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Article

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Current scenario of the wind energy in Pakistan challenges and future perspectives: A case study



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ABSTRACT

Electricity plays an important role in the socioeconomic growth and social prosperity of any country. It is to be considered as the basic need for human development. Nowadays, low production of electricity is a serious problem in Pakistan, which directly restricts the development of the state. One-third of Pakistan's population does not have any electricity in the rural areas and about 10–12 hours load shedding in urban areas and is quite common. Although, the state of Pakistan always shows a deficit in the conventional resources, but no progress was also being made in the renewable resources such as the wind and solar energy. Therefore, it is better to utilize these natural assets in order to fulfill the electricity supply the country. In this manuscript, our main objective is to study and outlooks the country energy profile situation vis-à-vis wind energy potential characteristics of the most important wind corridor in the southern part of the country. Pakistan has around 1100 kilometers (km) coastal line for the wind energy potential, but in this manuscript, we have chosen one of the most suitable wind corridors of the southern part of the country. We also tried to prove theoretically that this wind zone is more favorable for country consumer demand. Moreover, future perspective and the major challenges during windmill implementation is also being discussed herein.

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1. Introduction

Energy is the fundamental necessity for the human and socio-economic development of a country. Furthermore, a simple way in order to express the growth of a country is the energy contribution per capita. It was reported that the production ratio of fossil fuel for North America, Europe, and Pacific Asia to be about 10, 57 and 40 years respectively, and it is necessary to reduce reliance on oil as referred to (see Makkawi et al., 2009). Moreover, the Pakistan energy need is highly dependent on oil, liquefied gasoline and natural gas. These sources contribute about 85% of the whole electricity supply for the country, while, the contributions of coal, nuclear and hydroelectricity are about 4.5%, 1.1% and 9.2%, respectively (Harian et al., 2009; Clarke and Trinnaman, 2004; Khan and Qayyum, 2009; Mirza, 1995). In 1947, after the independence of Pakistan, the total power generation was around 60 MW for its 31.5 million

residents i.e. ~4.5 units/consumer. It is important to note that, it was not enough, even at that time to fulfill the requirement of the consumers. Moreover, with a rapid growth in modern and social life, there is a tremendous increase in demand for the production of electricity. At the end of the 1970s, the power production reached up to 1.3 GW with the installation of different power houses. After the 1980s, power production increased and touched with the power network up to 3 GW. Ten years later the power production capacity was about 7 GW. In 1998, the whole power sector was restructured laid with the foundation of the Pakistan Electric Power Company (PEPCO). It is stated that before 1998, there were only two electric utility companies, one was the Karachi Electric Supply Company (KESC) served in Karachi region, whereas, another was the Water and Power Development Authority (WAPDA) which served for the rest of the country. Afterwards, it has been restructured a wing power in WAPDA in order to separate commercial entities, which make up of four generation companies (GENCOs), and eleven distribution companies (DISCOS) and one transmission company National Transmission Despatch Company (NTDC). Ten distribution companies are responsible for delivering electricity to the consumers, and KESC is responsible for organizing the total demand for its personal production in addition to buying from NTDC,

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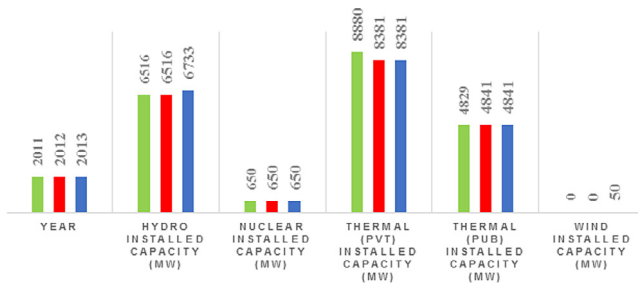


Fig. 1. Installed power sectors in Pakistan.

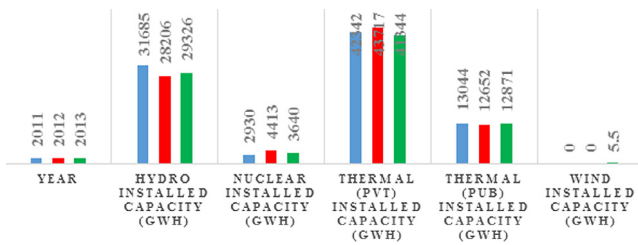


Fig. 2. Power generation sector wise.

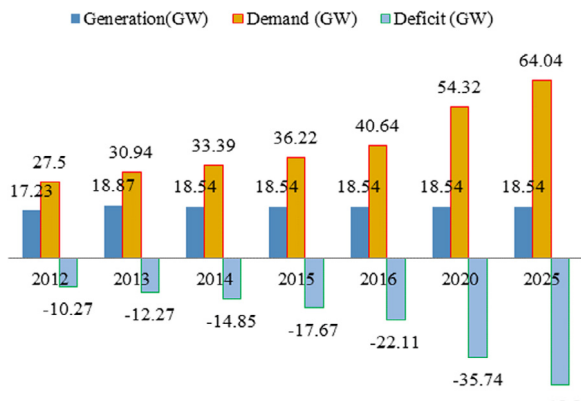


Fig. 3. Pakistan power generation, demand and deficit in different years.

Independent Power Producers (IPPs) and Karachi Nuclear Power Plant (Kanupp). In the 2000s, the annual electricity use in the residential sector had been increased per consumer and each annual industrial client also reached at the peak level in the widening gap between supply and demand. In the year 2006, the Asian Development Bank reported that about 45% of Pakistan residents lacks the basic need of electricity (Yearbook, 2003). In 2008, there were a worsened power crisis conditions in Pakistan, and the power shortage has increased by 4 GW.

The Pakistan installed power generation capacity outlooks by the year 2011–2013 including all generation sources is depicted in Fig. 1. It is clearly observed that, the thermal (Pvt) power plant uses the oil/gas sources for the power production. As referring to the (see Saadi et al., 2012), the power generation capacity sector wise in the year 2011–2013 is depicted in Fig. 2, the different sources have been utilized for the generation of electricity even wind, but here it is again reminded to the readers that the wind potential contribution percentage is negligible for the generation of electricity.

As we know that, Pakistan is an electricity deficit country, and in the near future, the electricity crises intensity will be at a maximum level (Mian and Khwaja, 2004). In the year 2012–2015, electricity crises situation increases 3% per year as depicted in Fig. 3.



Fig. 4. Pakistan 1st 50 MW wind power plant (Zorlu energy Turkish company) 2012.



Fig. 5. Pakistan 1st 100 MW solar power plant (Chinese company) 2015 (Tso and Yau, 2007).

It is reminded to the readers that, matter-of-fact that free source such as a huge wind and solar energy potential available in large amount yet not being intended to be exploited for the generation of electricity (Baloch et al., 2015a,b). In which one of the example Zorlu energy from Turkish company installed around 50 MW at Sindh wind corridor near Jamshoro city in 2012 as shown in Fig. 4, and the grid based solar farm around 100 MW installation with the collaboration of Chinese company is located within the Quaid-e-Azam Solar Park in Bahawalpur, Pakistan in 2015 as shown in Fig. 5.

It is reminded to the readers that, globally renewable energies such as: solar, wind, could meet the rapid demand of the consumer, and it could fulfill the increasing power shortages demand of the Pakistan. It is reminded to the readers that, globally renewable energies such as: solar, the wind, could meet the rapid demand of the consumer, and it could fulfill the increasing power shortages demand of the Pakistan (Harijan et al., 2009). In this research study, we initiate and investigated one free energy zone namely Jamshoro city Sindh province for power generation from southern part of Pakistan, where the maximum wind speed reaches around 14 m/s.

The literature was carried out using IEEE Explore Digital Library (Musial and Ram, 2010), Google Scholar (Heymann, 1998), Science Direct (Jonkman and Musial, 2010) and Research Gate (Gipe, 2009). The key terms searched on these data engines were 'wind energy systems' and 'wind energy profile situations in Province of Sindh Pakistan and world' etc. Furthermore, all the searched research articles were properly checked and the appropriate article related to our problem were included in the literature survey. However, major consideration has been given wind energy performance in Sindh (Pakistan) main corridors, wind speed and proper selection of windy zones.

2. Global investment on clean energy sector status

Globally, most of the conventional sources (which produces CO₂) dependent countries are trying to shift their power houses on renewable sources because conventional sources will be exhaust in the future. Therefore, we put an immediate attention in

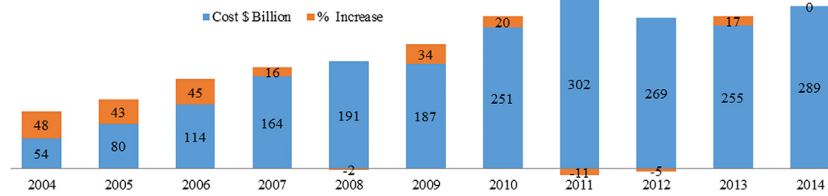


Fig. 6. Global investment on clean energy (Awan et al., 2014).

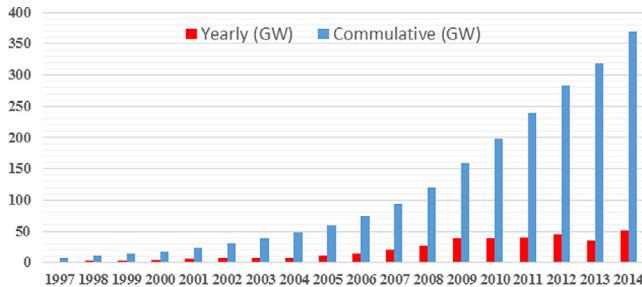


Fig. 7. Total installed wind energy capacity of the world since 1997–2014 (Mozumder and Marathe, 2007).

order to fulfill the requirement of the country power issues and protection from the effects of global warming. Moreover, nowadays Pakistan taken keen interest in order to handle the renewable resources through the valuable machinery for power generation in which one of the example is Bahawalpur city Pakistan, where a 100 MW solar project was successfully completed on 5th May 2015 with the collaboration of China which is world's largest grid-connected power plant (Tso and Yau, 2007). As referring to the (see Rehman, 2004), and the reminded to readers that in F.Y 2011, several countries spent their greatest incomes for executing on the renewable energy resources. The global investment on green energy is depicted in Fig. 6.

3. Global wind energy development status

Globally, rapidly increasing power demand, enhance the power costs and pursuit to minimize the pollution of the environment due to the nonrenewable energy resources have stimulated to exploit renewable energy sources. Among other renewable energy resources the wind energy is the most dominant and indispensable choice for power generation. Being, pollution free, endless and inexpensive sources. Wind resources are rapidly raising renewable sources in both developed and developing countries (Saidur et al., 2010; Bianco et al., 2009). In Pakistan and Malaysia, several scientists and researcher have been conducted research in the field of renewable energy, which consists the feasible study in renewable energy utilization (Khahro et al., 2014; Lau et al., 2010; Ngan and Tan, 2012). It is very much important to take an attentive regarding power generation from wind potential. Due to the rapid energy crises such as oil and their costs in 1979, several researchers, engineers and scientists were taken interest and appraisals regarding free energy sources such as wind potential. The total installed wind energy capacity of the world since 1997–2014 is illustrated in Fig. 7 (Mozumder and Marathe, 2007). Beside this, several continents and their top three wind installed capacity are depicted in Fig. 8 (Mozumder and Marathe, 2007). Globally, according to the collected literature, Asia Continent and China is on the top in wind energy capacity having cumulative installed capacity is around 142 GW and 115 GW in 2014, respectively (Mozumder and Marathe, 2007).

4. Pakistan wind energy development status

As referring to the (see Wu et al., 2011), and in the year 2012, according to the report of National Renewable energy Laboratory (NREL), United States that the Pakistan have a huge amount of wind energy potential around 346 GW for the power generation. A complete wind map of Pakistan wind corridors are shown in Fig. 9. It is projected for wind energy scenario, that around 0.5 TW can be produced at the end of 2016. In the Sindh wind corridor zones, the wind speed reaches approximately about 5–12 m/s (Sheikh, 2010). Pakistan have the coastal line of Sindh, which has abundant sources of wind up to 20 GW electricity generation potential. Globally, renewable energy wealth has huge potential and can react to the world power mandate. The world can enhance the power source into the markets, safe and secure extended periods of the viable power supplies and diminish global atmospheric conditions. It also offers commercially smart opportunities to come across the definite prerequisites for energy services mainly for rural areas and developing regions. Further, it will produce employment openings for local public and indigenous trade for the industrial side for manufacturing point of view. However, proper utilization of wind potential only exists within the Sindh province for power generation, may fulfill the mandate of electricity crises in the country (Muneer and Asif, 2007). Furthermore, according to the international standards, it is essential to construct more easy wind potential classification in detail as showed in Fig. 9 (right side chart), we can consider our selected wind corridor for proper utilization in order to fit larger wind power plant, and it is a collective work out for installing the wind mill unit in wind zones. As referring to Table 1, it is observed that the each class showing in the wind speed in meter per second and wind power density in watt per m^2 at an altitude of 30 and 50 m of the wind turbine beyond the ground level.

5. Research source information

In this paper, the data for analysis purpose has been taken from several sources such as Pakistan Metrological Department, National renewable energy research, water and power development authority, published research articles, research journals, books and some online data.

6. Description of study region

The Pakistan's coastal line wind area in the map is close to 1100 km, in which 250 km falling in Sindh province. In this paper, we focus only one coastal wind zone in southern part of Pakistan in order to describe and exploit the wind power potential from selected zone. However, selected wind corridor is Jamshoro city as depicted in Fig. 10. Moreover, according to the international standards a few points should be kept in mind while selecting a suitable zone for installing wind towers as discussed below:

- The wind tower should be kept far away from the local barrier to the wind.
- Selected area should be enyos of the greater part of the zone.

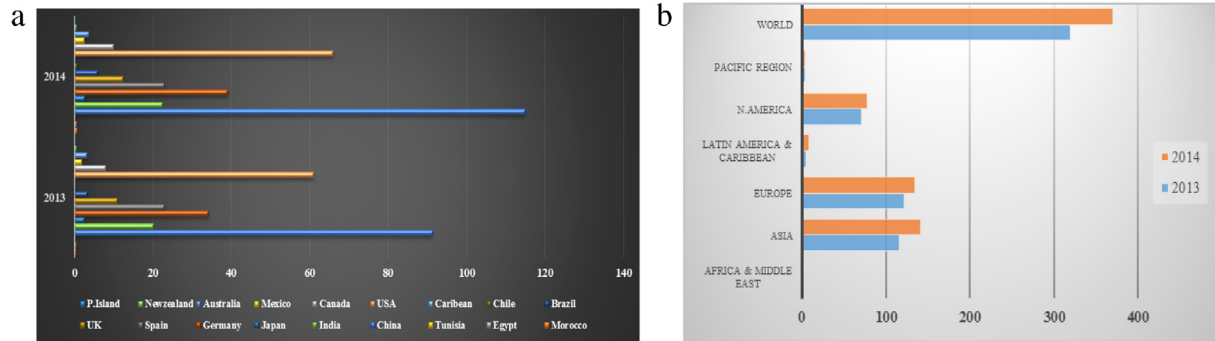


Fig. 8. (a) Top eighteen wind installed capacity in FY 2013–2014 of countries. (b) All continents wind installation in FY 2013–2014.

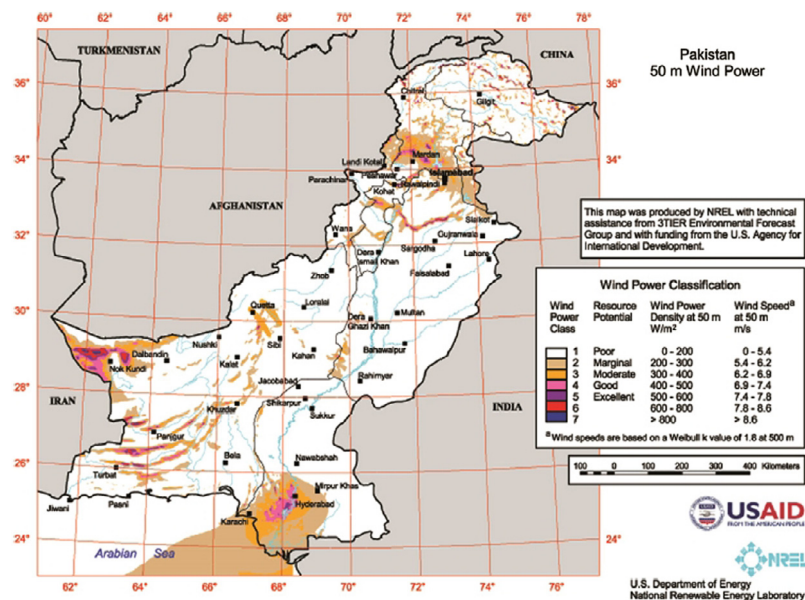


Fig. 9. National renewable energy laboratory survey report map.



Fig. 10. Diagram of study wind corridor (Reports, 0000).

However, wind speed data of the selected zone have been investigated and validated in hourly basis at different heights

such as at 10, 30 and 50 m continuously through an anemometer for a mentioned wind zone of the Sindh province with the

Table 1

Various estimated factors of Jamshoro wind zone at 50, 30 and 10 m wind turbine hub-height.

Name of study zones	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg:
Jamshoro @ 50 m height													
Wind speed	5	5.6	6.3	8.3	10.1	12.1	13.9	12.5	9.8	5.9	5.8	6.5	8.5
k'	1.8	1.7	1.7	2.1	2.5	2.7	4.4	3.4	2.8	1.8	1.7	2.1	1.9
C	6.7	6.4	7.2	9.4	11.4	13.6	15.6	14	11.1	6.7	6.6	7.4	9.6
Standard deviation	3.4	3.5	3.9	4.2	4.4	4.8	3.5	4	3.8	3.5	3.5	3.3	4.7
Wind power density	277	261	373	644	1008	1619	2102	1607	859	280	275	315	771
Jamshoro @ 30 m height													
Wind speed	3.7	4.4	5	6.7	8.4	10.2	11.6	10.3	8.2	4.5	4.3	4.9	6.9
k'	1.9	1.8	1.8	2.1	2.5	2.7	4.5	3.6	2.8	1.8	1.9	2.2	1.9
C	5.3	5.1	5.7	7.6	9.5	11.5	13.1	11.6	9.3	5.2	5	5.7	7.8
Standard deviation	2.6	2.7	3	3.4	3.6	4.1	2.9	3.2	3.1	2.6	2.4	2.4	3.9
Wind power density	128	125	180	341	578	985	1246	908	499	125	106	136	423
Jamshoro @ 10 m height													
Wind speed	2.4	2.5	2.7	4	5.4	6.7	7.7	6.7	5.4	2.3	1.9	2.4	4.2
k'	1.5	1.5	1.5	1.9	2.2	2.5	4.2	3.5	2.5	1.4	1.6	1.6	1.4
C	2.8	2.9	3.2	4.5	6	7.5	8.6	7.5	6	2.6	2.3	2.8	4.9
Standard deviation	1.7	1.8	1.9	2.2	2.6	2.8	2	2.1	2.3	1.7	1.3	1.6	3.1
Wind power density	27	29	39	81	162	284	353	243	144	26	14	24	160

support of Pakistan Metrological department (Pak MD), according to geographical structure the Jamshoro city longitudinally $68^{\circ}.263''$ on east and $25^{\circ}.433''$ latitude on north.

7. Analysis of wind potential: mathematical explanation

7.1. Wind potential calculation

The maximum wind energy potential can be obtained from the following equation (Bagiorgas et al., 2007):

$$\tilde{V}_\omega = C \left\langle \frac{k'}{k' + 2} \right\rangle^{-0.5}, \quad (1)$$

where in Eq. (1), \tilde{V}_ω is the maximum wind energy, k' , C are the dimensionless factor and weibull factor respectively.

7.2. Average wind deviation

As referring to the (see Chang et al., 2003; Öztöpal et al., 2000), in most of the locations, the wind velocity always changes with altitude, which primarily depends upon on two parameters terrain roughness and mixing of the atmosphere.

The wind speed deviation with altitude relation is described as follows:

$$\tilde{V}_{avg2} = \tilde{V}_{avg1} \left(\frac{h'_2}{h'_1} \right)^n, \quad (2)$$

where in Eq. (2), \tilde{V}_{avg2} , \tilde{V}_{avg1} , are the average wind speeds at h'_2 and h'_1 altitudes respectively, and the exponent power n is the land surface roughness atmosphere stability, and its maximum and minimum limits is the “0.5” and “0.05” respectively (Manwell et al., 2010):

7.3. Wind power density

The wind power that estimated the output side of the wind turbine through a swept base region is described as follows (Baloch et al., 2015a, 2016):

$$P_{wind} = \frac{1}{2} \rho \pi R^2 V_\omega^3 \quad \text{and} \quad P_{wind} = P_t \frac{1}{C_p \omega_t}, \quad (3)$$

$$C_p = 0.73 \left(\frac{151}{\lambda_c} - 13.2 \right) e \left(18.4 \frac{1}{\lambda_c} \right)^{-1}$$

where in Eq. (3), ρ is the air density (kg/m^3), R is the turbine blade length (m), ω_t is the turbine speed (radian/s), P_t is the turbine power, and C_p is the power coefficient expressing the aerodynamic rotor turbine efficiency, its theoretical limit is around in between $1/5$ and $2/5$, and practical limit is $2/10$ – $4/10$ (see Baloch et al., 2015a, Baloch et al., 2016), and from C_p equation λ_c is the tip speed ratio and can be characterized as follows considering at zero degree of pitch angle (Baloch et al., 2015a, 2016):

$$\lambda_c = \left(\frac{1}{\lambda - 0.002\delta} - \frac{0.003}{\delta^3 + 1} \right)^{-1}. \quad (4)$$

Furthermore, monthly/yearly power density defined as the ratio of wind power density per unit area of a turbine at a specific wind zone and can be described as follows (Celik, 2004a; Borowy and Salameh, 1996):

$$\text{Power Density} = \frac{P_{avg, wind turbine}}{\pi R^2}. \quad (5)$$

The average output wind power is a key factor compared with rated power, because it calculates the output energy from a period of time, in this manner influencing the cost-effective probability of a wind scheme. However, various wind machines have various effectiveness at the output power curves (Rehman, 2004; Borowy and Salameh, 1996; Garcia et al., 1998; Lu et al., 2002; Torres et al., 2003), Eq. (6) can be used for simulation purpose with the mechanical turbine.

Electrical Power

$$= \begin{cases} 0 & \langle V_{cut in} > V_\omega \rangle \\ P_{rated} \frac{V_{cut in}^{k'} - V_\omega^{k'}}{V_{rated}^{k'} - V_{cut in}^{k'}} & \langle V_{rated} \geq V_\omega \geq V_{cut in} \rangle \\ P_{rated} & \langle V_{cutout} \geq V_\omega \geq V_{rated} \rangle \\ 0 & \langle V_\omega > V_{cutout} \rangle, \end{cases} \quad (6)$$

where,

Average Electrical Power

$$= P_{rated} \left\langle \frac{e^{-(V_{cut in}/C)^{k'}} - e^{-(V_{rated}/C)^{k'}}}{(V_{rated}/C)^{k'} - (V_{cut in}/C)^{k'}} - \frac{1}{e^{(V_{cutout}/C)^{k'}}} \right\rangle.$$

$V_{cut in}$, V_{rated} , V_{cutout} , P_{rated} are the cut in, rated, cut off speed and rated power respectively.

The capacity factor (CF) is defined as the ratio of average power rated to the theoretical maximum energy at the output during

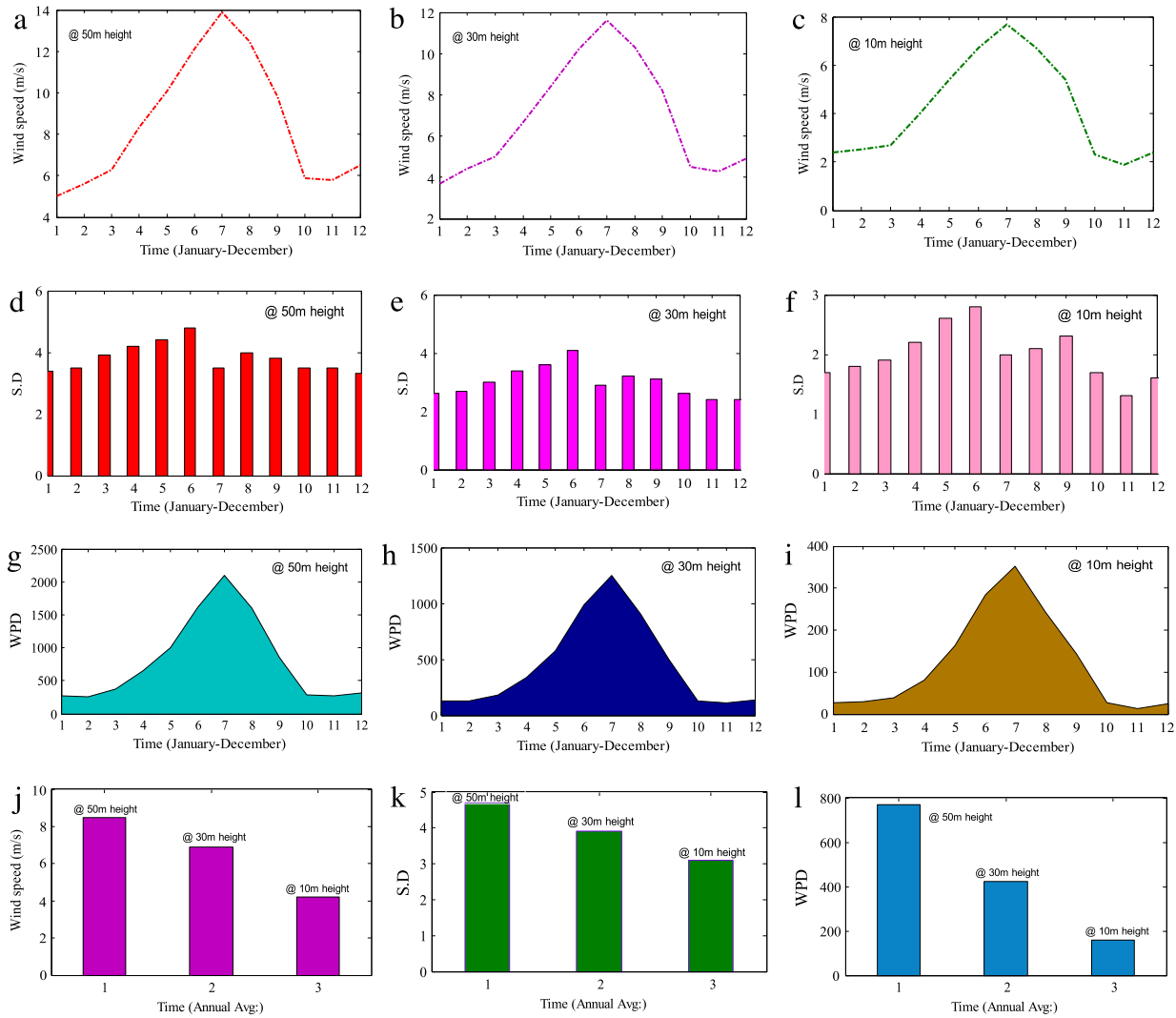


Fig. 11. (a)–(c) Monthly wind speed (m/s) from Jamshoro station at 50 m, 30 m and 10 m height respectively. (d)–(f) Monthly standard deviation from Jamshoro station at 50 m, 30 m and 10 m height respectively. (g)–(i) Monthly wind power density from Jamshoro station at 50 m, 30 m and 10 m height respectively. (j), (k) and (l) annually average wind speed (m/s), standard deviation and wind power density from Jamshoro station at 50 m, 30 m and 10 m height respectively, by using Table 1 (see Fig. 11).

specific in time span and can be characterized as follows:

$$\text{Capacity factor (CF)} = \frac{\text{Average electrical power}}{\text{Rated electrical power}}. \quad (7)$$

The theoretical limit of CF is 100%, and the practical limit is between 20% and 70%, and mostly it is around between 20% and 30%. Nevertheless, the wind turbine cost-effective possibility does not only rely on CF, but also alternative electrical power system expenditures. Furthermore, low CF does not mean that the project is not appropriate for the specific study zones.

The standard deviation can be described as follows:

$$\Delta = \left(c^2 \left\{ \gamma \left(1 + 2/k' \right) - \left[\gamma \left(1 + 1/k' \right) \right]^2 \right\} \right)^{1/2}, \quad (8)$$

where in Eq. (8), γ is the gamma function and can be described in detail (see Celik, 2004a, Akpinar and Akpinar, 2004, Balouktsis et al., 2002, Ulgen and Hepbasli, 2002, Celik, 2004b, Köse, 2004, Celik, 2003, Deaves and Lines, 1997, Persaud et al., 1999, Seguro and Lambert, 2000, Lun and Lam, 2000).

8. Results and discussion

In this case, the power has been generated based on most popular wind turbine supposed a German company GmbH

constructed a wind turbine Bonus 600/44 MK IV type, and expected life is around 20 years. This type of turbine have maximum capacity is 600 kW having cut in and cut out wind speed is 3 m/s and 25 m/s respectively, with 50 m hub height, three numbers of blades and 44 m diameters of the rotor. Therefore, we simulate analytical wind data through software Matlab in order to calculate the approximate outcomes. However, we have been Jamshoro city wind corridor of Sindh province for the estimation of output electric power at 50 m wind turbine hub heights using only one year data along with monthly and annually capacity factor, and standard deviation, wind power density, significance of C and k' respectively at 10 m, 30 and 50 m wind turbine heights, respectively as shown in Table 1. Furthermore, to the best of authors knowledge, from selected wind station namely: Jamshoro, in order to generate electrical units in MW h and capacity factors in (%), monthly and annually at 50 m hub height has been estimated and can be easily visualize in Fig. 12, respectively. It is concluded from the results that only with selected wind zone, annually around 2.1 GWh units can be generated from one station in which from April to September we can generate maximum power during peak demand in summer season and the same situations occurs in capacity factor as shown in Fig. 12. and therefore estimated power can fulfill the electricity crisis issues in a region which badly effects in the living standards of human beings.

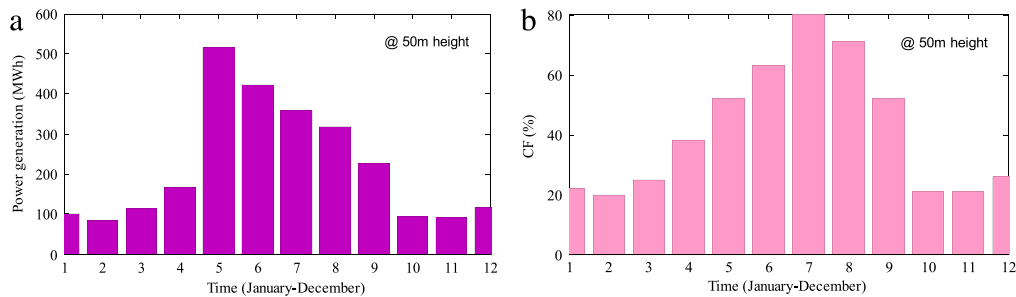


Fig. 12. (a) Monthly power generation in (MWh) from Jamshoro station at 50 m hub height. (b) Monthly capacity factor (%) from Jamshoro station at 50 m hub height.

9. Challenges for installing wind energy projects

Electricity crises issues in Hyderabad Electric Supply Company (HESCO) could be minimized in order to install wind mill units in selected coastal line. However, there are some challenging factors regarding the installation of wind mills which are described as follows:

- As referring to the [Kennedy-Darling et al. \(2008\)](#), the initial investment is very high, even though conventional power plant life cycle cost is higher than wind mill unit. According to report by May, 2015, daily per capita income of the consumer is around 430-Pk Rs (4.3 US-dollar) and has been increased (see [Selvam et al., 2009](#)), so it is not a good per capita for the consumer which install individual local wind mills. In this situation, it is not possible for GoP in order to install an expensive wind plant. However, it is better if local wind mill companies have to be grown in the Pakistan, and with that competitor should come in the market with low cost and maximum windmills can be designed and the initial cost can be minimized.
- It is necessary in order to select a suitable site for wind mill units. The improper investigation could be results in reduced output energy than the calculated one. For example, in some places close to larger building structures are not suitable due to wind turbulence and shear for wind mill unit. The consequences that the output wind energy can be minimized due to the effects of wind turbulence and shear ([Short, 2002](#)). At this time, GoP took keen interest in order to survey a suitable site selections with the help of Pakistan Metrological Department from the southern region of Sindh and some from Balochistan Province.
- In electrical power system, the power quality is a big issue especially in wind mills due to the uncertain wind speed. The irregular shape of the input from the wind turbine system which may cause to diminish the life of electrical machines and increases the losses ([Volut and Schonek, 2007](#)). Therefore, it is necessary we should follow the rules of International Electrotechnical Commission (IEC) and other international standards for power quality while implementing wind mills.
- As referring to the available literature (see [Pierpont, 2009](#), [Punch et al., 2010](#)), the low frequency noise has a bad effect on human health. Such type of noise may effects on human mind and body. Therefore, it is very important for the researchers that they should strictly follow the international standards and improve the mechanical design of wind mills in order to minimize the low frequency noise at the output side which effects on human health.
- There are several benefits for power companies like HESCO and individual consumers in order to install large and small wind mill units respectively, and some benefits that are more suitable during electricity crises situation specially for HESCO utility company which are described as follows ([Midilli et al., 2007](#); [Saidur et al., 2011](#); [Wang et al., 2011](#); [Depuru et al., 2011](#); [Bachram, 2004](#)):
 - Meeting electricity demand.
 - Increases generation capacity.
 - Reducing line losses.
 - Reducing greenhouses gas emission.
 - Clean and polluted free atmosphere.
 - Carbon credit.
 - More reliable power.
 - Reduction in power tariff.
 - A road maps to the smart grid.

10. General incentives from gos for foreign investors

Government of Sindh, possesses considerable power generation potential from wind energy around 50 GW in coastal line of Sindh Province, having monthly average wind speeds range is close 8 m/s ([Boyd, 2009](#)). According to the renewable energy policy in 2006, GoS have provided a number of incentives in order to attract foreign companies for investing their business regarding the installation of wind mills in the country mainly wind corridor which is briefly described as follows ([Boyd, 2009](#)):

- Specific reason land available for the eligible investors an attractive annual rentals for the direct impact area is 102 Pk Rs (~one dollar)/sq yard/annum.
- Straight tariff rate around 16 Pk Rs (~13.2 cents) per electricity unit has been set for all those investors who are willing to complete given tasks/projects in 1.5 years.
- Long term policy around (20 years) throughput agreements with the Power Purchaser i.e. Wapda backed by GoP through the Implementation Agreement and Sovereign Guarantee (IASG), purchase of whole power produced through the project for the entire concession period.
- A complete wide-ranging exposure to investors against the risk of change of rules through Force Majeure provisions and political risk.
- Certification of buy-back of the competence in the case of termination of the project.
- 5 years winds speed data are available from several GoP sources such as PMD, in order to estimate the accurate performance, direction, density, power at the output side etc.
- Complete wide-ranging tariff rules on a cost rate plus basis.
- Fiscal incentive/motivation throughout a zero income tax, solitary involvement of local exchequer would be a 7.5% withholding tax on dividends declared across the life of the project.

11. Pakistan wind energy projects status

GoP was assigned a task to the Alternative Energy Development Board (AEDB) in order to implement renewable energy projects specially wind and solar energy projects. With the contribution of AEDP, there are several renewable energy projects which are listed as [Table 2](#).

Table 2
Pakistan wind power plant projects status.

#	Name of city	Name of province	Name of company	Installation agreement (MW)	Status	Ref
1	Bhambore	Sindh	Zephyr Power Ltd	50	Under construction, to be completed by Dec 2016	Website (0000a)
2	Jhimpir	Sindh	Yunus Energy Limited	50	6 MW operational since 2009; 50.4 MW added in March 2013. Pakistan's first wind power station	Website (0000b)
3	Jhimpir	Sindh	Wind Eagle (Pvt) Limited	50	Operational since Dec 2012	Website (0000b)
4	Jhimpir	Sindh	UEPL Wind Power Pakistan (Pvt) Ltd	100	Under construction	Website (0000c)
5	Jhimpir	Sindh	Trident Energy (Pvt) Ltd	50	Under construction	Website (0000a)
6	Jhimpir	Sindh	Tricon Boston Corporation	50	Under construction	Website (0000a)
7	Jhimpir	Sindh	Titan Energy Pakistan (Pvt) Ltd	50	Under construction, to be completed by Dec 2016	Website (0000c)
8	Jhimpir	Sindh	Three Gorges First Wind Farm Pakistan Ltd	49.5	Under construction	Website (0000d)
9	Thatta	Sindh	Thatta Power Plant	150	Operational since Jan 2015	Website (0000e)
10	Khutti Kun, Mirpur Sakro	Sindh	Tenaga Generasi Limited	49.5	Under construction	Website (0000b)
11	Jhimpir, Thatta	Sindh	Tapal Wind Energy Ltd	30	Under construction	Website (0000a)
12	Sindh	Sindh	Sapphire Wind Power (Pvt) Limited	49.5	Under construction wind energy project.	Website (0000b)
13	Jhimpir	Sindh	Sachal Engineering Works (Pvt) Limited	50	Under construction	Website (0000b)
14	Jhimpir	Sindh	Metro Wind Power Co Limited	50	Under construction.	Website (0000b) , Website (0000c)
15	Karachi	Sindh	Mbm Engineering Company	1	LoI issued	Website (0000f)
16	Jhimpir	Sindh	Master Wind Energy Limited	49.5	Under construction, to be completed by Dec 2016	Website (0000b)
17	Jhimpir	Sindh	Jhimpir Wind Power Plant	56.4	6 MW Operational since 2009; 50.4 MW added in March 2013. Pakistan's first wind power station	Website (0000f)
18	Jhimpir	Sindh	Jhimpir Wind Energy Project (FFCEL)	49.6	Operational since Dec 2012	Website (0000e)
19	Bhambore	Sindh	HydroChina Dawood Power Ltd	50	Under construction	Website (0000a)
20	Jhimpir	Sindh	Hawa Energy Ltd	50	Under construction	Website (0000a)
21	Jhimpir	Sindh	Hartford Alternate Energy	50	Under construction	Website (0000a)
22	Jhimpir	Sindh	Gul Ahmed Wind Power Limited	50	Under construction, to be completed by Dec 2016	Website (0000b)
23	Gharo	Sindh	Gharo Wind Power Plant	50	Under construction.	Website (0000b)
24	Khutti Kun, Gharo	Sindh	Foundation Wind Energy-I & II Pvt. Ltd	100	Operational since Jan 2015	Website (0000d)
25	Jhimpir	Sindh	Finerji (Pvt) Ltd	50	Under construction	Website (0000a)
25	Jhimpir	Sindh	Dewan Energy (Pvt) Ltd	50	Under construction	Website (0000a)
26	Bhambore, Gharo	Sindh	Dawood Power (Pvt) Limited	50	Under construction wind energy project	Website (0000b)
27	Jhimpir	Sindh	China Sunec Energy (Pvt) Ltd	50	Under construction	Website (0000a)
28	Gharo	Sindh	Bhambore Wind Project	50	Under construction	Website (0000b) , Website (0000d)
29	Punjab	Punjab	AM Pak Energy	50	LoI issued	Website (0000g)

12. Conclusion, recommendation and future perspective

To the best of authors knowledge, authors selected more favorable wind zone located at the southern part of Sindh Province have a massive free energy potential. Economic investigation outlooks of wind power potential from selected wind corridor are concluded as follows:

- It is reminded to the readers that the monthly and annual average wind speed from Jamshoro wind station as shown in [Table 1](#), and it is observed that the selected wind zone is most suitable for power production, according to the international standards in case of wind turbine classifications, if wind speed ranges in between 7.2–8 m/s and 8–8.8 m/s at 30 m and 50 m height that would be an excellent zones for installing wind turbines respectively. Furthermore, in our selected zone the annual average wind speed reaches at best category.
- From the outcomes, the selected zone is suitable for power production in which the maximum and minimum wind speed reaches around 13.9 m/s and 5 m/s at 50 m heights respectively, having superior capacity factor.

- Electrical units generated from selected wind zone is enough in order to overcome the load shedding situation in a region.

Finally, it is concluded that the analysis and investigation outcome shows that Sindh province of selected study has a massive wind potential for electricity generation. Therefore, it is reminded to the GoS and GoP, they should utilize a golden wind zone on an urgent basis by having per unit generation cost is minimum from other conventional sources with zero CO₂ emission will be an extra benefit for human health safety.

We therefore, put forward a few recommendations for Gos and GoP in order to minimize the load shedding as well as to provide the power to rural areas of a country.

- On an urgent basis, GoP requires to focus on new national energy policies, and mainly on low cost and minimum time based projects such as alternative energy resource, in order to tackle the electricity crises issues and furnish the power requires of the country.
- Thermal/gas power plants are too old and their efficiency is <15% such as Uch Power Plant located in Punjab Province

having capacity is around 800 MW, but due to aging it generates only few MW.

- iii. The governor system of power companies (GENCO'S, NTDC and DISCO'S), should be improved.
- iv. Nontechnical losses such as power thefts should be cut off on power distribution side.
- v. GoS coordination with GoP and related institution implement a home based small wind mill units at windy zones, specially in rural areas.
- vi. The over all technical losses are around 20%–30% due to the old infrastructure of power grid, power stations and transmission/distribution, according to international standards these technical losses should be minimized at minimum level.
- vii. GoP, should motivate and provide suitable incentives to foreign companies/investors in order to focus on an urgent and time based on completion of alternative projects such as wind and solar for the ongoing power issues.
- viii. GoP should introduce a research and development fund for alternative energy projects so that national top ranking institutions and research and development organizations could sort out the best option for introducing and disseminating the exploitation of alternative sources.

Also we put forward a few comments for future research directions in the area of alternative energy enlargement in Sindh, Pakistan.

- Most important future development of the research study must consist a prerequisite of an effective strategy in order to evaluate the accuracy of wind energy generation systems.
- More significantly, various technique systems should be developed for predicting the wind speed.
- Various up-to-date algorithms are known for software based techniques probabilistic interpretation and much more need to be future research objectives.
- More advanced software tools for sculpting, drawing, development, analysis, testing and justification of the abilities and modularity of a wind energy system integrated with power-grid and internet.
- Keeping in view, it is concluded that, all research study stated above needs to focus on the significant concerns such as: safety, cyber security, minimum cost, feasibility, compliance, and monitoring should be an objective for further research and analysis.
- A potential home based wind turbine model projects should be researched in order to implement in suitable wind zones in rural areas where up to now there is no power.

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References

- Akpınar, E.K., Akpınar, S., 2004. Determination of the wind energy potential for Maden-Elazığ, Turkey. *Energy Convers. Manage.* 45, 2901–2914.
- Awan, , Bilal, Ahmad, Ali Khan, Zeeshan, 2014. Recent progress in renewable energy—Remedy of energy crisis in Pakistan. *Renewable Sustainable Energy Rev.* 33, 236–253.
- Bachram, H., 2004. Climate fraud and carbon colonialism: the new trade in greenhouse gases. *Capitalism Nat. Socialism* 15, 5–20.
- Bagiorgas, H.S., Assimakopoulos, M.N., Theoharopoulos, D., Matthopoulos, D., Mihalakakou, G.K., 2007. Electricity generation using wind energy conversion systems in the area of Western Greece. *Energy Convers. Manage.* 48, 1640–1655.
- Baloch, M.H., Kaloi, G.S., Wang, J., 2015a. Feasible wind power potential from costal line of Sindh Pakistan. *Res. J. Appl. Sci. Eng. Technol.* 10, 393–400.
- Baloch, M.H., Wang, J., Kaloi, G.S., 2015b. A point of view: Analysis and investigation of wind power from southern region of Pakistan. *Int. J. Energy Convers. (IRECON)* 3, 103–110.
- Baloch, M.H., Wang, J., Kaloi, G.S., 2016. Stability and nonlinear controller analysis of wind energy conversion system with random wind speed. *Int. J. Electr. Power Energy Syst.* 79, 75–83.
- Balouktsis, A., Chassapis, D., Karapantsios, T.D., 2002. A nomogram method for estimating the energy produced by wind turbine generators. *Sol. Energy* 72, 251–259.
- Bianco, V., Manca, O., Nardini, S., 2009. Electricity consumption forecasting in Italy using linear regression models. *Energy* 34, 1413–1421.
- Borowy, B.S., Salameh, Z.M., 1996. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. *IEEE Trans. Energy Convers.* 11, 367–375.
- Boyd, E., 2009. Governing the clean development mechanism: Global rhetoric versus local realities in carbon sequestration projects. *Environ. Plan. A* 41, 2380–2395.
- Celik, A., 2003. Weibull representative compressed wind speed data for energy and performance calculations of wind energy systems. *Energy Convers. Manage.* 44, 3057–3072.
- Celik, A.N., 2004a. A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey. *Renew. Energy* 29, 593–604.
- Celik, A.N., 2004b. On the distributional parameters used in assessment of the suitability of wind speed probability density functions. *Energy Convers. Manage.* 45, 1735–1747.
- Chang, T.-J., Wu, Y.-T., Hsu, H.-Y., Chu, C.-R., Liao, C.-M., 2003. Assessment of wind characteristics and wind turbine characteristics in Taiwan. *Renew. Energy* 28, 851–871.
- Clarke, A., Trinnaman, J., 2004. *World Energy Council Survey of Energy Resources*. Elsevier Science & Technology Book, ed: London.
- Deaves, , Lines, I., 1997. On the fitting of low mean windspeed data to the Weibull distribution. *J. Wind Eng. Ind. Aerodyn.* 66, 169–178.
- Depuru, S.S.S.R., Wang, L., Devabhaktuni, V., 2011. Smart meters for power grid: Challenges, issues, advantages and status. *Renewable Sustainable Energy Rev.* 15, 2736–2742.
- Garcia, A., Torres, J., Prieto, E., De Francisco, A., 1998. Fitting wind speed distributions: a case study. *Sol. Energy* 62, 139–144.
- Gipe, P., 2009. *Wind Energy Basics*. Chelsea Green Pub. Co.
- Harijan, K., Uqaili, M.A., Memon, M., Mirza, U.K., 2009. Assessment of centralized grid connected wind power cost in coastal area of Pakistan. *Renew. Energy* 34, 369–373.
- Heymann, M., 1998. Signs of hubris: the shaping of wind technology styles in Germany, Denmark, and the United States, 1940–1990. *Technol. Cult.* 39, 641–670.
- Jonkman, J., Musial, W., 2010. Offshore code comparison collaboration (OC3) for IEA task 23 offshore wind technology and deployment. *Contract* 303, 275–3000.
- Kennedy-Darling, J., Hoyt, N., Murao, K., Ross, A., 2008. *The Energy Crisis of Nigeria: An Overview and Implications for the Future*. The University of Chicago, Chicago.
- Khahro, S.F., Tabbassum, K., Soomro, A.M., Liao, X., Alvi, M.B., Dong, L., et al., 2014. Techno-economical evaluation of wind energy potential and analysis of power generation from wind at Ghara, Sindh Pakistan. *Renewable Sustainable Energy Rev.* 35, 460–474.
- Khan, M.A., Qayyum, A., 2009. The demand for electricity in Pakistan. *OPEC Energy Rev.* 33, 70–96.
- Köse, R., 2004. An evaluation of wind energy potential as a power generation source in Kütahta, Turkey. *Energy Convers. Manage.* 45, 1631–1641.
- Lau, K.Y., Yousof, M., Arshad, S., Anwari, M., Yatim, A., 2010. Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions. *Energy* 35, 3245–3255.
- Lu, L., Yang, H., Burnett, J., 2002. Investigation on wind power potential on Hong Kong islands—an analysis of wind power and wind turbine characteristics. *Renew. Energy* 27, 1–12.
- Lun, I.Y., Lam, J.C., 2000. A study of Weibull parameters using long-term wind observations. *Renew. Energy* 20, 145–153.
- Makkawi, A., Tham, Y., Asif, M., Muneer, T., 2009. Analysis and inter-comparison of energy yield of wind turbines in Pakistan using detailed hourly and per minute recorded data sets. *Energy Convers. Manage.* 50, 2340–2350.
- Manwell, J.F., McGowan, J.G., Rogers, A.L., 2010. *Wind Energy Explained: Theory, Design and Application*. John Wiley & Sons.
- Mian, A.R., Khwaja, A.I., 2004. Do lenders favor politically connected firms? Rent provision in an emerging financial market, Rent Provision in an Emerging Financial Market (December 2004).
- Midilli, A., Dincer, I., Rosen, M., 2007. The role and future benefits of green energy. *Int. J. Green Energy* 4, 65–87.
- Mirza, S., 1995. Privatisation in Pakistan: Ferozsons.
- Mozumder, P., Marathe, A., 2007. Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy* 35, 395–402.
- Muneer, T., Asif, M., 2007. Prospects for secure and sustainable electricity supply for Pakistan. *Renewable Sustainable Energy Rev.* 11, 654–671.
- Musial, W., Ram, B., 2010. Large-scale offshore wind power in the United States: Assessment of opportunities and barriers, NREL; Energetics, Inc.
- Ngan, M.S., Tan, C.W., 2012. Assessment of economic viability for PV/wind/diesel hybrid energy system in southern Peninsular Malaysia. *Renewable Sustainable Energy Rev.* 16, 634–647.
- Öztopal, A., Şahin, A.D., Akgün, N., Şen, Z., 2000. On the regional wind energy potential of Turkey. *Energy* 25, 189–200.

- Persaud, S., Flynn, D., Fox, B., 1999. Potential for wind generation on the Guyana coastlands. *Renew. Energy* 18, 175–189.
- Pierpont, N., 2009. Wind turbine syndrome: A report on a natural experiment: K-Selected Books Santa Fe, NM, USA.
- Punch, J., James, R., Pabst, D., 2010. Wind turbine noise: what audiologists should know. *Audiol. Today* 22, 20–31.
- Rehman, S., 2004. Wind energy resources assessment for Yanbo, Saudi Arabia. *Energy Convers. Manage.* 45, 2019–2032.
0000. Reports: Online Available: www.pakmet.com.pk [Assessed 2015].
- Saadi, M., Manzoor, R., Wuttisittikulkij, L., 2012. Proposal for low cost GSM based electric meter for efficient and automated meter reading for developing countries. In: Proceedings of the World Congress on Engineering.
- Saidur, R., Islam, M., Rahim, N., Solangi, K., 2010. A review on global wind energy policy. *Renewable Sustainable Energy Rev.* 14, 1744–1762.
- Saidur, R., Rahim, N., Islam, M., Solangi, K., 2011. Environmental impact of wind energy. *Renewable Sustainable Energy Rev.* 15, 2423–2430.
- Seguro, J., Lambert, T., 2000. Modern estimation of the parameters of the Weibull wind speed distribution for wind energy analysis. *J. Wind Eng. Ind. Aerodyn.* 85, 75–84.
- Selvam, K., Kanev, S., van Wingerden, J.W., van Engelen, T., Verhaegen, M., 2009. Feedback-feedforward individual pitch control for wind turbine load reduction. *Internat. J. Robust Nonlinear Control* 19, 72–91.
- Sheikh, M.A., 2010. Energy and renewable energy scenario of Pakistan. *Renewable Sustainable Energy Rev.* 14, 354–363.
- Short, L., 2002. Wind power and English landscape identity. *Wind Power View: Energy Landsc. Crowded World* 43.
- Torres, J., Prieto, E., Garcia, A., De Blas, M., Ramirez, F., De Francisco, A., 2003. Effects of the model selected for the power curve on the site effectiveness and the capacity factor of a pitch regulated wind turbine. *Sol. Energy* 74, 93–102.
- Tso, G.K., Yau, K.K., 2007. Predicting electricity energy consumption: A comparison of regression analysis, decision tree and neural networks. *Energy* 32, 1761–1768.
- Ulgen, K., Hepbasli, A., 2002. Determination of Weibull parameters for wind energy analysis of Izmir, Turkey. *Int. J. Energy Res.* 26, 495–506.
- Volut, S., Schonek, J., 2007. Electrical installation guide according to IEC International Standards. In: Schneider Electric, France.
- Wang, P., Huang, J., Ding, Y., Loh, P.C., Goel, L., 2011. Demand side load management of smart grids using intelligent trading/metering/billing system. In: PowerTech, 2011 IEEE Trondheim, pp. 1–6.
- 0000a. Website Link: <http://www.aedb.org/currestatus.htm>.
- 0000b. Website Link: <http://www.thenews.com.pk/Todays-News-4-167078-Two-wind-power-projects-approved>.
- 0000c. Website Link: <http://www.upm-cdm.eu/upms-pakistani-metro-power-and-gul-ahmed-wind-energy-projects-registered-with-the-cdm-2/>.
- 0000d. Website Link: <http://www.renewableenergyworld.com/rea/news/article/2015/01/pakistans-winds-blow-slow>.
- 0000e. Website Link: “FFC Energy ties to grid 50-MW wind farm in Pakistan”.
- 0000f. Website Link: <http://www.MBM-ENG.COM>.
- 0000g. Website Link: China Renewable Deals. <http://www.dawn.com/wps/wcm/connect/dawn-content-library/dawn/news/home/> DAWN Media Group (Retrieved 19.12.2010).
- Wu, B., Lang, Y., Zargari, N., Kouro, S., 2011. *Power Conversion and Control of Wind Energy Systems*. John Wiley & Sons.
- Yearbook, P.E., 2003. Hydrocarbon development institute of pakistan, Ministry of Petroleum and Natural Resources, Government of Pakistan.