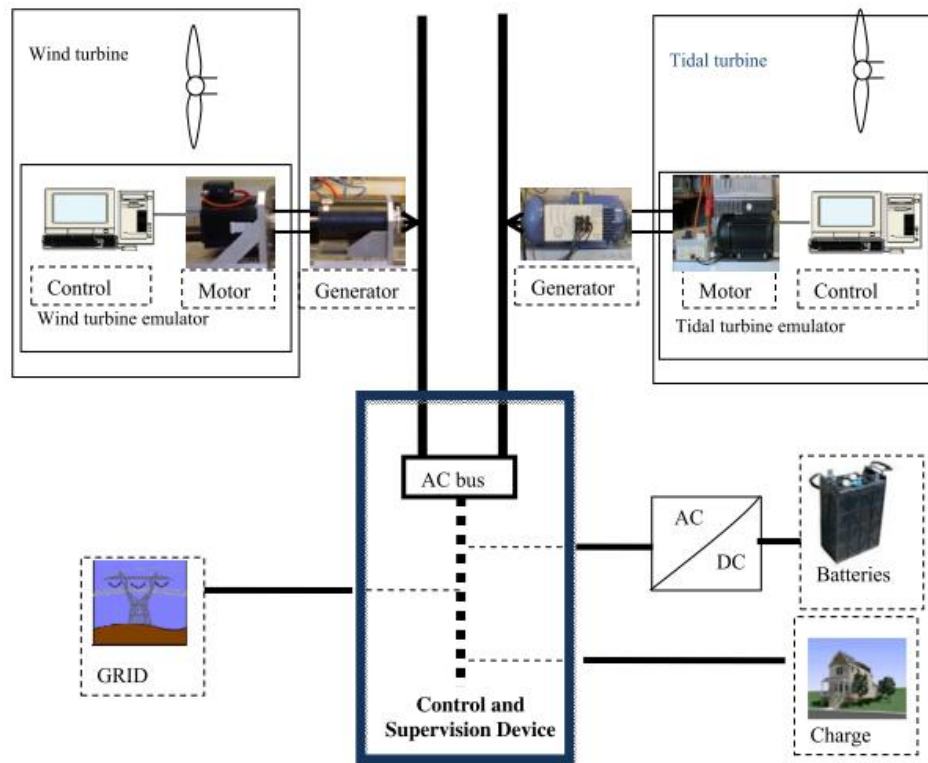
Fig.11: hybrid connection wind turbine emulator-tidal turbine emulator

CONCLUSION

This paper presents a concept research for tidal turbine-offshore wind turbine hybrid connection system based on real time simulation. The paper puts forward the reasons why such a study is welcomed at this moment.

It is developed the general structure of a hybrid structure concerning the using of two real time emulators: a wind turbine emulator and a tidal turbine emulator. Both of the emulators are conceived with the hardware-in the-loop simulation principles.

The structures of the two emulators are presented, in the succeeding of the paper. The wind turbine emulator has in composition an informatics system and an electromechanical system, based on a permanent magnet synchronous simulator and a synchronous generator. The tidal turbine emulator is formed from a software system and an electromechanical system, which contains an asynchronous drive: a doubly feed induction generator and an active break.

The final part of the paper proposes the structure connection between the emulators and research directions that are to be studied from now on.

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