ABSTRACT

A professor of Civil and Environmental Engineering at the Stanford University, Mr. Mark Jacobson theorized that the global wind potential is estimated to be 72 terrawatts (72 million megawatts), India, according to Dr. Mark Jacobson, has vast potential for wind power. There are significant areas in India where wind speeds reach in excess of 25 kilometer per hour, at a 100 meters height, and at these speeds, it is possible to generate energy at a cost that competes with the likes of non-renewable coal and gas sources. Even if India were to tap 20% of this potential, she would be able to cater to about seven times the world’s current energy requirements. Further, it may be the case that Dr. Jacobson’s observation on the potential for wind power generation and distribution in India is beneficially confined to the Indian landmass alone, which provides even more reason to pursue this alternative energy source.

To date, no systematic measurements have been instituted to ascertain the wind potential for power generation at sea (offshore), around the Indian coastline. However, some measurements have been carried out in the past to prove, if at all it is needed, that very favorable conditions exist around the Indian coastline for harnessing wind energy to generate the electricity. Many countries in the west, like the U.S., U.K., Netherlands, Denmark, and Spain, have set up wind farms at sea for generation of electricity. However, in India, from about the early ‘90s, many technical papers have been presented at national and international conferences relating to this subject matter. Several scholarly articles have been written on this subject, specifically urging concerned authorities to institute policy changes and support establishment of wind-mills at sea for power generation. Unfortunately, no
single efforts has been made to date to verify, even on experimental basis, the possibility of offshore wind energy generation. The reason for this reluctance is not completely known, but it may be postulated that most technical papers do not provide sufficient real world demonstrators and are not persuasive enough.

Today, one often sees advertisements on popular Indian television channels. Each advertisement supported by recognized brands like major electric machinery manufacturers; each showing a number of windmills installed at sea, with an impressive voice-over asking viewers the question, “How can you power a planet hungry for electricity without damaging it?” Unfortunately most of these recognized brands, each an industrial giant in its own right, have not been able to tap into this abundantly available energy source, irrespective of the vast Indian coastline. Such failings appeal to the interests of a marine engineer, who often wonders whether the fear of the sea is preventing entrepreneurs, engineers, and authorities alike, from casting their safety net into the sea when it comes to harnessing wind energy in our country.

Recently ISRO, the Indian Space Research Organization, successfully launched the space mission Chandrayaan I. Along with this Rs.3,80,000 Crores lunar mission launch came one of the main objectives - to search for helium 3, which is thought to have brought life to earth, and subsequently, to solve energy problems and provide electricity for several years. While it is indeed laudable to see that the government sparing no efforts, it should be noted that we are going to the moon – a spatial source that is nearly ‘three hundred and eighty five thousand kilometers’ away from the earth, for clues to an energy shortage problem; the answer to which lies along both of our major coast lines, much closer to home. Even at a range of ‘five kilometers’ into the sea, from the coast, the sustainable wind is sufficient to harness wind energy that will meet very similar needs as would any other non-renewable energy resource.

These observations make one wonder whether Indian authorities bear any seriousness about tapping any of the available sources of clean energy for sustainable
development and environmental protection. According to well-placed sources, some other possible reasons for our reluctance to venture into the sea include our previous failures in wave energy projects, at Vizhinjam in kerala and the OTEC project, off the Kulasekarapattanam coast in Tamilnadu. At this point, it should be noted that both these projects were handled by persons with technical competence that has been routinely challenged. For one, it has been observed that these engineers lacked maritime knowledge and did not belong to the maritime fraternity. To some, this may not sound like much; but the knowledge and experience of a maritime engineer are not limited to technical know-how. Maritime experience includes a “feel” for the sea, the interaction of the sea with foreign objects, and the structural knowledge that comes from operating maritime structures and machineries, all at sea. Be that as it may, an attempt is now being made to revive the interest in renewable sources of the energy, including wind, wave, and surface currents, each of which are available in plenty at sea. Accordingly, I now present a marine engineer’s perspective to renewable energy generation and its related best practices.

Our interest has also been boosted by the fast deteriorating environment, primarily due to indiscriminate burning of fossil fuels. This has brought into sharp focus the urgent need for an environment-friendly power generation technology for sustainable development. Offshore power plant technology, using renewable energy sources at sea, is the perfect solution. This paper expounds this technology, first by tracing the origin and growth of the windmill, perhaps the oldest technology for harnessing non-conventional energy, then to the economics of the installation and operation of an offshore wind energy power plant. In this paper, I present further support illustrating the urgent need for incrementing the installed capacity of power generation in the country, to meet a need that is ever-growing. However, at the same time, I will also allude to the recently concluded earth summit in Rio De Janiero, Brazil, which has increased awareness about pollution threats from burning fossil fuel and its dangerous consequences. In view of these two conflicting requirements, I describe, in great theoretical and practical detail, a feasible idea for harnessing energy from wind on an offshore platform or farm. I also discuss certain design features and criteria for establishing and maintaining the daily chores on an offshore
power station. The discussion above greatly encouraged me to delve into some new concepts in offshore power generation. The title of my dissertation is ‘INTEGRATED OFFSHORE POWER STATION FOR HARNESING ALTERNATE SOURCES OF ENERGY’.

The thesis is divided into six chapters as follows:

Chapter one – History of windmills: This chapter covers wind mills from 5000 BC, till today. This provides context to the intent of technology and policy changes over the course of the years. I include descriptions of prior inventions relating to wind power generation and the technical work of global innovators to build momentum related to my study. I describe the different types of windmills, their construction, and a detailed theory of various experiments conducted. The subject matter covered here systematically spans decades of technical learning that we have endured along the way. Further, this chapter includes an extensive study windmill-powered electricity generation and the practical approach towards related technological advancements worldwide. I include my observations from a detailed study, involving various countries, in capacity augmentation, to increase wind energy production. I conclude this chapter by relating my observations from the development of windmills, to technology growth, policy, and surmise that time is of the essence.

Chapter two – Modern horizontal axis windmills: This chapter covers modern horizontal axis windmills components and blade aerodynamics, including the layout of the components. In this chapter, I describe the technical construction details of a 1500 kW wind turbine generator for the purpose of this research. Wind power has a number of benefits that set it apart from other renewable energies. For example, wind is globally available in abundance both on land (onshore) and at sea (offshore), and this will not change over the years. My study reviews a projected growth in worldwide wind energy installation over the years till 2022. I also review the increases in sizes and ratings of modern wind turbines over the years. The advancement in technology in this field has not lagged and continues to be studied in
efforts to enhance power output efficiency, while providing other advantages related to harnessing clean energy. A detailed study in modern components for the safety of the wind mill is highlighted, including a proposed automatic windmill braking system to ensure that a windmill may not be structurally harmed in storms and in gale-wind-like conditions, both of which are more common today than ever before.

**Chapter three – Case studies in worldwide offshore wind farm pilot projects:** In this chapter, I deal with global offshore windmills and large pilot offshore wind farms. The case studies include technical details of current systems, and observations of poor execution and mismanagement, including environmental and coastal deterioration due to the same. A study of country-wise pilot projects in deep water and shallow water is also reviewed in order to establish cost and time factors during construction of such structures. My review will also identify the technical difficulties of implementing corrective action in future projects of such scale and complexity. I cover related investigations on such technical issues as laying underwater cables in various wind mill foundations. Further, at this point in my paper, I evaluate local government approvals and support towards offshore wind farm in much detail. My evaluation stems from a study of bad bank loans awarded to various offshore wind farm contractors and the sub-standard contract documents. In conclusion, this chapter covers the requirement to plan ahead, cover for contingencies, and follow plans as best possible to meet time, technology, and resource limitations.

**Chapter four – Proposed modification to windmills:** In this chapter, I describe the concept of the innovation, discussed by and large in the previous chapters. Offshore wind power is known as the largest indigenous energy resource in the world, with a potential encompassing in shallow and deep waters regions. The known generation capacity for offshore turbines has increased in size, from a standard 1.5 MW wind turbine to 5 MW. One reason for the increase in capacity is attributed to a fact that offshore wind turbines are more exposed to higher wind speed resources and comes with fewer fixed costs that could lead to lower investment costs. I present an initial re-design of the windmill using a vertical shaft and gear
arrangement in order to transfer all the components from the top of the nacelle to the floor level of the tower. This would greatly reduce the weight on the nacelle and would subsequently reduce maintenance costs. My calculations for the shaft and gearing are exemplary, but relate to data from actual components used in the field today. I propose a second option of re-design, utilizing an integrated drive hydraulic pump and a hydraulic motor. Thus, an abundant wind resource available to an offshore structure may be optimized in harnessing clean power. I conclude by providing information and related data applicable in selection of a hydraulic pump and a suitable hydraulic motor for a proposed 1.5 MW offshore pilot project wind turbine generator in India.

Chapter five –Economics of offshore windmills: This chapter of my dissertation covers the existence of the early offshore wind farm and the countries ready to invest in the offshore projects. The shortage of electric power and the increase in worldwide economic development compelled many countries to go install offshore windmills. According to the future projections worldwide, a total of 80 GW offshore wind turbines could be installed by 2020 with three quarters from Europe. GWEC Report. Offshore wind has a number of advantages, such as higher wind speeds and less turbulence than on land and fewer environmental constraints. Large scale wind farms may be employed for harvesting offshore wind energy. Operation and Maintenance (O&M) aspects play an important role in the cost of electricity harnessed offshore, adding up to 30% of the costs of a kWh. Thus, it is increasingly relevant to find ways to reduce O&M costs for offshore wind farms. Furthermore, offshore aspects are particularly suitable for large scale development near the major port cities around the world, which also reduces the need for long transmission lines. While offshore wind energy is a relatively new technology with significant opportunities for cost reduction, technical innovations, revolutionary developments, and generating employment, it will change the face of renewable energy across the world. This chapter also describes the initial capital cost of wind farm and energy generation cost per kilowatt (kW). A detailed study on maintenance methods and operation costs are analyzed here, related to worldwide offshore projects for introducing better methods. I conclude by providing a disclosure for one method of
reducing O&M costs, with a suggestion that it should be adopted, because it has the potential to reduce O&M costs to 10% in contrast to existing O&M costs, which is at 28%.

Chapter six – conclusion: In this concluding chapter, I describe potential for further research in offshore wind mills utilizing contra-rotating fan blades. This technology already exists in ship’s propelling systems and has largely been tested on large ocean-faring vessels, in heavy seas. There are many advantages that these blades have over the single bladed propeller, but one of the most impressive advantages to researchers was that a ship could generate additional thrust, even though there was a reduction in load to the ship’s engine and therein, her fuel consumption. This could be further implemented and investigated in offshore wind mills. The combination of these new blade designs, in addition to a good wind profile, could easily lead to generation efficiency anywhere between 15 to 25 percent more than current electricity generation methods using existing wind mills. Furthermore, this could bring down the cost of the electricity generation. I conclude this chapter by proposing further research, because research in contra-rotating windmill blades is not the only option ahead of us. In one example, research relating to monitoring systems for lubricating oil conditions is a critical area. Additionally, further research is needed develop much need supporting infrastructure for offshore windmills. For example, research relating to development of safer and more efficient undersea electric cables and pipeline technology for fresh water delivery from ashore resources. Further support systems are required for a “renewing system” for remotely adding lubricating oil to replace spent oil within the system. I also include a brief discussion of the use of MATLAB –Simulink software to remotely compute and analyze cost data, which may then be used to optimize the cost structure for an offshore wind farm.