VIVACE (Vortex Induced Vibration Aquatic Clean Energy). A new concept in generation of clean and renewable energy from fluid flow

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ABSTRACT

Any device aiming to harness the abundant clean and renewable energy from ocean and other water resources must have high energy density, be unobtrusive, have low maintenance, be robust, meet life cycle cost targets, and have a 10–20 year life. The vortex induced vibration aquatic clean energy (VIVACE) converter invented by Bernitsas and Raghavan, patent pending through the University of Michigan satisfies those criteria. It converts ocean/river current hydrokinetic energy to a usable form of energy such as electricity using VIV successfully and efficiently for the first time. VIVACE is based on the idea of maximizing rather than spoiling vortex shedding and exploiting rather than suppressing VIV. It introduces optimal damping for energy conversion while maintaining VIV over a broad range of vortex shedding synchronization. VIV occurs over very broad ranges of Reynolds (Re) number. Only three transition regions suppress VIV. Thus, even from currents as slow as 0.25 m/ s, VIVACE can extract energy with high power conversion ratio making ocean/river current energy a more accessible and economically viable resource. In this paper, the underlying concepts of the VIVACE converter are discussed. The designs of the physical model and laboratory prototype are presented. A mathematical model is developed, and design particulars for a wide range of application scales are calculated. Experimental measurements on the laboratory prototype are reported in the sequel paper and used here for preliminary benchmarking.

Keywords: - *Vortex flow, Energy Generation, Flow over cylinder, Vortex induced vibration, High Reynolds's number*

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1. Introduction

Demand of Energy is increasing day by day worldwide electric energy is major type of energy which is in demand due to its various domestic to industrial uses electric energy is mostly produced from thermal power plants, only in India around 68.19 % of total energy comes from fossil fuel which is around 155968.99 MU As on 30-09-2013 [1], and rest comes from other resources which include nuclear, wind, hydro etc. More over the requirement of power is increasing by day by day to meet the requirement of the energy it is required to harness the energy from all known resources, and due to perishing fossil fuel new technologies are to be invented and used to meet the requirement of energy.

Water is the world's largest energy storage medium. Marine energy, which is clean, renewable, abundant and available worldwide, comes in five forms: currents, waves, tides, thermal gradient, and salinity gradient. To extract the water energy, various devices such as watermills, tidal dam, and turbines are used .Professor Michael and his group at the University of Michigan Marine Renewable Energy Lab has come up with a new idea to extract water energy, through VIVACE.

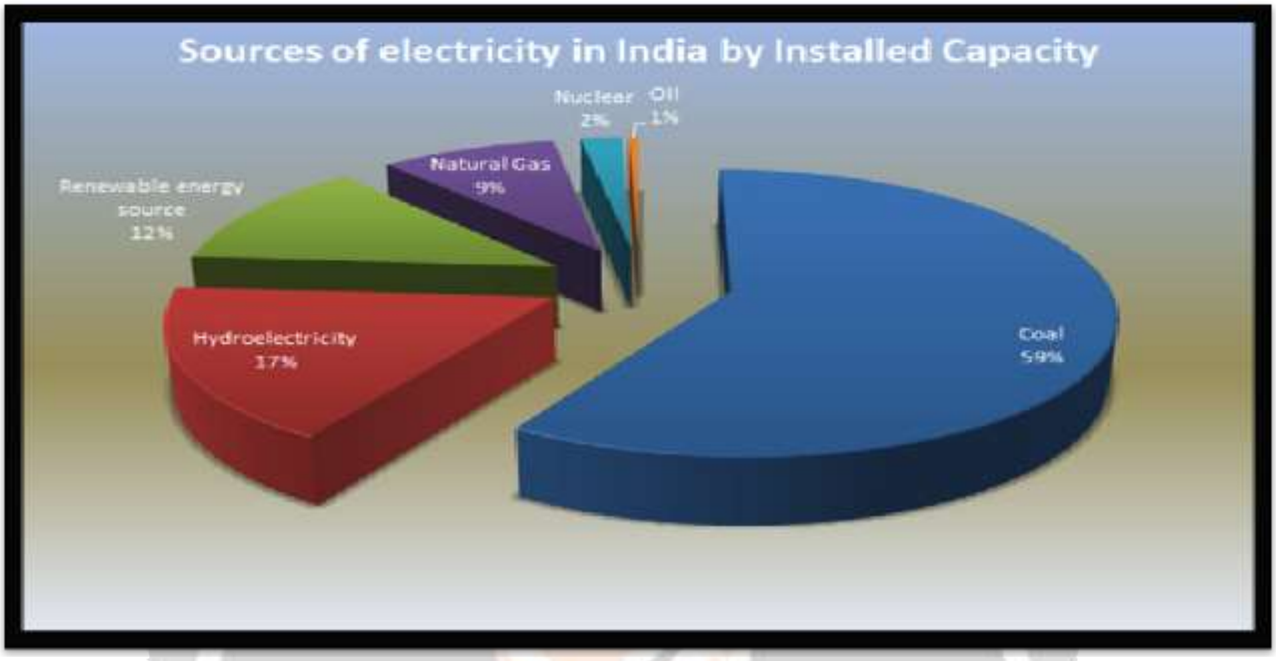

Fig.1 Sources of electricity in India by installed capacity

VIVACE is the name of machine which is used to harness the energy available with underwater currents of ocean and rivers, The overall objective of this project is to design and build a Power Take Off system for a VIVACE Converter. This system will be comprised of four sub-functions. First it must convert the oscillatory motion of the VIVACE into motion that is usable for energy conversion. Second it must convert the kinetic energy into electrical energy. Third it must be able to transmit the electrical energy so that it can be used. Finally it must seal electrical equipment in a dry environment.

2. Working of VIVACE

2.1 Working

This phenomenon was first observed by Leonardo-Da Vinci as “Aeolian Tones”. The Collapse of Tacoma Bridge due to very low wind speed gave the idea of VIV. The VIVACE Converter, however, is designed to do the opposite: (a) maximize rather than suppress VIV and (b) harness rather than mitigate VIV energy. The presence of blunt bodies like cylinder in the flow causes alternating vortices on above and below of the cylinder. The vortices create the lift on the cylinder which moves it up and down on its springs, creating mechanical energy. Then, the machine converts the mechanical energy into electricity. The VIVACE system converts the mechanical energy into electricity via rotary or linear generators. The modules are designed to be reusable and are considered less of a threat to marine life than turbines because of their slow movement. Working of machine is explained in Fig 2.1[1].

Just a few cylinders might be enough to power an anchored ship, or a lighthouse. These cylinders could be stacked in a short ladder. It is estimated that array of VIVACE converters the size of a running track and about two stories high could power about 100,000 houses. Such an array could rest on a river bed or it could dangle, suspended in the water. But it would all be under the surface. Because the oscillations of VIVACE would be slow, it is theorized that the system would not harm marine life like dams and water turbines can.

The working prototype is just one sleek cylinder attached to springs. The cylinder hangs horizontally across the flow of water in a tractor-trailer-sized tank in his marine renewable energy laboratory. The water in the tank flows at 1.5 knots. The diagram of such prototype is shown in Fig 2.2[1].

2.2 Site Selection

Selection of proper site at where we can install the system is very important. The selected site must have enough current to have the motion of cylinder and also proper depth should be selected for best results .We search for various sites along the coastline of Gujarat such as Porbandar, Jamnagar, Div, Dahej etc. We found that Based on measurement of waves, currents and tides off Dahej in Gulf of Khambhat, the hydrodynamics is studied. Estimated tidal constituents show that primary lunar semi-diurnal constituent M2 was the strongest constituent and the amplitude was found to be around 4.5 times strong as that of the major diurnal constituent K1. Currents were predominantly tide induced with speed upto 3.3 m/s and were towards north-northwest during flood tide and south-southeast during ebb tide. Residual cross shore and alongshore current was found to be varying with the corresponding change in the cross shore and alongshore wind speed.

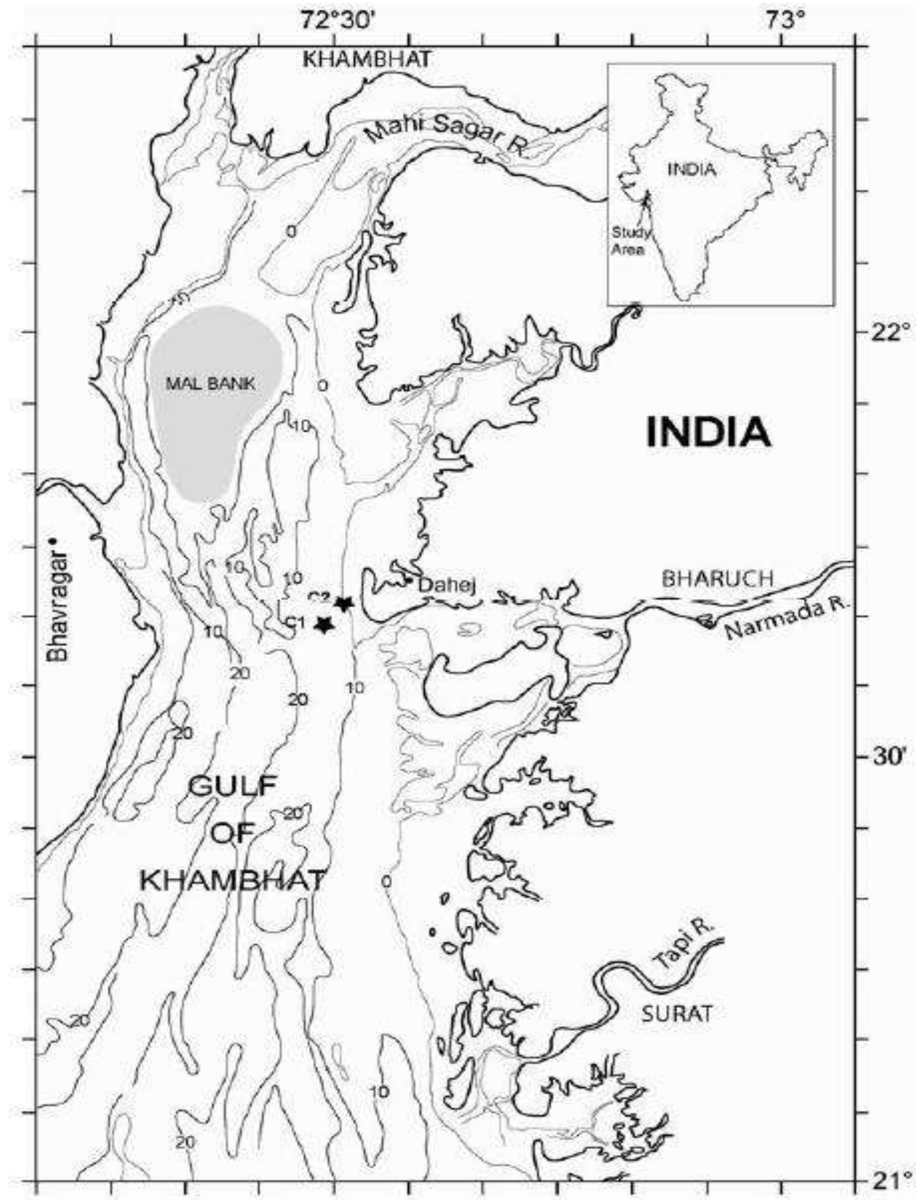

Fig.2 Selected site Dahej, Gulf of Khambhat.

The tidal range at Gulf of Khambhat is the largest along the Indian coastline. Due to the large tidal range, strong currents are observed in the Gulf. Current speed of 3 m/s was recorded at 24 m water depth and 3.3 m/s at 14 m water depth. Currents were predominantly tide the flood current was much stronger. Around 40% of the measured u component of currents was due to tide and 88% of the measured v component of currents was due to tide.

3. Design

3.1 Mechanical to electrical power

The reciprocating motion of the cylinders can be used in many ways to harness its energy. The most straightforward option is to harness the linear motion for the electromagnetic induction based generator. If a rotary generator or hydraulic generator is used, however, other methods must be utilized to convert the cylinder's linear oscillation into rotary motion.

One such method is a belt system. The end of the cylinder would be attached to a belt which is in turn wrapped around a rotor. The up and down motion could then turn the rotor back and forth. Similarly, a straight gear could be fashioned at the end of the rod so when it moved vertically, it would turn a gear on the rotor. For both proposals, a transmission mechanism (e.g. gears) could be added in order to change the angular speed to a desired value.

Another way is to use a crankshaft. This would convert the linear motion into a constant rotary motion exactly like the piston in your car does. Then the rotary motion is used for a rotary generator. It would be beneficial because there would be no alternating current from the rotor switching directions.

To convert electrical energy from mechanical energy we have various mechanisms which are shown in fig 2.4

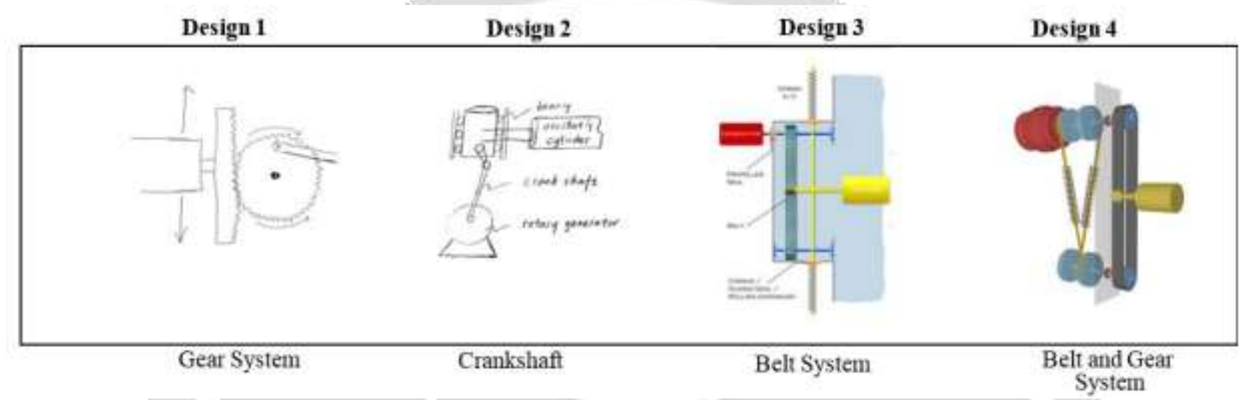

Fig.3 Various conversion mechanisms

In design 2 there may be a chances of failure of bearings so maintenance will be high. If we use belt drive there may be a chances of tear n failure of belt drive which is used in Design 3&4.Design 1 is selected for the conversion as it is low cost, more reliable and less maintenance option compared to other option available.

3.2 Main design of VIVACE

VIVACE is the name of machine which is used to harness the energy available with underwater currents of ocean and rivers. The overall objective of this project is to design and build a Power Take Off system for a VIVACE Converter. This system will be comprised of four sub-functions. First it must convert the oscillatory motion of the VIVACE into motion that is usable for energy conversion. Second it must convert the kinetic energy into electrical energy. Third it must be able to transmit the electrical energy so that it can be used. Finally it must seal electrical equipment in a dry environment.

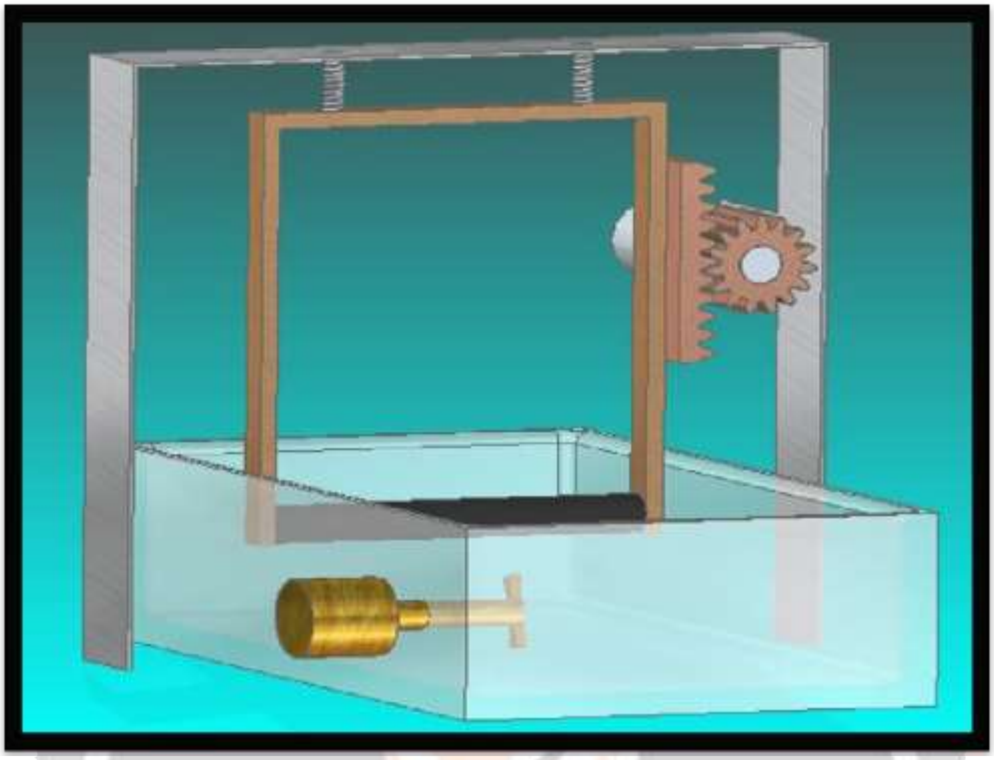

Fig.4 Actual design of VIVACE

4. Actual working model of VIVACE

Fig.5 Actual working model of VIVACE

5. Conclusion

We discussed investigations performed to study various hydrodynamic aspects of the, VIVACE (Vortex Induced Vibrations Aquatic Clean Energy) Converter. Suggestions are made for further research needed to improve performance of the VIVACE Converter. Investigations performed in this Dissertation on VIVACE Converter shed light on various aspects of VIV which have been not explored before. This was made possible because the fundamental model of VIVACE is a highly damped VIV system with relatively high Reynolds number.

Further investigation on hydrodynamic aspects of VIVACE will complement VIV knowledge available in the open literature. In the present study, VIVACE Converter has been designed and tested. In our experiments, it was shown that the VIVACE Converter extracts energy successfully and efficiently from fluid flow by enhancing rather than spoiling vortex shedding and enhancing rather than suppressing VIV and harnessing rather than mitigating VIV energy.

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