Literature Review of Ocean Current Turbine

Noor Rahman, Saeed Badshah, Abdur Rafai, Mujahid Badshah

Abstract— This Paper discussed the historical review, current status of ocean current turbine, challenges and problems in the way of the ocean current turbine commercialization. As we known that fossil fuel resources in the world are limited and we can't depend on them for the future energy needs of the world. For this purpose the researcher have find such sources of energy which are sustainable, green, environment friendly and have no impact on human lives, which includes renewable energy sources like solar, wind, and ocean energy sources. In this review paper, we also focused on the initiative of the ocean current energy technology and the efforts of different countries, companies and scientist for the development of ocean current turbine to extract power from ocean current energy including Marin Current Turbine Ltd (MCT), Florida Atlantic University (FAU). We summarized the current status and recent development in the field of ocean current turbine. We discussed some earlier projects and prototypes. The paper also discusses the impact of the ocean current turbine on the environment and marine life. Some of the current limitation and problems are also identified in the way of ocean current turbine development like grid connection.

Index Terms— Ocean Current, Turbine Blade, Fossil Fuel, sustainable, renewable energy, Marine Life, Technology

1. INTRODUCTION

Now a day's Humanity is facing energy crises and researchers are working to solve these energy crises. They are exploring the new energy resources which will be less harmful and less environment damaging. The ocean has covered about 70% of our planet earth and it composed of a huge potential energy in different forms. The oceans absorb the sun radiation and heat up and circulates between different areas [1] As Ocean are spread over 70 % of our planet earth, they hide a huge potential of energy in the form of ocean current, tides, waves, and temperature difference. Our study will be limited to the ocean current and ocean current turbine to extract energy from the ocean current.

2. ENERGY FROM OCEAN CURRENT USING OCEAN CURRENT TURBINE

The proper history of the extraction of ocean current energy starts after the first oil crises in the world in 1970 after which researchers consider ocean energy for power generation. [2] For this purpose we need ocean current turbines. Ocean Current Turbine is basically a micro hydro kinetic turbine and generates electricity from ocean current flow. Horizontal and Vertical Axis Turbine are mostly employed for the extraction of energy from ocean current. Recently the researchers are working on the ducted horizontal axis turbine to more efficiently extract energy from ocean current.

3. INITIATIVE IN OCEAN CURRENT ENERGY

In past (1970-1990) the UK and its government contribute a key role to highlight the field of ocean current energy extraction and to develop the ocean current turbine. Still UK is leading the world in the field of ocean current turbine.
In the 21st Century the commercialization of the ocean current turbine will create a new industry for clean and renewable energy production.
Main study and work on the ocean current energy and Ocean Current Turbine is carried out in United Kingdom, Canada, USA, Norway, Australia, France etc

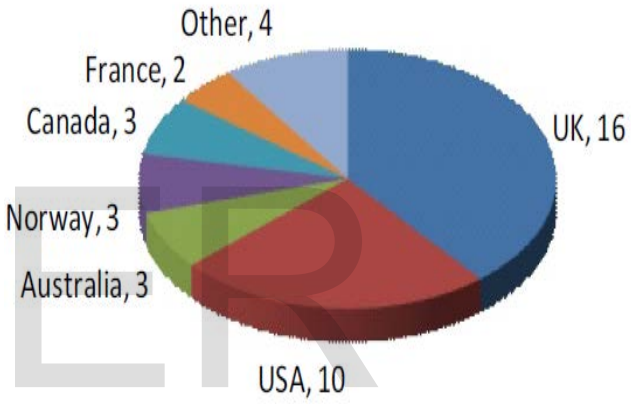

Fig.1. Countries with the number of ocean current turbines [3]

In United State, (2005- 2006) the electric power research institute (USA) conducted a research study for the Ocean energy resource and to installed ocean current turbines there. They identified seven locations in the southern coast of Florida (USA) with high ocean energy potential [4]. The ocean current at Florida (USA) is relatively constant with a very small seasonal fluctuation. The Ocean Current at Florida (USA) has an estimated total energy of 25 GW. [5] Ocean water has high energy capacity as compare to the wind energy. Some ocean energy sites in the North of United State of America have approximately 21Tetrawatt-hour/year of energy capacity. [4]

4. EARLY PATENTS ON OCEAN CURRENT TURBINES

In the past several patents were published to extract energy from Ocean using Turbine. Some of the early patents published in the year and beyond 1980.
William & Mouton on August 1980 published the Electricity Generation from Ocean Water velocity. In this patent the power plant uses the turbine wheels within nozzles submerged in the ocean current to produce power from the ocean current [6].
Lazar J. Wracsaricht on 15th December 1981 published a patent on self contained electrical generating device for placement in ocean current. This generating device converts kinetic energy of

ocean current into electricity using blade geometry. The blade configuration increases the flow rate of ocean current. The stator and rotor are radially located outwardly from the hub of generating system to reduce the resistance of flowing water and increase the flow rate of ocean current. The whole system is supported by spoke like legs [7]. Osvaldo Tomassini on 17th March 1981 published a patent on a rotor having slid able blades. The slid able blades are used to efficiently produce energy from ocean current. The structure includes four columns from the seabed which support a circular monorail system. The exterior and interior gear rack on monorail engage with motors within the circular housing. Electrical generators are contained within a control house supported by vertical rack structure. An automatic control device can position the rotor vertically and horizontally to get the optimum velocity of ocean current [8].

Gerald T. Howard on 26th January 1982 published a system for extracting useful energy from ocean current. He uses drag type devices that change the thro and fro motion of this device into rotating type movement and generate electricity and [9]. Michael L. Haining on 8th August 1995, published a patent on a hydroelectric power plant having several combination of turbines which floats inside the ocean and generates electricity or useful power [10].

5. EARLIER PROJECTS AND PROTOTYPES FOR OCEAN CURRENT TURBINES

In the year 2000, United Kingdom Government founded the marine current turbines Ltd (MCT).This company developed tidal stream generators [11]. Marin Current Turbine Ltd (MCT) developed ideas of tidal power developed by peter Fraenkel. Marine Current Turbines Ltd (MCT) had installed a 300 kW prototype "SeaFlow" in May 2003 at Bristol Channel 1.1 km offshore. This turbine has twice blades and is connected to the ocean floor foundation on a column. The turbine can move upward and downward on the column for work relating to this ocean current turbine. This is the world first real current turbine and SeaGen Company Largest turbine ever since. In 2008 the Marine Current Turbine Company have developed a new turbine "SeaGen" a 1.2 Megawatt Ocean current turbine and installed this turbine in strangford Lough, Northern Ireland connecting to national grid. The "SeaGen" use the same technology as the "Seaflow". The Seaflow is connected to the grid. The company MCT Limited tried to introduce the sea current turbine into the market for the future commercial purpose. The company aimed was to do experiment on this turbine for the future installation of these turbines on large scales. [12]

In 2003 in America the FAU (Florida Atlantic University) took the offer of five million dollar grant to build the centre of Excellence for marine current turbines in USA, Florida. This centre will focus on the utilization of the available energy in the Florida sea for the power generation of the future. [13]

In the FAU Ocean Engineering Deprtment the Van Zwietn Driscoll Deane and the Leonessa used the math's models and simulations to build the Design for the ocean Turbine. They build the prototype to generate maximum power from the ocean current. [23]

In the UK the IHC Engineering Business Company has build the turbine and installed the first prototype Stingray in 2002 in Shetland Island [14]. This turbine worked for four years and it has supported by DTI (English Department of Business, Enterprise and Regulatory Reform part) New and Renewable Energy R&D grant [14]. This turbine has the capacity of 150 kW of electricity generation and it delivered up to 150 kW during testing and is submerged 36 meter below the ocean surface where the ocean current is 2 m/sec [1]. Since 1980, the Blue Energy Company in Canada is working on Vertical Axial Flow Turbine and for this purpose they have developed 6 ocean current turbine prototypes which extract energy from the ocean current and convert it into electricity [15]. A Prototype "Venturi Energy Generating Apparatus" installed in the Florida Gulf Stream had generated up to 4kW electricity from Florida Stream [1]. This prototype was completed in 1984 and installed in April 1985. After successful testing, installation and operation the Company have build the Davis Hydro Turbine on Commercial level [1].

In 2011 in France, EDF renewable energy in corporation with Hydrohelix has thrown back the project "Marenergie" (Project first developed by Hydrohelix then gave up because of financial problems) installed in Britain in 2011 near Paimpol which consists of 03 turbines connecting to the grid and the power produced is 4MW, and supply electricity to 20,000 houses. [1].

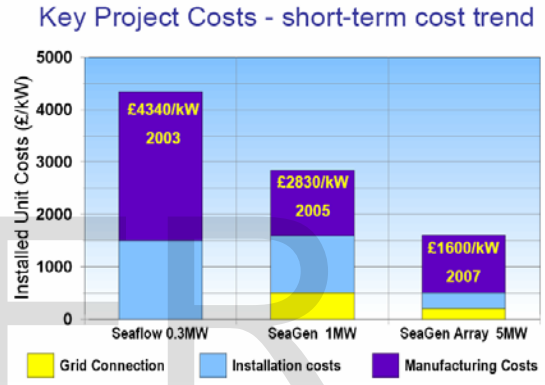

Fig.2. Key Ocean Energy Turbines Technology Project Costs Trend [1]

In USA, New Energy Corporation developed a 5kW in stream hydrokinetic generator in the summer 2008 and installed this generator in Yukon River in Alaska at Ruby to test it for 1 month, which extract electricity from the Yukon River free water flow and provide power to the Grid [16].

Florida Atlantic University FAU in the United State of America is working on the ocean current turbine, but commercially up to now no one have the Performed the physical demonstration the turbine to extract the energy from the current of ocean waters because the system is too expensive further its requires installation, maintenance and environmental impacts evaluation study [17]. Florida Atlantic University (FAU) in 2012 built an experimental non commercial research turbine to provide the first platform for the development of turbine components to test the failure prediction and monitoring of turbine so that they get the turbine performance and behaviour at the ocean level [18].

The 26th IAHR symposium in 2012 on Hydraulic Machinery and Systems held at Tsinghua University, Beijing, China. In this symposium they discuss the performance prediction and structural safety of a 50KW ocean current turbine. They performed the unsteady computational fluid dynamics simulations on the ocean current turbine rotor assembly for performance and cavitation predictions [19]. In 2012, a team from the department of mechanical engineering, International Islamic University Islamabad performed the Turbine FEA. [20].

In October 2012 an experiment the Tainan Hydraulic Laboratory of National Cheng Kung University prepared a submerged turbine for the extraction of electricity from ocean current. The team want to install it off the coast of taitung country. The velocity of Kuroshio Current ranges from 1 to 1.5 m/sec and have a capacity to generate 10 to 15 Kilowatts/sec electricity. [21]

An IEEE student member in January 2013 performed an experiment on ocean current turbine. During the experiment they performed the numerical simulation on the ocean current turbine to predict the turbine performance. [22].

The ocean current turbine up to the date developed is 50% Horizontal Axis current turbine following by the vertical axis current turbine. Some other design have also been tried by the researchers including the Venturi, Hydrofoil etc

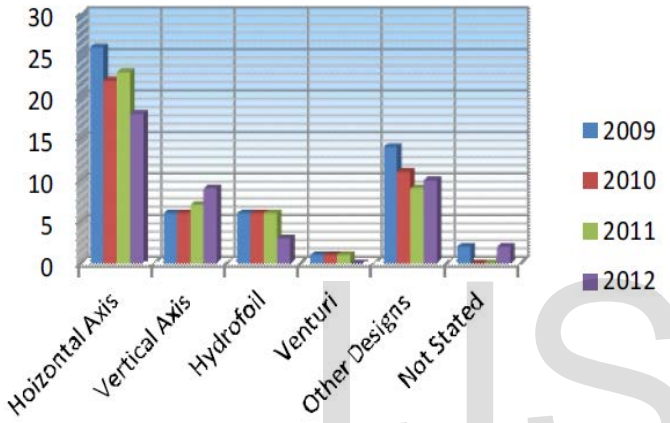

Fig.3. Different Types of Ocean Current Turbines [03]

6. DISCUSSION OF PREVIOUS RESEARCH WORK

In October 2006, at university of Southampton UK a team performed the Studies of wake of an ocean current turbine, which was scaled downed to 1/30 and positioned at horizontal axis. In the experimental water circulating channel they test a horizontal axis, 0.4 meter diameter ocean turbine from this experiment they determined the wake characteristics, turbine performance, and turbine thrust over a range of ocean current speed. The result of the experiment showed that earlier investigation is important before installing array type marine current turbine to avoid the effect of blockage. [24] Another group of researcher at the University of Southampton UK in 2006 perform test for measuring power and thrust of marine current turbines under various hydrodynamic flow conditions in a cavitations tunnel tank. The test was carried out on a marine current turbine having a diameter of 800mm with a 2.4m x 1.2m tunnel cavitations and a 60 meter long tank for towing. The results provide a view of a single turbine insight operation and the variation in the performance with the rotor tip immersion. Result suggests that solid wall cavitations tunnel is applicable for the deep water immersion of Marine current turbine. [25]

At the University of Buenos Aires Argentina, a team has presented a paper in 2007, regarding the Diffuser augmented floating hydro-turbines for marine current power generation. They focused on the technology change of the turbine geometry to extract more power from the ocean current using ocean current turbine. They focused on use of large rotor on which power exerted from channel water flow. [26] A team at Michigan State University, USA in January 2012 present a paper with the flow distribution and power generation of ducted composite material marine current turbines (CMMCTs) using Computational Fluid Dynamics (CFD). The study showed that a novel manufacturing approach similar to filament winding is able to produce the ducted composite material marine current turbines (CMMCTs), which have significant advantages over traditional ocean current turbine geometry. The production of high- performance and light-weight CMMCT can be rapid and inexpensive.

[27] In 2009, Charles and Roger published a paper about marine current turbine effects on USA, Florida Sea Environment effects. They find that the open flow turbines are used in Florida Ocean for the power generation. These open flow turbines give a harmless passage to the marine species. Whoever the failure of these turbines, its repair and turbine installation can harm the marine life and ocean environment. [28] In 2009 the universities of Korea conducted a study based on numerical techniques for an optimal marine turbines arrangement in the ocean water. From the flow these turbine they finds that the optimal marine turbine arrangement for the maximum electricity is possible. From this study they find that the distance between two turbines is approximately three times the diameter of marine turbine. They suggest this arrangement of oceanc turbines for the maximum utilization of ocean current for power production. [29] A team at the DGA Hydrodynamics and Guinard Energie France in May 2013 performed the Designing and model testing of an optimized ducted marine current turbine. They design a new turbine with a ducted rotor which rotates freely about a vertical axis fixed on a floor. The duct increase the velocity of the ocean flow in the turbine thus enables the turbine to generate more power. They performed the Reynolds Average Navier–Stokes calculations which enable them to know the flow rates in the duct theoretical. They also get the flow calculation experimentally inside the duct. The numerical calculations confirmed by the experimental results lead them to an optimum design of the duct and of the rotor that achieves a high power coefficient of 0.75. The duct has been designed to maximize the power coefficient without minimizing its dimensions so its size is quite huge. Moreover the crucial parameter to finalize the viability of the project is to assess the prices of the duct which should be compared to the price of the higher diameter rotor. In the future they have the plan to do future work to investigate the stability in the current of the couple of current turbines, ability to orientate with the current direction changes, and the superimposed effect of waves. [30]

7. FUTURE OF OCEAN CURRENT TURBINE

The consistent struggle of the Marine Current Limited (MCT) UK and Florida Atlantic University have successfully highlighted a renewable, clean, sustainable, and green source of energy known as Ocean Current energy. MCT Ltd and FAU have designed and prepared several prototypes for the testing. But in spite of these efforts still we have to go beyond a long to commercialize the ocean current turbine. The important fact is that the prototypes generation is increasing year by year and this

will bring the ocean current energy turbine on the commercial scale very soon.

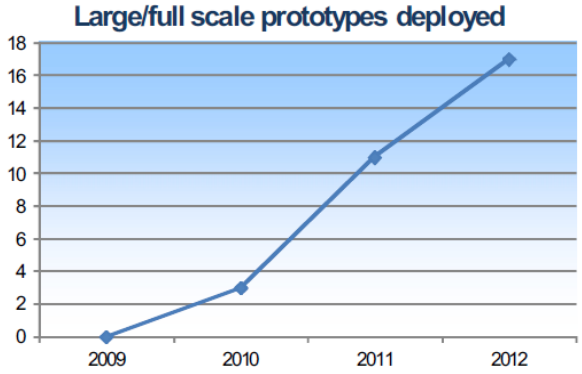

Fig.4. Prototypes Deployed [03]

In the 21st century the European Union and the international community are committed globally to decrease the carbon dioxide and produce more energy from renewable energy resources. Several countries are working on ocean current turbine and their number is increasing with the passage of time. Man y countries are now thinking of the ocean current turbine parks development where they will generate power from ocean current energy. USA is looking to develop an ocean current turbine park at the Florida state.

The researcher on the ocean current turbine is now considering the ducted ocean current turbine which will generate more power as compared to the old designed technology. The ducted ocean current turbine has the ducted channel. This duct increases the ocean velocity at its section where the turbine is located. One of the problems with the ocean current turbine is that an optimum ocean velocity/flow need for the smooth running of the marine turbines. Who ever with the use of duct in the ocean current turbine will solve these slow speed phenomena of the ocean and it will become possible to install the ocean current turbine at the sites where the ocean current speed is low. However as the size of the duct is huge and is more than the diameter of the rotor Hence this will increase the prize of the project. However the power production will also increase with the installation of the duct. Proper economic feasibility will be required to known whether the duct is feasible economically or not as it physical.

8. Conclusions

The world energy demand is increasing. The inhabitant of the earth will need an additional 45% energy in 2030 [31]. Currently world energy mainly depends on fossil fuels. These fossil fuel energy resources are not only limited on the earth but also polluting our earth atmosphere. The emission of carbon dioxide from the burning of fossil fuels is responsible for the global warming and ozone layer depletion. Therefore the researchers' aims to replace the present fossils fuel energy resources with some alternative green, clean and sustainable energy resources. Renewable energy resources are the most favourable and safe energy resources for the earth future. But most renewable energy resources like solar and wind are not available round the clock during 24 hours. In past few decades the researchers have identified a new source of renewable energy in the form of ocean energy to generate clean energy for the earth in the future. If the all renewable energy in the sea is 0.1% and if converted into electric power then it will be 5 times more than the present electricity demands of the world because ocean are spread on 70% of the earth surface. [32] The ocean energy is available round the clock. Its green, renewable, reliable, sustainable and durable and is available on a very large scale. The ocean hides a huge useful energy more than from the wind energy, because the density of the water is 800 times greater than the air density. It is about 3 times greater than the air/wind density. [33] The researchers predict that in 2050 the electricity production from ocean resources will cross 645 Tetra watts Hour.[31]Recently a new idea about ducted ocean current turbine is under the progress to increase the power production from the ocean current energy .The ducted ocean turbine have the advantage that it can be install at the ocean sites where the velocity is slow and the ordinary turbine does not generate enough power. They also find that a designed arrangement of these turbines will ensure more power production from the ocean current. This designed arrangement of turbines will lead to the generation of marine turbine park deep in the sea. In fact of all these researches and projects the Ocean Current Turbine development is still in the developing phase with a strong promise to the future renewable energy share in the energy sector. Some problems exist in the commercialization of the ocean current turbine. These problems include the avoidance of drag from cavitations, these cavitations decrease the turbine efficiency, and other problems are the blade corrosion and its prevention, prevention of marine growth at the turbine blades and the system maintenance and reliability. These problems are the main hurdle in the way of the ocean current turbine commercialization. The research and work is still continued to resolve all these issues that are related with the marine turbines. The repair work on turbines deep inside the ocean is not easy because it is install deep the ocean and that make its maintenance complex. In the near future our earth inhabitants will became able to extract energy on a large scale from such a useful source in the nature. The commercialization of the ocean current turbine may deteriorate the marine and coastal life. The open flow design of the ocean current turbine will not affect the marine life too much but the construction and grid connection will deteriorate the coastal environment. Hence advance precautions must to take to avoid the bad impact of the ocean current turbine on our earth environment.

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European Ocean Energy Association.**Printing**: ImprimerieBietlot, Belgium
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