In this article, a technique for the reduction of total harmonic distortion (THD) in distributed renewables energy access (DREA) composed of wind turbines is introduced and tested under the wind speed conditions presented in Tamaulipas, Mexico. The analysis and simulation are delimited by a study case based on wind speeds measured and recorded for one year at two highs in the municipality of Soto La Marina, Tamaulipas, Mexico. From this information, the most probable wind speed and the corresponding turbulence intensity is calculated and applied to a wind energy conversion system (WECS). The WECS is composed of an active front-end (AFE) converter topology using four voltage source converters (VSCs) connected in parallel with a different phase shift angle at the digital sinusoidal pulse width modulation (DSPWM) signals of each VSC. The WECS is formed by the connection of five type-4 wind turbines (WTs). The effectiveness and robustness of the DREA integration are reviewed in the light of a complete mathematical model and corroborated by the simulation results in Matlab-Simulink®. The results evidence a reduction of the THD in grid currents up to four times and which enables the delivery of a power capacity of 10 MVA in the Tamaulipas AC distribution grid that complies with grid code of harmonic distortion production.

Estimating the power output is one of the elements that determine the

techno-economic feasibility of a renewable project. At present, there is a need

to develop reliable methods that achieve this goal, thereby contributing to wind

power penetration. In this study, we propose a method for wind power error estimation

based on the wind speed measurement error, probability density function, and wind

turbine power curves. This method uses the actual wind speed data without prior

statistical treatment based on 28 wind turbine power curves, which were fitted

by Lagrange's method, to calculate the estimate wind power output and the corresponding

error propagation. We found that wind speed percentage errors of 10% were propagated

into the power output estimates, thereby yielding an error of 5%. The proposed

error propagation complements the traditional power resource assessments. The

wind power estimation error also allows us to estimate intervals for the power

production leveled cost or the investment time return. The implementation of this

method increases the reliability of techno-economic resource assessment studies.

Due the different possibilities for fit the Probability Density Functions

adjustable to a wind speed data set, a best fit selection criterion is developed

based on slope, intercept values and standard errors of Ordinary Linear Regression

model calculated from the probabilistic model and experimental data. Uncertainty

associated with measuring instruments is analyzed, and an interpretation is presented

in terms of the electric power generated. In addition, a methodology is proposed

to generate scenarios of energy production used in financial evaluations, which

is possible since the wind speed data used retain its uncertainty. The relevant

conclusions are that a sampling technique based on representative average wind

speeds does not reproduce the original distribution of wind speed data set, since

for the observed sample, the parameters of the fitted distributions vary depending

on sampling time. Accordingly, assessments based on this sample technique leads

to a resource underestimation.

The use of small wind turbines (SWTs) is an alternative energy strategy

with increasing potential for satisfying in situ electrical demands and should

be studied to promote social penetration. The Valley of Mexico Metropolitan Area

(VMMA) has air pollution issues that need to be addressed. This has resulted in

programs for monitoring atmospheric variables, such as wind speed. By selecting

and using 3 years’ worth of available data, we developed a methodology to study

the technical and economic feasibility of using SWTs in the VMMA. To this end,

28 SWT models were assessed at 18 locations to estimate annual energy production.

In light of certain data characteristics, an adjustment to the power production

was proposed for the specific case of using SWTs. Cash flow analysis and annualized

net present value (ANPV) were used to determine economic feasibility for each

location; furthermore, electric home feeds in the VMMA were considered to model

local economic conditions. Similar wind conditions were observed within the VMMA;

however, only two wind turbine and location models provided positive ANPV values.

The extra annual benefit for each project was calculated by associating the cost

per mitigation of CO2 emissions, which may provide an economic strategy for promoting

the penetration of this technology.

Wind turbine for low power applications is a clean energy alternative

to contribute global warming mitigation. The correct description of wind speeds

is crucial to determine the economic viability of a wind power project. The sampling

technique used in resource assessment is supported by van der Hoven's work, which

concludes that minimum dispersion occurs between 0.1 and 2hours mean time. International

standards for wind turbine power characterization are also based on this work.

Here we analyze the influence of using different mean times over data dispersion

and wind resource assessment and analyze an adequate mean time for small wind

turbine (SWT) applications that contributes to the development of reliable resource

assessments. We found a maximum dispersion around 1minute mean time. The stable

wind conditions region was not found in the dispersion analysis presented here.

Using this time in SWT resource assessment will detect the largest amount of changes

in the time series that may contribute to power production. Resource assessments

calculated show that using 1 and 10minutes as mean times generates power resource

assessments with a difference around 17%, which may be a factor that prevents

SWT penetration. There exist at least two factors to obtain reliable power resource

assessment, the SWT selection and ensemble mean time.

The accurate assessment of wind turbine output power is crucial in the

process of sizing wind farms. Typically, this assessment is based on the manufacturer’s

characteristic power curve, which relates wind speed to power output. However,

the manufacturer’s power curve is often an idealized representation that may not

accurately reflect the actual power output of the turbine under real-world conditions.

To address this limitation, various techniques have been employed to develop more

precise power curves, including curve fitting, artificial intelligence, probabilistic

models, and Gaussian processes. This paper introduces a novel method for modeling

the power curve that takes into account the specific conditions at the wind turbine’s

location. The method involves transforming wind speed data into a graph that resembles

the phase space commonly used in statistical mechanics. By applying the k-means

algorithm to this phase space, clusters of wind speeds can be identified. Furthermore,

the corresponding clusters of wind turbine output power can be determined based

on the identified wind speed clusters. These clusters of power data provide valuable

information for constructing a more accurate power curve using an adjustment function.

By utilizing this method, the authorss demonstrate a significant improvement in

the accuracy of power output estimation compared to relying solely on the manufacturer’s

power curve. The proposed approach considers the unique characteristics of the

wind speed data and incorporates them into the modeling process, resulting in

a more reliable representation of the turbine’s power output. This advancement

represents a significant step forward in optimizing the sizing of wind farms and

ensuring their efficient operation.

In the fundamental stage of resource assessment, high-quality wind speed

measurements are required to estimate power production. However, this high-quality

data is not always available, and therefore the analysis of alternative sources

becomes essential. In this work, we analyze the ability of MERRA-2 to represent

wind speed characteristics at 24 anemometric stations in Mexico. The assessment

was carried out using the Pearson correlation coefficient between the observed

time series, and the obtained by interpolating bias-corrected reanalysis-estimated

wind speed to all locations for different time-averaging periods. Results showed

that the reanalysis' performance is not uniform throughout the country; it depends

on the time resolution, local orographic conditions, and the relationship between

the local flow and the large-scale circulation. Based on these results, the country

was subdivided into eight regions. The best-represented region was the Chivela

Pass, where the winds are tightly linked to the interaction between the large-scale

circulation and the local orography. The worst performing regions were located

where the land sea-mask and orography at the reanalysis' resolution may not be

accurate enough to reproduce the station's wind speeds. Reanalysis-estimated capacity

factors exhibit large interannual variability in some stations, which can have

significant consequences for the operation of individual wind farms and the power

grid. The results show that, while caution should be exercised when applying reanalyses

to wind resource assessment in Mexico, reanalysis wind power estimates can be

a valuable tool to investigate the feasibility and installed capacity requirements

for Mexico to meet its renewable energy targets.

Mexico's national electric grid comprises ten regional systems, with one

isolated in the south of the Baja California Peninsula. In addition, providing

electricity access remains a challenge in the country. Therefore, distributed

renewable energy solutions are relevant to satisfy the electricity demand and

promote grid development. Distributed renewable energy access (DREA) based on

a wind energy conversion system integrated into low-voltage direct current (LVDC)

networks is presented. The DREA is analysed and simulated under wind speed conditions

measured and recorded for one year at Baja California Sur. A representative variability

is applied to five type-4 wind turbines based on wind speed turbulence intensity

analysis. The generated power is transferred through a bidirectional dual active

bridge converter, controlled by a novel small-signal model using a single closed-loop

proportional-integral control, owing to its modularity, power density, and ability

to transfer power from LVDC to high-voltage direct current. The effectiveness

and robustness of the proposed DREA are assessed via a complete mathematical model,

corroborated by the simulation results in MATLAB-Simulink®, and validated by experimental

results using the real-time simulator Opal-RT Technologies® and laboratory prototyping.

The results indicate a DC-link voltage compensation and integration of a power

capacity of 150 kW in the LVDC networks with an efficiency of 94%.

The climate crisis has led to an increased interest in renewable energy,

and in wind energy in particular. Wind farms with the largest generating potential

are generally located offshore. In this study we consider the case of Mexico,

a sub-tropical country in North-America. Due to Mexico's location, offshore wind

farms (OWF) would be at risk of damage from strong winds associated with tropical

cyclones (TCs) in both the Pacific and the Gulf of Mexico basins. Thus, here we

ask whether there are any regions in Mexico combining a high generating potential

and a low risk from tropical cyclones. To answer this question, the ERA5 reanalysis

has been used to identify two sites on the Pacific coast and two sites in the

Gulf of Mexico with high wind power potential. Then, using the ERA5 reanalysis

and TC best-track observational data, the potential effects of four major hurricanes

and the climatological hazard posed by TC-related damaging winds on OWFs at those

sites have been investigated. The return period for TCs with near-surface winds

exceeding 50m s−1, a threshold associated with increased structural damage likelihood,

has been estimated at as low as 8 years for the Gulf of Mexico and above 64 years

for Pacific coast. Therefore, in terms of the magnitude of the TC-related hazard,

the Pacific coast sites are found to be preferred as locations for the development

of OWFs. These results are relevant for any planning of offshore wind energy in

Mexico, and the methodology applicable to any other sub-tropical region in which

the risk of tropical cyclones is present.

The characterization of wind speed and its variability at a site is important

for wind resource assessment. The most readily available wind measurements are

at 10 m above ground level. These measurements can then be extrapolated vertically

to estimate wind power production. In this work, the Monin–Obukhov similarity

method was implemented to estimate the wind speed vertical profile within the

surface boundary layer for a southeast Mexican site, considering seasonal and

diurnal variations of the surface boundary layer stability parameters. Additionally,

a power-law method was implemented where the wind shear exponent was set following

the International Electrotechnical Commission (IEC) standard and using a variable

wind shear exponent. The results showed that the log-law and the variable wind

shear method produce better estimates than the IEC standard. The mean power production

was estimated at hub height (80 m above surface level) using anemometric data

from the Mexican Wind Atlas and then compared with that calculated using the equivalent

wind speed estimated from variable wind shear exponent and log-law model. No influence

of the vertical wind speed variation within and on top (up to 117.5 m) of the

surface boundary layer was found on the mean power production for a wind turbine

with a diameter of 90 m and a hub height of 80 m.

Based on the Van der Hoven’s seminal work, wind power industry has adopted

the 10 min mean time as the proper sampling to estimate resource assessment. However,

research within the literature questions the generalization of the 10 min as a

standard measure of minima dispersion due to the particular geographic characteristics

where the measurements took place. In this work is analyzed the power spectrum

of a high-frequency wind speed time series and its influence over the resource

assessment in the region of La Ventosa, Oaxaca, Mexico. Power spectrum analysis

from a monthly, seasonal, and annual time series results show a defined synoptic-scale,

diurnal, and semi-diurnal variations, which changes in amplitude throughout the

year. To study the influence of power spectrum in wind resource assessment were

estimated and compared the capacity factors of a typical 2 MW wind turbine against

measured wind speed with 1, 5, 10, 60, and 360 min mean times, we found that a

maximum difference of 1.4 % . Resource assessment was also estimated using reanalysis

data and WRF results, finding similar to high-resolution estimations, highlighting

bias-corrected WRF performance, offering reliable results to model power performance

after a statistical correction.

Wind speed turbulence intensity is a crucial parameter in designing the

structure of wind turbines. The IEC61400 considers the Normal Turbulence Model

(NTM) as a reference for fatigue load calculations for small and large wind turbines.

La Ventosa is a relevant region for the development of the wind power sector in

Mexico. However, in the literature, there are no studies on this important parameter

in this zone. Therefore, we present an analysis of the turbulence intensity to

improve the understanding of local winds and contribute to the development of

reliable technical solutions. In this work, we experimentally estimate the turbulence

intensity of the region and the wind shear exponent in terms of atmospheric stability

to analyze the relation of these design parameters with the recommended standard

for large and small wind turbines. The results showed that the atmosphere is strongly

convective and stable in most of the eleven months studied. The turbulence intensity

analysis showed that for a range of wind speeds between 2 and 24 m/s, some values

of the variable measured were greater than those recommended by the standard,

which corresponds to 388 hours of turbulence intensity being underestimated. This

may lead to fatigue loads and cause structural damage to the technologies installed

in the zone if they were not designed to operate in these wind speed conditions.

Understanding near-surface wind variability is crucial to support wind

power penetration on national electrical grids. High-resolution numerical simulations

are often proposed as the best solution to study the fluctuation of wind resources.

We compare Weather Research and Forecasting (WRF) and Modern-Era Retrospective

Analysis for Research and Applications version 2 (MERRA-2) bias-corrected wind

speeds at hub height at different spatial resolutions and transform them to wind

power production using a logistic power curve fitted to wind power measurements;

the comparisons are based on error statistics and time series spectral analysis.

The results show that numerical models reproduce observed wind speeds with correlations

higher than 0.9 for WRF and 0.8 for MERRA-2. Moreover, annual observed wind power

is reproduced with a maximum difference from observations of 0.011. However, each

resolution reproduces the magnitudes of high-resolution periodicities differently

so that there is a clear relationship between grid size and signal variance at

high frequencies, as variance is indirectly proportional to frequency. This relationship

is expected for wind speed, but based on results, it can be associated also for

capacity factor sampled at hopublished\_urly intervals. Therefore, the main benefit of high

spatial resolution lies in the added variance in frequencies at sub-daily time

scales. The study of the added value of high-resolution simulations in this region

contributes to current efforts to develop reliable forecasting tools and strategies

to support the development of wind power as a reliable energy source.

Given the increasing integration of wind-based generation systems into

the electric grid, efforts have been made to deal with the problem of power quality

associated with the intermittent nature of these systems. This paper presents

a new modelling approach oriented towards harmonic distortion analysis of the

induction machine for wind power applications. The model is developed using companion

harmonic circuit modelling, which is a natural approach for analysis of the adverse

effects of harmonic distortion in electric power systems, and represents an easier

solution method than the well known dynamic harmonic domain, since it solves algebraic

equations instead of state-space differential equations. The structure of the

companion circuits simplifies both the formulation and solution for power systems

with wind-based generation systems. This approach is especially useful for analysis

of the harmonic interaction in transient and steady states between the wind power

generator and the power system, whose interconnection is made through electronic

converters. The proposed model allows us to compute the dynamics of the wind turbine,

which are influenced by disturbances such as changes in the wind velocity, voltage

fluctuations, electric waveform distortion, and mechanical vibrations, among other

factors. Moreover, the cross-coupling between harmonic components at different

frequencies is considered. The proposed model represents an integral framework

of the electrical and mechanical subsystems of a wind turbine, allowing for analysis

of the interactions between them, and understanding power quality degradation

behaviour as well as causes and consequences, while also giving useful information

on the field of simulation and control. To test the performance of the proposed

model, a test power system is used to obtain the behaviour of a wind turbine induction

generator in response to typical power quality disturbances, i.e., harmonic distortion,

and voltage sags and swells. Then, the dynamics of the variables considering their

harmonic interactions are analysed.

Mexico is an attractive candidate for offshore wind energy development

due to its geographical location with extensive coasts in the Pacific Ocean and

Mexico''s Gulf. Although potential offshore wind areas have been geographically

assessed, an evaluation of the seasonal variations of the capacity factors has

not been considered for the feasibility of the locations. This research identifies

potential zones for offshore wind development in the Gulf of Mexico, implementing

geographical restrictions such as the Economic Exclusive Zone, distance from the

coast, protected areas, bathymetry, and capacity factor seasonality. Wind speeds

were obtained from 39 years of reanalyses historical data and two reference wind

turbines of 5 and 10 MW were included in the analysis. Three potential areas were

identified from the results: the northeast Tamaulipas, the western Campeche, and

the northern Yucatan. Monthly mean capacity factors above 45% were estimated from

October to June, with the maximum values near 60% between March and April. Conversely,

minimum values were observed from July to September but consistently higher than

30%. The analyzed zones show suitable technical conditions for offshore wind development.

Further analysis is needed to validate the wind speed conditions, in addition

to the evaluation of economic factors, the study of extreme weather conditions

like tropical cyclones as well as characteristics in the intertropical region.

Solar and wind time variability may be mitigated by complementing each other, providing firm power to the national grid at local and regional scales. The field commonly utilizes reanalysis data; however, it is crucial to conduct bias analysis and validation to enhance reliability. Mexico’s vast geography and resource potential demand a comprehensive study to validate the accuracy of modeling critical meteorological variables in power estimations. This study explored wind and solar resources' local and regional complementarity using experimental and ERA5 data. A bias-correction method was used to identify bias effects on power estimations and the reliability of long-term capacity factor analysis. Spearman’s coefficient was used as the complementarity index. The results show that the capacity factor of wind turbines is affected by bias-correction methods compared to that of photovoltaics. Spearman’s coefficient, in general, is robust over bias-correction. The Yucatan Peninsula displays significant potential throughout the year, Spearman -0.6, for combining offshore wind farms with onshore photovoltaics. During summer, the north-central, northeast regions and the Baja California Peninsula offer significant potential for combining wind and solar energy, -0.6 and -0.5 values, respectively. Incorporating renewable energy requires further analysis of local integration and technical limitations to create sustainable long-term solutions.