Off Shore Wind Turbines: A Solution To Energy Crisis In Pakistan

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Abstract-There is increasing power and energy shortage in Pakistan from last two decades. It is the need of the time to explore new avenues for power production, keeping in view the environmental impact and the concept of sustainability. Utilization of wind energy for production of power become very attractive in current scenario. Massive wind energy potential is available at the coastal areas of Sindh in Pakistan. In this research wind data available from Pakistan Meteorological Department (PMD) is analyzed and it is found that off shore wind turbines having lots of benefits over onshore wind turbines have promising applicability in Karachi coastal areas. Hence with the help of off shore wind turbines the total electricity load of Karachi city i.e. 2500 MW can be handled. For this purpose a practical scheme has also been proposed.

Keywords-Wind energy, Off Shore Wind Turbine, Feasibility Analysis, Energy Crisis, Power Calculation.

I. INTRODUCTION

During last few decades, Pakistan has been facing serious energy crisis. The major disadvantage of this energy crisis is the slowdown of developing process and it is also affecting overall progress in Pakistan Therefore, to meet the energy requirements in the country government is planning for renewable energy resources. Pakistan Meteorological Department (PMD) carried out a comprehensive survey to find out the wind Potential along the windy area of the country. The survey report indicates that there is a huge wind potential for collecting wind energy by using the modern technologies, especially in the Sindh coastal areas [i]. In Karachi there is severe power shortage at about 3 to 8 hours per day that causes huge economic losses for the city. Karachi is the greatest industrial city of the country, located at 24.861N and 67.011E along the coastal areas of the Arabian Sea. Karachi is the city of large population of 13 million currently it is facing power shortage problems [ii]. Wind energy is a vast resource of energy in Pakistan, a huge wind potential is available in Pakistan from which a significant amount of energy can be achieved efficiently [iii].A survey report presents a huge wind corridor is available in coastal areas of Sindh. For the running of turbine minimum wind velocity required is 3 to 4 m/sec. So luckly in Pakistan at Sindh corridor this wind velocity is 6 to 7.5 m/sec which is perfect to run the turbine. Survey report presented that Pakistan has a huge wind potential for the production of 300,000 MW electricity from wind & solar resource [iv] [v]. Pakistan electricity load forecast (MW) from 2007 to 2030 in three categories low, medium and high is given. In 2007 for all three categories demand was 19000 MW. Following Table shows the summary of forecast results.

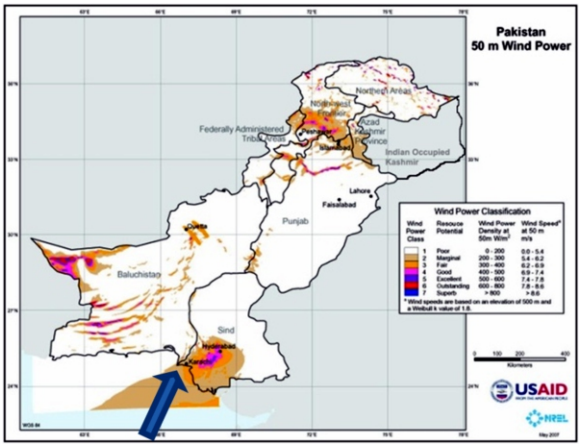

Fig. 1. Wind map of Pakistan

TABLE I
SUMMARY OF FORECAST RESULTS

Description	2007	2010	2015	2020	2025	2030	G.R. (2007-30)
Sale (GWh)							
Low Scenario	83463	112311	176178	261042	370882	500117	8.1%
Medium Scenario	83463	112955	181018	276937	409874	578560	8.8%
High Scenario	92447	113355	185239	295706	470527	735592	9.9%
Generation (GWh)							
Low Scenario	111078	143910	212724	307328	436911	589460	7.5%
Medium Scenario	111078	144711	218448	325740	482080	680330	8.2%
High Scenario	111078	145233	223618	348182	554680	868434	9.4%
Peak Demand (MW)							
Low Scenario	18883	24339	35271	51296	73041	98557	7.4%
Medium Scenario	18883	24474	36217	54359	80566	113695	8.1%
High Scenario	18883	24562	37075	58120	92762	145304	9.3%

Akhlaque AHMED et al. Analyzed data of coastal wind areas for the selected regions, the study was conducted to find out the availability of wind for wind energy generation .Authors studied the distribution of wind with the help of Weibull distribution. They also tested different wind turbines. It was found that, some locations were suitable for wind utilization [vi].The most comprehensive investigation of the wind potential was undertaken by Pakistan Meteorological Department and it was analyzed that coastal areas of Sindh have larger wind power potential than coastal areas of Baluchistan. The report also indicated that, Sindh coastal areas have comparatively higher wind potentials than other areas of Pakistan[vii]. Due to larger and greater infrastructure cost, connection of small villages to the national grid station is very expensive. Some experts, opinion is that WAPDA (Water and Power Development Authority) has not enough power to provide in these villages. In these villages electricity can be supplied by using wind power, because the wind with greater wind velocity is available round the year in these areas. National Renewable Energy Laboratory (NREL), developed the wind maps that show a greater potential of 346,000 MW in the coastal areas of Pakistan. NREL has discovered the windy coastal areas in the south part of Pakistan. The NREL wind map of Pakistan has given a greater improvement to the wind power generation in the coastal areas with greater power potential. Now this potential area has got much importance for the development of wind energy. In the current study the windy stations like paradise point, French point, Hawks bay, Karachi, Kakapir, Manora beach, Clifton beach and bundle Island were selected. This wind corridor is spread over 60 Km in length.

II. WIND POWER POTENTIAL IN PAKISTAN

To produce electricity through wind power is the rapidly progressing technology. Political, economic and some technical services are developing some procedures and methods to highlight the value of the wind power. In Pakistan there is incredible wind power potential, but unfortunately at present situation the services for power generating through wind potential is not so enough in the country. There is a long coastline area of 1000 km. which is used for the installation of off shore wind turbines like that of Netherlands UK, Japan, Denmark etc. In Pakistan wind power generation started very late, at present no significant power generation projects are in progress. In the same wind power potential and geographical environment as found in Pakistan. India has installed its ten turbines of 55 KW plant at Gujrat in 1986. [8]

In the current study, the project area that is under consideration for wind power potential is 60 Km along the Sindh coastline spread over up to 100 Km deep northward and latitude 25°N approximately.

A. Ongoing Projects in Sindh

Alternative Energy Development Board of federal government has started 9 projects including commissioned and under construction at Jhimpir for total capacity of 484.4 MW, and three projects of 150MW at gharo. All these projects are at different stages. In these projects 84 wind turbines are installed in the villages of Thatta Sindh to supply electricity at 580 homes, besides this in the 49 villages, 3,000 households in the Thatta district. In these 29 projects total Projects Capacity under cost plus regime expected to achieve FC in near future is 50 MW and total projects advanced stage projects capacity is 150 MW and Total Project Capacity below Tariff Stage is 814 MW.

TABLE II
TOTAL COMMISSIONED AND UNDER CONSTRUCTION PROJECTS AT JHIMPIR

Name	M/s FFC Energy Ltd.	M/s Zorlu Enerji Pakistan (Pvt.) Ltd.	M/s Three Gorges Pakistan First Wind Farm (Pvt.) Ltd.	M/s Sapphire Wind Power Company Ltd.	M/s Metro Power Company Ltd.	M/s Yunus Energy Ltd.	M/s Master Wind Energy Pvt. Ltd.	Tapal Wind Energy Pvt. Ltd.	M/s United Energy Pakistan Pvt. Ltd.	**Total**
Capacity (MW)	49.5	56.4	49.5	50	50	50	50	30	99	484.4

TABLE III
TOTAL COMMISSIONED AND UNDER CONSTRUCTION PROJECTS AT GHARO

Name	M/s Foundation Wind Energy II (Pvt.) Ltd.	M/s Foundation Wind Energy –I Ltd.	M/s Hydro China Dawood Power Pvt. Ltd	**Total**
Capacity (MW)	50	50	50	**150**

III. TYPES OF WIND TURBINES

Wind turbines are categorized into two basic types on the basis, on which turbine spins. The turbines which rotate in horizontal axis are mostly used. One of the example is the wind mills, similarly the wind turbine that rotates in vertical axis are the vertical axis turbines. These are not frequently used.

A. Offshore Wind Turbines

Offshore wind turbines are installed inside the sea. Offshore wind is same as that of earthly wind technologies; in the sea the wind potential is stronger and consistent due to this greater wind potential large size wind turbines are to be erected by vessels. The difficulty is to place a structure in a dynamic ocean environment.

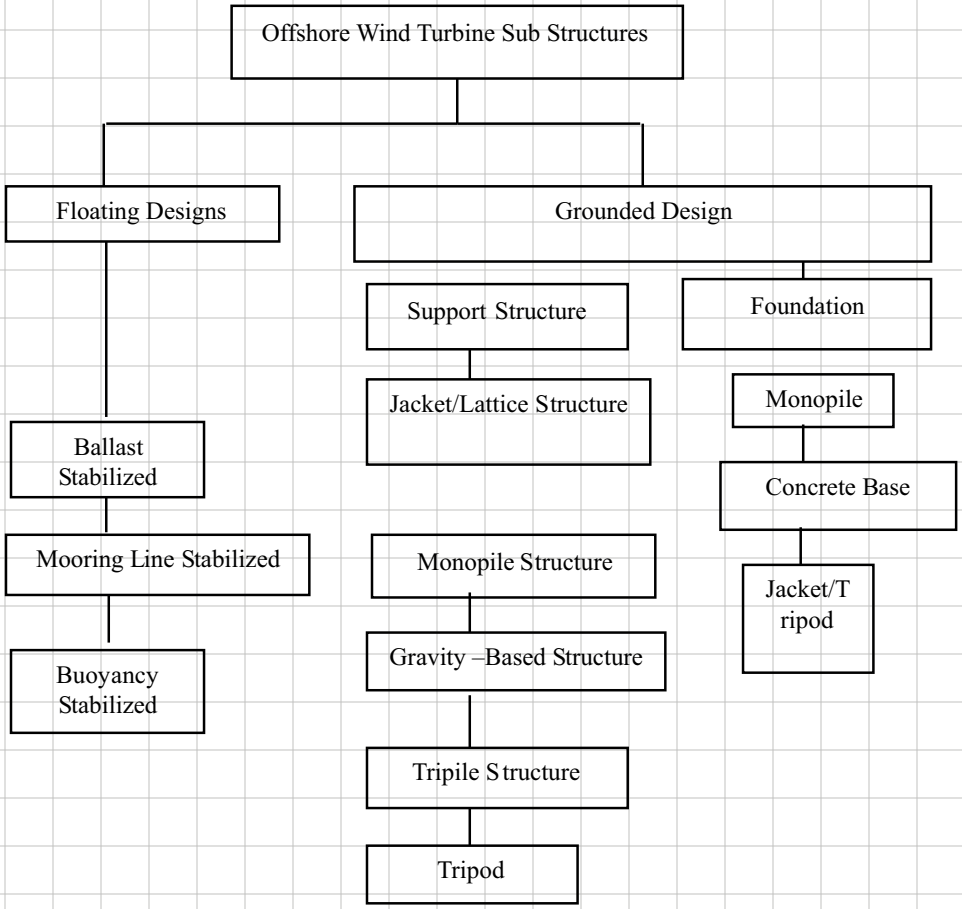

Fig. 2. Types of offshore wind turbines

B. Benefits of offshore wind turbine

Offshore wind turbines have the similar benefits as compared with the onshore wind turbines, wind turbines have not carbon emissions through its whole lifecycle, Fuel is not used in the wind power so it is free of cost as compared to the other electricity generation methods like the conventional power sources. Wind power does not rely on the freshwater [viii]. Offshore winds are stronger and more consistent than onshore winds so it is expected that the turbines can operate at their maximum capacity for a longer period of time [ix]. As the wind power increases, there is possibility to 150% increase in power generation through offshore wind turbines [x]. And the capacity factor of the wind farm also increases from 25 to 40% [xi]. The offshore wind farms are not disturbed with turbine noise as that of onshore wind farm, due to this offshore wind farm can use far larger turbines [xii]. In the sea, using offshore wind power larger turbines are used because there is high and consistent wind velocity that makes the wind turbines more economical and attractive.

C. Comparison of offshore and onshore wind turbines

Offshore wind power projects have one major advantage over the onshore wind power projects; In the offshore, wind is more powerful and consistent Some current studies indicated that offshore wind is more powerful so it is very difficult and costly to place infrastructure in the sea. So the installed capacity at sea is very small in comparison with installed capacity on land. Offshore wind energy is renewable and clean, so it reduces the fuels and fossils, due to this it can challenge the air pollution and climate changes. Onshore wind farms have greater negative impact on aesthetics of the landscape compared to offshore wind farms, because the onshore wind farms are mostly visible. The major disadvantage of offshore wind energy farm is a huge construction cost. Offshore wind energy forms are constructed powerfully to bear the rough weather conditions, the cost for installing an offshore wind turbine was $5 million for 1 MW in 2010, while installing an onshore wind the installing cost is between $2-2.5 million per megawatt.

D. Global Scenario of off shore wind turbine

From the last decade wind energy has become clean and environment friendly source of energy. This is getting importance worldwide for the availability of basic source and inexpensive technology to convert

the wind into useful energy [xiii]. In Sweden in 1990 first offshore wind turbine was installed. It was a single 220 kW power and 250 m away from the coast at 7 m water Depth and was supported on Tripod. Similarly First Offshore Wind Farm was installed in Denmark 1991. Plant contained 11 turbines of 450 kW power and 1.5 – 3 km from coast at 2-6 m Water Depth and was supported Gravity Foundation. In Japan First offshore wind farm of 16 MW was installed in 2004 and it is expected to upgrade at the power of 1 GW by 2020 [xiv]. Recently in Europe 14 forms of 3.3 GW are under construction, and 7 projects of 1.2 GW are under planning phase. Following figure indicates that in European countries 4995MW, China 509.5 MW and in Japan 33.8 MW power is generated through offshore wind plants. Having the world's 6th largest sea space, According to the Japan Wind Power Association statement, a huge offshore wind power potential is about 600 GW, from which 15% is achieved by the foundation of fixed bottom turbines while the remaining is achieved by using the floating foundation technology [xv]. Most of Japan's potential wind power capacity is located offshore, the most common regions where the floating foundation technology is used are Kyushu Tokyo, and Chubu, while in Tokyo fixed bottom foundation turbines are used.

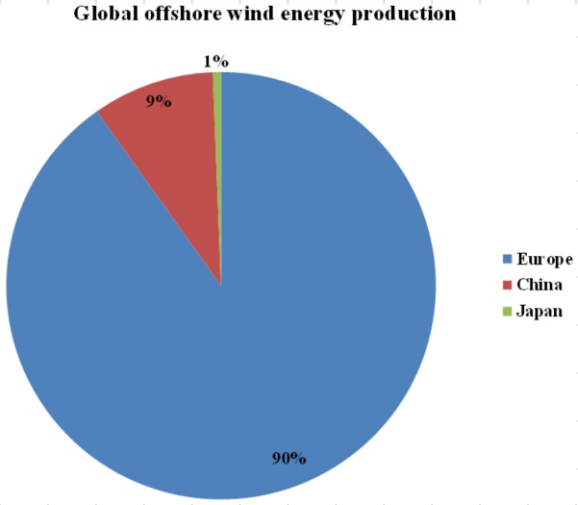

Fig. 3. Global offshore wind energy production

IV. Methodology; Analysis & Discussions

A. Average Wind Speed at Karachi

By using the Log Law and Power Law wind speed at different height is calculated by the following relations.

$$\frac{u}{ur} = \frac{Ln(\frac{Z}{Zo})}{Ln(\frac{ZR}{Zo})}$$

Where

UR is the wind speed at reference height ZR

Mostly engineers uses Power **Law** to determine the increase in wind velocity with the available height,

$$U/UR = (Z - D/ZR)^{\alpha}$$

Where:

α is the exponent for power law

$$\alpha = Ln(\frac{Ln(\frac{Z}{Zo})}{Ln(\frac{ZR}{Zo})})/\ln(Z/ZR)$$

At 50 meters height the wind velocity is computed, and monthly average at 50 meters height, is presented in graph.

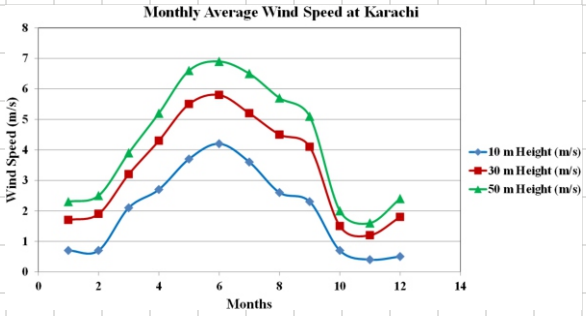

Fig. 4. Monthly average wind speed at Karachi

Table shows monthly average wind speed at different heights of 10, 30 and 50 meters. After computing the results At the height of 10 meters, the average wind speed less than 5 m/s was achieved, The maximum average wind speed recorded in June that was observed 4.2 m/s. At the height of 30 meters. The average wind speed was achieved during May to July that was 5 m/s, while 5.8 m/s was recorded as the maximum average wind speed for the month of June. At the height of 50 meters, a very consistent and high average wind speed was recorded that was ≥5.0 m/s during the whole period of 6 months from April to September, The maximum average wind velocity that was recorded is 6.9 m/s in June.

B. Diurnal Wind speed Variation

Figure shows the annual diurnal wind speed variations at the Karachi sea shore. Wind speed was calculated at different heights of 10, 30 and 50 meters. At 30 meters height the average wind speed varies from wind varies 2.6 m/s to 4.7 m/s and at the height of 50 meters it was recorded from 3.4 m/s to 5.7 m/s.

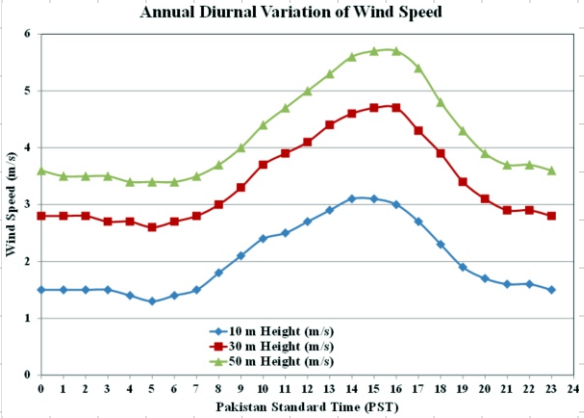

Fig. 5. Monthly Diurnal Variation of wind speed

V. Ideal Wind Power Calculation

A huge piece of land is required for wind form at the coastal areas near Karachi. Two projects of 50 MW and 3000 MW required 1283 and 26000 acrs respectively, In the current study 50 MW offshore wind form total 33 turbines of 1.5 MW each is suggested. Theoretically wind power is calculated by the following general equation

$P_{avail} = C_p * 1/2 * \rho * A *$ (1)

Where

C_p= Power coefficient ρ= Density if the oncoming air

A= Swept area of the rotor V= Velocity of the wind

The swept area of the turbine is calculated from the blade length using the area of a circle equation:

$A = \pi r^2$ (2)

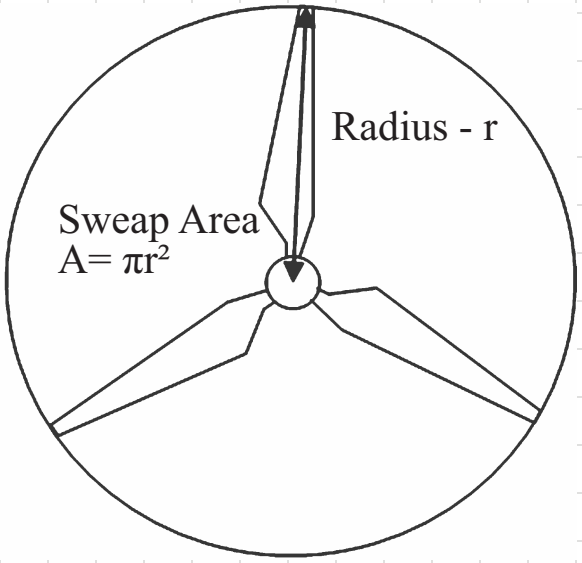

Fig. 6. Blades of Turbines

Tower height= 80 m

Blade Length=38 m

Average wind speed= 6.9 m/s

Power= 1.5 MW

A. Wind Farm Design

When designing the wind farm it is important to combine the wind date with topographical information to design the wind farm. This date may be used for wind flow, sound levels and turbine performance to elevate the location of wind turbines. Access to roads, local electrical network and turbine foundations is also designed

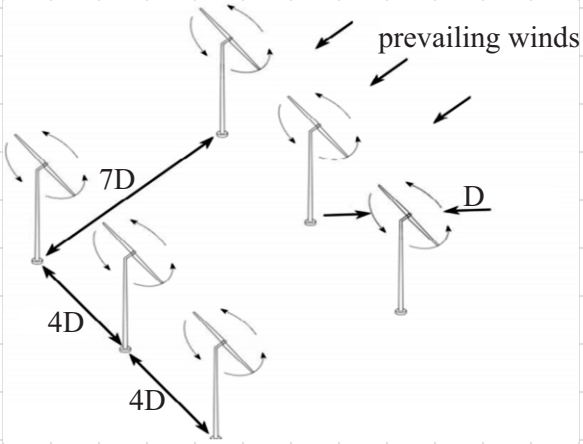

Fig 7: Wind farm Design

B. Foundation Design

Selection of the Foundation for the overall development of offshore wind turbines, the concept plays an important role as a major financial consequences attached to their decisions. Typically, Foundation expenses general expenses 25-34%. Wind turbine foundations are of two types that can be classified as: fixed (or that the seabed is grounded) and floating. Although the system is grounded Foundation supports most of the currently installed or operating turbines, offshore wind turbines (OWTs), due to the shape and form of dynamically sensitive structures because they are slim in the vicinity of the frequency of excitation frequencies by the environmental and mechanical load. The location, the status of the environmental impacts of soil and wind velocity second the monopile design was very suitable for the location of the foundations on the Karachi

1) Loads acting on the foundations

Different types of the loads act on the wind turbine tower, these loads are ultimately converted to the foundation of the tower and this can be of two types: static or dead load and the dynamic loads (a) The load that act at the hub level is the lateral load (b) In near

foundation of the tower load crushed against the substructure of the tower of foundation.. (c) Vibration is generated in the tower due to wind velocity, this vibration act as a load at the hub level. Because of unbalancing of the rotor, mass and aerodynamics.

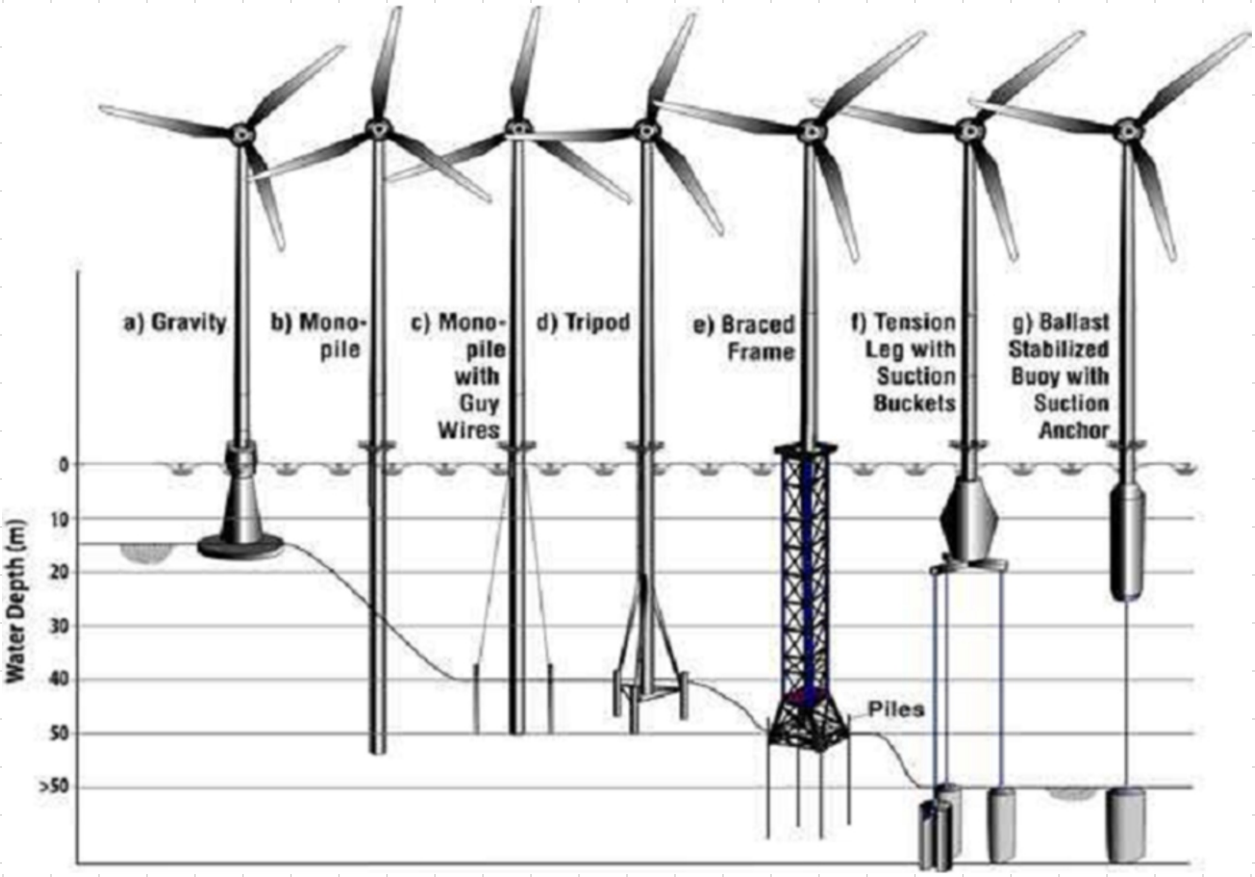

Fig. 8. Various types of support structures and their applicable water depth

VI. Recommendations

Some recommendations are concluded that, enough space is provided by the ports to accommodate installation of the turbines. For the installation of turbines Self-installing systems must be developed to minimize the installation costs. Practical knowledge and Training courses should be developed, a strong collaboration between the different companies should be developed for the new projects. Since the wind turbines are designed on the basis of size and the foundation structure [xii]. There is a need to develop such a control system where all these basic needs are to be met. New SOPs techniques and tools should be developed for the promotion of the wind farms. More tests/surveys are to be conducted to locate the proper sites (small and large scales) near the coastal areas.

VII. Conclusions

There is shortage of power in Pakistan, so government is adopting different methods to fulfill the requirements. To get the electricity through wind energy by using offshore wind turbine is one of them. In the current research the wind corridor near Karachi that is in length of 60 Km where wind speed was calculated. From the results it is concluded that there is a huge power potential in this wind corridor where average wind velocity is 7 m/s. On behalf of this data, a proposed wind power is also calculated. It is also concluded that off shore wind turbine farm is suggested near Karachi to meet the power requirements.

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