Importance Ranking for Revenue of A Wind Farm Case Study: Spain

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***Abstract*—Gaining profits from a wind turbine is a complex and multi-variable dependent process. Well-known parameters such as wind speed, electricity market price, wind turbine health status, production efficiency and regional renewable energy policies might be deemed the main influential factors for generating revenue. Although they all contain a significant level of unpredictability due to limitations of observation and measurement, it is still possible to track their impulses with response of the revenue. In this study, the authors rank the importance of the parameters given above in respect to revenue. The Rminer package has been used to perform the importance ranking analysis.**

I. Introduction

Renewable energy, in this case wind energy, is an accepted solution for serious global issues that include environmental problems. However, we should be aware of that this is still a business and in order to be sustainable, the wind energy investment must be a profitable option. The traceable variables for wind energy are electricity market price (dependent on fossil fuel prices, regulations, consumer behavior and demand-supply counterbalance), wind speed (mainly characterized by intermittency and lack of predictability), technology (turbine type, health status, age of wind turbine, reliability, down-time frequency and power curve) and policy changes(subsidy schemes, taxes etc.). As a business, wind energy is highly dependent on these parameters as can be seen in detail in the next paragraphs.

- Electricity Market Price:
  - Petroleum prices: Wind energy must compete with conventional energy sources which are highly dependent on fossil fuel prices, that these have decreased significantly in recent years. Even though fossil fuel prices had started to increase slowly by the beginning of 2016, the crude oil prices dropped by 75%, with most of the decrease from the drop in the price of oil. The globally decreasing economic growth rates, price competition between fossil fuel producer countries and shale gas [1] can be counted among the reasons for the (large) decrease [14].
  - Renewable energy: The weather and the season are the main parameters for renewable energy production, as an example, hydro-power has a serious impact on electricity market prices in spring season. Its share increases on energy supply due to high precipitation amount and snow-melt[3].
  - Consumer Behavior: The main parameter for the determination of demand is the consumer behavior, which varies by time and date.
- Policy: The 2020 national target for Spain has been set so that renewable resources will cover 20 % of total energy consumption [4]. In 2012, the share of renewable energy in the gross final energy consumption was 14.3%. In 2013 it increased to 15.3% and in 2014, it reached 16.2% [10]. According to The Spanish Wind Energy Agency (AEE) Statistics, wind energy is ranked as the third source for the generation of electrical energy despite the stagnation in the increase of installed capacity in 2015 [9]. Subsidy scheme was changed many times and premium for wind energy is stopped, tariff deficit became one of the serious issues of wind energy sector.[2],[7]
- Technology: Wind turbines suffer from harsh environmental conditions. Wind blows (with the greatest force) on top of mountains or in the middle of the desert, so that wind farms in cold climates are frequently inaccessible during winter, and the technology to mitigate the effects of snow, ice, sand, and storms is expensive. Due to Spain statistics, the majority of wind turbines in operation consist of turbines older than 15 years, with 66% being over this age in 2014. Only 4% of wind turbines in operation had been in use for less than ten years in 2014 [7]. It is good to remind that ten years age refers to early wear out phase of wind turbine in bathtub curve concept[13],[11]. Expensive component changes are mandatory due to decreased reliability.
- Wind Speed: Wind is the primary parameter which regulates production as intermittent and unpredictable component.

The parameters above are investigated to define their relative importance to revenue. This analysis is helpful for decision making mechanisms and priority selection for the management of wind farm asset. It can also help to determine an appropriate budget for Operation and Maintenance(O&M) costs, and if it is necessary, to implement a hedging strategy for producing electricity.

II. Approach and Methods

Supervisory Control And Data Acquisition (SCADA) based event logbooks, wind speed, wind power measurements, wind power estimations(based on theoretical power curve), hourly electricity market price values, which are taken from Mercado Iberico de la Electricidad(OMIE:Iberian electricity market for Spain and Portugal) and the subsidy (after publishing of RD-L 2/2013 [7][8]) are used as the input parameters. Input data are prepared as one data frame with ten minutes time steps from 01.01.2013 to 31.12.2015. The variables included are described below.

1. Downtime and theoretical energy are the explanatory variables for technology.
2. Subsidy, which represents amount of support due to tariff scheme of government, is the policy based parameter.
3. Electricity market price and wind speed(in cubic form due its effect on produced power) are used directly.
4. Produced energy is the hybrid parameter which stands for technology, management decisions and wind speed.
5. Final parameter is the revenue, which is the product of electricity price(with subsidy vs without subsidy) and the produced energy .

Importance ranking is done based on the Rminer package importance function [5]. A Fit model using principal component analysis regression and importance ranking is performed within a 1 dimensional sensitivity analysis frame with measure of average absolute deviation around median (AAD) [5],[6],[15],[12]. More details about the followed methodology will be provided in the full paper.

Changes in regulation provided two different scenarios for the study. One with the electricity prices under subsidy scheme and the other without subsidy.

III. Main Body of the Abstract and Preliminary Description of the Results

The numerical results obtained in the analyses are presented in figure 1 and table I. Power component represents produced energy (MWh) and Powerteo (MWh) stands for estimated energy based on theoretical power curve. WS is the measured wind speed (m/s), Market_ price stands for electricity market price (Euro/MWh), Subsidy is the government support to cover difference between market price and fixed premium (same units than Market_ price variable). Downtime is taken into account as factors with a label for failure, production loss and efficient production.

The results show that subsidy decreases the effect of the wind speed and increases the will (the operation strategy to balance O&M costs) for higher power production amounts. In the case where there is no subsidy, the technological parameters (specifically downtime and theoretical power curve) increase in importance, while the revenue suffers more from wind speed and market price fluctuations. WS appears to be disconnected from produced power but this can be due to the fact that the study focused on the revenue with the regulation change. Moreover, the more relevant change, from one scenario to the other, is seen in the market price.

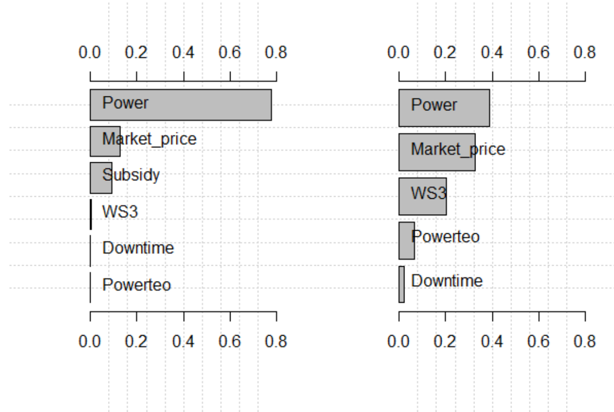

Fig. 1. Variable importance ranked by a 1-D sensitivity analysis under ADD measure: revenue under subsidy scheme (left) and without subsidy scheme (right).

TABLE I
Importance Indicators of Variables (Relative Variable Importance)

Parameter	Revenue with subsidy	Revenue without subsidy
WS3	0.24%	20.07%
Power	77.80%	38.82%
PowerTeo	.02%	6.72%
Subsidy	9.18%	-
Market Price	12.74%	32.47%
Downtime	0.02%	1.93%

IV. Conclusion

The direct effects of Spain's wind energy policy change is analyzed with a real case study on revenues. Under a fixed subsidy scheme, maximum production is the key parameter and wind speed is the less effective parameter. After the scheme change, cheap production and beneficial selling time gained more importance as a key parameter, electricity price has increased its importance level in terms as a component of revenue. Some of the reasons of stagnation on investments for wind energy in Spain were the frequent regulation updates and a non-favorable subsidy scheme. This study proves that, this situation is not only a problem for new investments but also for wind farms in operation. Firstly under an unstable subsidy scheme it is hard to make profit projections, secondly this situation causes a requirement for a mind set change and flexibility in terms of O&M decisions and asset management.

V. Learning Objectives

- The wind energy sector requires stable and encouraging support schemes.
- The benchmarking among different effective parameters is a useful tool for decision making and analyze of current situation.
- Big data analysis and free-ware numerical tools, which are developed by academia(such as R), are the time efficient for applied sciences and the wind industry.

ACKNOWLEDGMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 642108. The authors would like to acknowledge the data support and expert opinion given by Compañía Eólica de Tierras Altas(CETASA) for the duration of this study.

REFERENCES

[1] U.S. Energy Information Administration. Natural gas/data/shale gas production. https://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm, 2016. [Online; accessed April-2016].

[2] International Energy Agency. Spain statistics. http://www.iea.org/policiesandmeasures/renewableenergy/?country=Spain, 2016. [Online; accessed April-2016].

[3] Juan-Carlos Ciscar and Paul Dowling. Integrated assessment of climate impacts and adaptation in the energy sector. *Energy Economics*, 46:531–538, 2014.

[4] European Comission. Progress towards 2020 targets. http://ec.europa.eu/europe2020/europe-2020-in-your-country/espana/progress-towards-2020-targets/index_en.htm, 2016. [Online; accessed April-2016].

[5] Paulo Cortez. Data Mining Classification and Regression Method. http://cran.r-project.org/package=rminer, 2016. [Online; accessed April-2016].

[6] Paulo Cortez and Mark J Embrechts. Using sensitivity analysis and visualization techniques to open black box data mining models. *Information Sciences*, 225:1–17, 2013.

[7] Asociación Empresarial Eólica. Eólica 14. toda la información del año 2014 que necesitas conocer sobre el sector. http://www.aeeolica.org/uploads/ANUARIO_2014-web_FINAL.pdf, 2014. [Online; accessed April-2016].

[8] Asociación Empresarial Eólica. Eólica 15. toda la información del año 2015 que necesitas conocer sobre el sector. http://www.aeeolica.org/uploads/AEE__ANUARIO_2015_web.pdf, 2015. [Online; accessed April-2016].

[9] Asociación Empresarial Eólica. Installed power. http://www.aeeolica.org/en/about-wind-energy/wind-energy-in-spain/installed-power/, 2016. [Online; accessed April-2016].

[10] Eurostat. Share of energy from renewable sources. http://appsso.eurostat.ec.europa.eu/nui/show.do, 2016. [Online; accessed April-2016].

[11] Roger R Hill, Jennifer A Stinebaugh, Daniel Briand, AS Benjamin, and James Linsday. Wind turbine reliability: A database and analysis approach. *Sandia National Laboratories, Albuquerque, New Mexico*, 87185, 2008.

[12] Ian Jolliffe. *Principal component analysis*. Wiley Online Library, 2002.

[13] JK Kaldellis. An integrated time-depending feasibility analysis model of wind energy applications in greece. *Energy Policy*, 30(4):267–280, 2002.

[14] Nasdaq Stock Market. Crude Oil. http://www.nasdaq.com/markets/crude-oil.aspx?timeframe=10y, 2016. [Online; accessed April-2016].

[15] Chiu David Chiu Yu-Wei. *Machine learning with R cookbook*. Packt Publishing Ltd, 2015.