Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 10, pp.23218-23224, October, 2018

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

EVALUATION THE WIND TURBINES FARM IN THE TOWN OF TAFILA / JORDAN

[1,*]Hani A. AL-Rawashdeh, [1,2]Ahmad O. Hasan and [3]Riad A. Ahmad

[1]Department of Mechanical Engineering, Al-Hussein Bin Talal University, Maan P.O. Box 20, Jordan
[2]School of Mechanical Engineering, University of Birmingham, Birmingham B15 2TT, UK
[3]Department of Mechanical Engineering, Al-Hussein Bin Talal University, Maan P.O.Box20, Jordan

ARTICLE INFO

Article History:
Received 21st July, 2018
Received in revised form
29th August, 2018
Accepted 17th September, 2018
Published online 29th October, 2018

Key Words:
Vestas, WindTurbines
Farm, Tafila, Benefit Cost Ratio,
Present Worth.

ABSTRACT

Tafila wind turbines farm is the largest project of wind energy to generate the electricity in Jordan until now. The major Tafilawind turbines farm (38 wind turbines) presents a 117-Mega Watt (3.075 MW/ Turbine) wind turbine power. Total design/build phase of the project is 21 months and the operations phase is 20 years, the total cost of the project is 290 million $ with100% funded through private investment which produce about4 % of the national electricity demand each year that is enough electricity to power 85,000 homes. The main objectives of this project is to reduce energy import dependency, reinforce reliability of supply and achieve energy security, contribute to Jordan's national strategy for energy as well as to regional targets in the field of clean energy (better to the environment) and reduce greenhouse gas emissions. This paper is to evaluate the Tafila wind turbines farm in terms of financial analysis.

Citation: Hani A. AL-Rawashdeh, Ahmad O. Hasan and Riad A. Ahmad, 2018. "Evaluation the Wind Turbines Farm in the Town of Tafila / Jordan", *International Journal of Development Research*, 8, (10), 23218-23224.

INTRODUCTION

Energy is a vital input in all sectors of any country's economy (Singh and Parida, 2013). Until late 1980s, energy has been generated largely by burning coal, hydrocarbon oil and natural gas leading to huge carbon emissions (Sangroya, and Nayak, 2015). Wind energy is clean and fuel free (Srinivasan *et al.*, 2017). Wind power has experienced a rapid growth in the world since the 1990s due to the limited quantity of fossil fuel resources (Eminoglu. and Ayasun, 2014). The first use of a windmill to generate electricity was by Charles F. Brush in Cleveland, Ohio in 1888. (AIMU, 2012). Vestas Company manufactures the wind turbines of this project. Vestas is the energy industry's global partner on wind power solutions. They design, manufacture, install, and service wind turbines across the globe, and with 78 GW of wind turbines in 75 countries, they have installed more wind power than anyone else. Through there industry-leading smart data capabilities and unparalleled 68 GW of wind turbines under service, they use data to interpret, forecast, and exploit wind resources and deliver best-in-class wind power solutions.

Corresponding author: **Hani A. AL-Rawashdeh,**
Department of Mechanical Engineering, Al-Hussein Bin Talal University, Maan P.O. Box 20, Jordan.

Together with our customers, Vestas more than 21,900 employees are bringing the world sustainable energy solutions to power a bright future. (www.vestas.com) Vestas V112-3.0 MW turbine designed for low and medium wind speed sites, the V112-3.0 MW turbine delivers a highly competitive cost of energy. The turbine delivers high productivity due to its large swept area, higher rotor efficiency and better serviceability and reliability, which in turn improve availability. (www.vestas.se/ Brochure V112-3.0 MW). Vestas V112-3.0 MW design a pitch regulated upwind, horizontal-axis wind turbine (HAWT) with three bladed rotor, pitch regulated with variable speed, operating at near-fixed rotational speed. However direct drive turbines with variable speed generator designs have a significant market share. Vestas V112-3.0 MW turbine has a rotor diameter of 112 m and a rated output power of 3.075 MW for each turbine. Wind turbines will typically start generating electricity at a wind speed of 3 m/s (10.8 Km/h), reach maximum power at 13 m/s (46.8 km/h). (www.vestas.se/ Brochure V112-3.0 MW)

The mainparts of a horizontal axis wind turbine are shown in Figure (3) (Svensson, 2010)

- Foundation
- Tower

- Nacelle
- Rotor blades
- Hub
- Transformer

The power generation capacity of wind turbines has increased significantly over the years with the use of taller towers. (Shrestha, 2015).

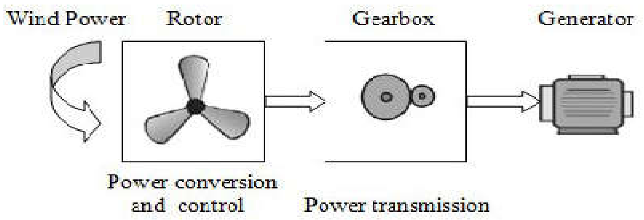

Figure 1. Mechanical components of wind turbine (Sarkar and Behera, 2012)

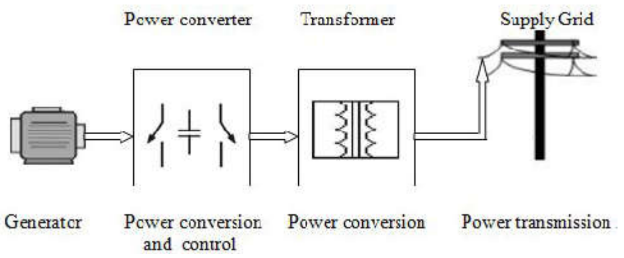

Figure 2. Electrical components of wind turbine (Sarkar and Behera, 2012)

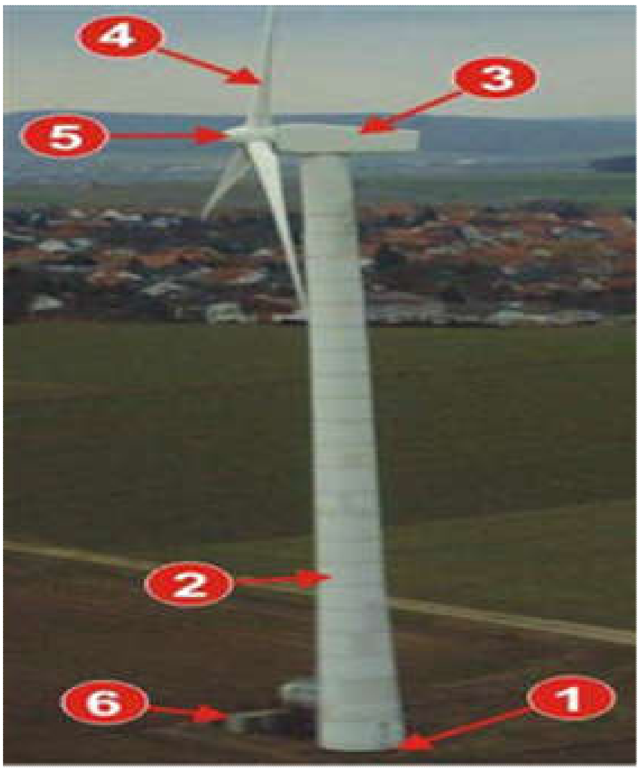

Figure 3. Horizontal axis wind turbine (HAWT)

Wind Energy in Jordan

Wind energy is available over parts of Jordan at low to moderate rate suitable for water pumping, while there are few regions having an excellent wind power suitable for power generation. Wind energy in Jordan used mainly for electricity generation and water pumping. In Jordan, more than 12 demonstration projects totaling 1620 kW of wind turbines were implemented, tested and evaluated for water pumping and electricity generation, where the use of wind turbines for pumping water is acceptable to people in remote areas. For electricity generation, there are two wind farms connected to the electricity grid in the Northern part of the country; one with a capacity of 320 kW in Al-Ibrahimy a, consisting of 4wind turbines of 80 kW each. The other has a capacity of 1125 kW in Hofa, consisting of 5 wind turbines of 225KW each (Al-Nhoud and Al-Smairan, 2015). In addition, Tafila wind turbine farm with 117 MW (3.075 MW/ turbine) and Ma'an wind power project with 80 MW (2 MW/ turbine).

Site characteristics

The selected location for the project is Tafila as shown in Figure (4), which is located in the south with the coordinates30.76160^o N, 35.69096^{o}E, and location elevation is 1400 m above sea level, which guarantees high wind speeds, where there are vast available and level areas suitable for the project implementation. (El-Tous *et al.,* 2012) as shown in Figure (5) the highest average wind speed in Jordan is in Tafila location with a value of (8.54 m/s). Figure (6) shows monthly average values of wind speed in Tafila for the year (2010). From the previous data it is clear that Tafila is the best choice for the implementation of the wind farm power.

Specification of the (Tafila wind turbines farm) Vestas V112-3.0 MW turbine.

The whole parts of horizontal axis wind turbine (HAWT) such as the turbine used by Vestas Company are shown in figure (8).

Tafila wind turbines farm cost analysis: There are many factors influencing cost structure, which classified into the following major categories: Figure (11)

- External factors: such as cost of materials, weather conditions, regulations, licensing procedures, site characteristics, steel prices and inflation.
- Internal factors: such as cost of labors, production methods, learning curves, innovation, standardization and scalability. (Blanco, 2009)
- The capital costs of a Tafilawind turbines farm is (290,000,000 $) which classified into the following majorcategories: Figure (12)
- The turbine cost: including rotor, blades, gearbox, tower and transformer; (wind turbines cost is 64% =185,600,000 $).
- Civil works: including construction costs for site preparation and the foundations for the towers; (foundations cost is 16 % = 46,400,000 $).
- Grid connection costs: This can include transformers and subs stations, as well as the connection to the local distribution or transmission network; (Grid connection costs is 11 %= 31,900,000 $).
- Other capital costs: these can include the construction of buildings, control systems, project consultancy costs, etc. (Planning & Miscellaneous cost is 9 % = 26,100,000 $).

The annual operations and maintenance cost of a Tafila wind turbines farm is (4,800,000 $) which classified into the following major categories: figure (13)

- Service and spare parts: (26 % = 1,248,000 $)
- Administration: (21 % = 1,008,000$)
- Land rent: (18 % = 864,000$)
- Miscellaneous: (17 % = 816,000$)
- Insurance: (13 % = 624,000 $)
- Power from the grid: (5 % = 240,000 $)

Calculation

- The capital costs of a Tafila wind turbines farm is (290,000,000 $)
- The annual operations and maintenance cost of a Tafila wind turbines farm is (4,800,000 $)
- The production of the Tafila wind turbines farm is 117 MWh*1000 = 117,000 KWh
- The total production of the Tafila wind turbines farm per year is 400 GWh

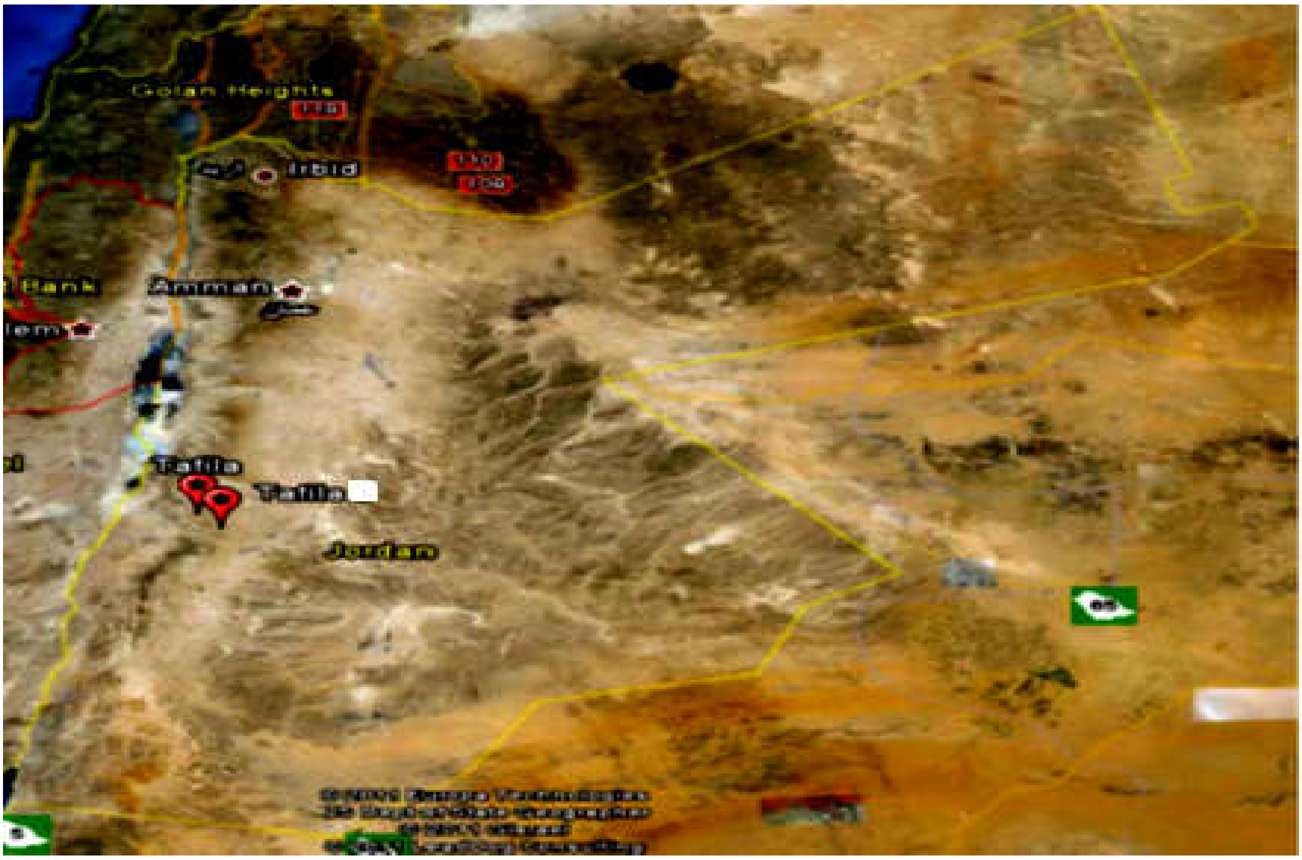

Figure 4. Location of Tafila in Jordan (El-Tous et al., 2012)

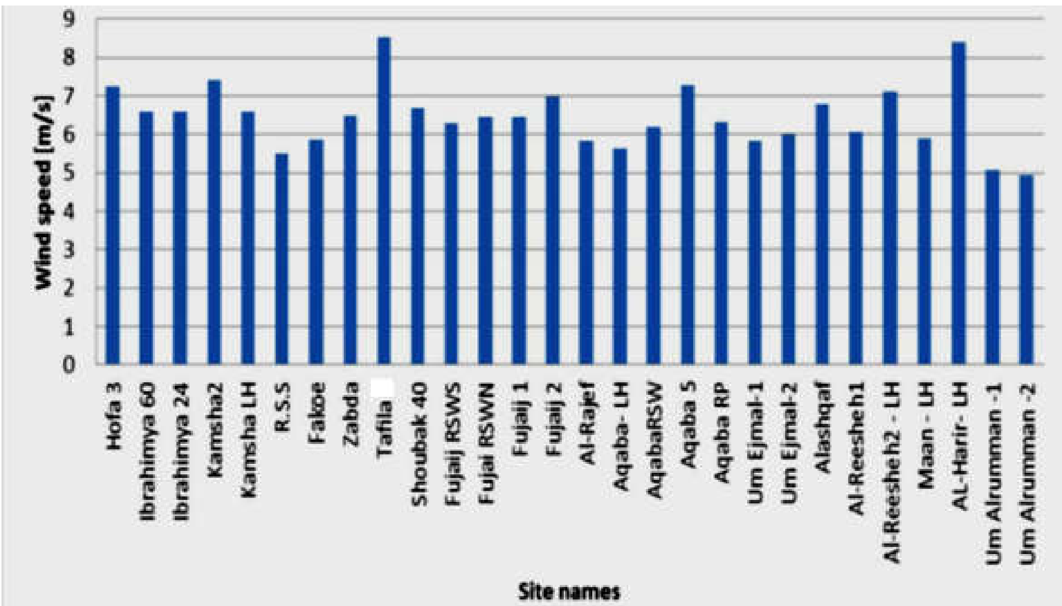

Figure 5. Average wind speed comparison for different locations in 12 months (2010) in Jordan(El-Tous *et al.*, 2012)

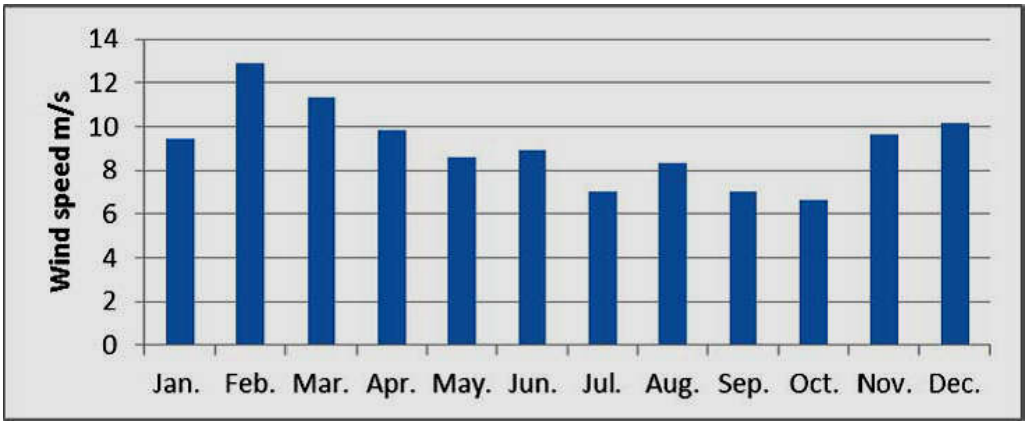

Figure 6. Monthly average values of wind speed in Tafila for the year 2010 (El-Tous *et al*., 2012)

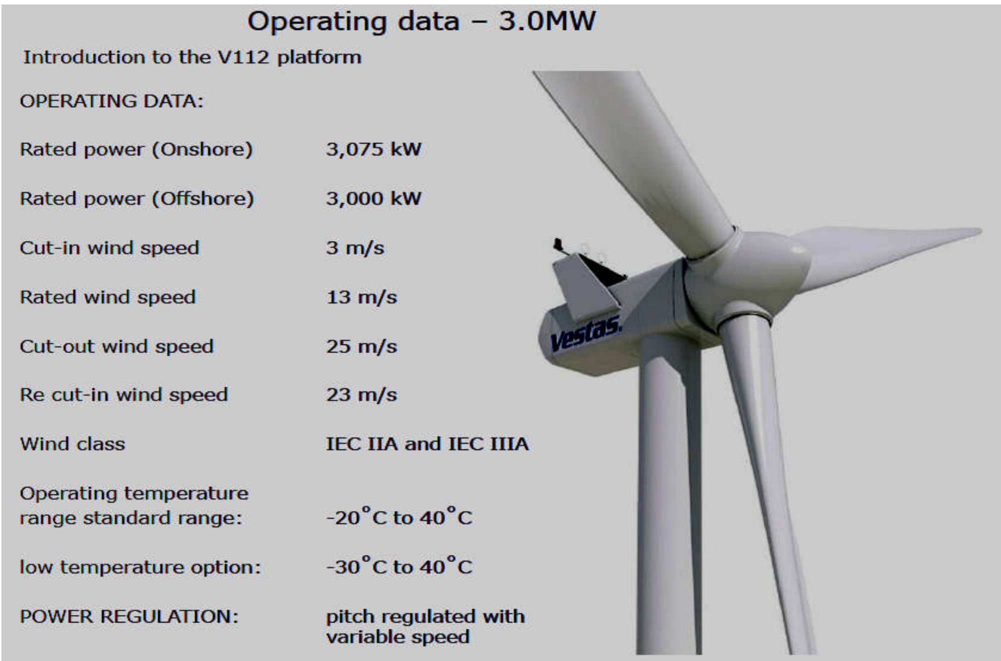

Figure 7. Vestas V112-3.0 MW Platform (www.vestas.se/Brochure V112-3.0 MW)

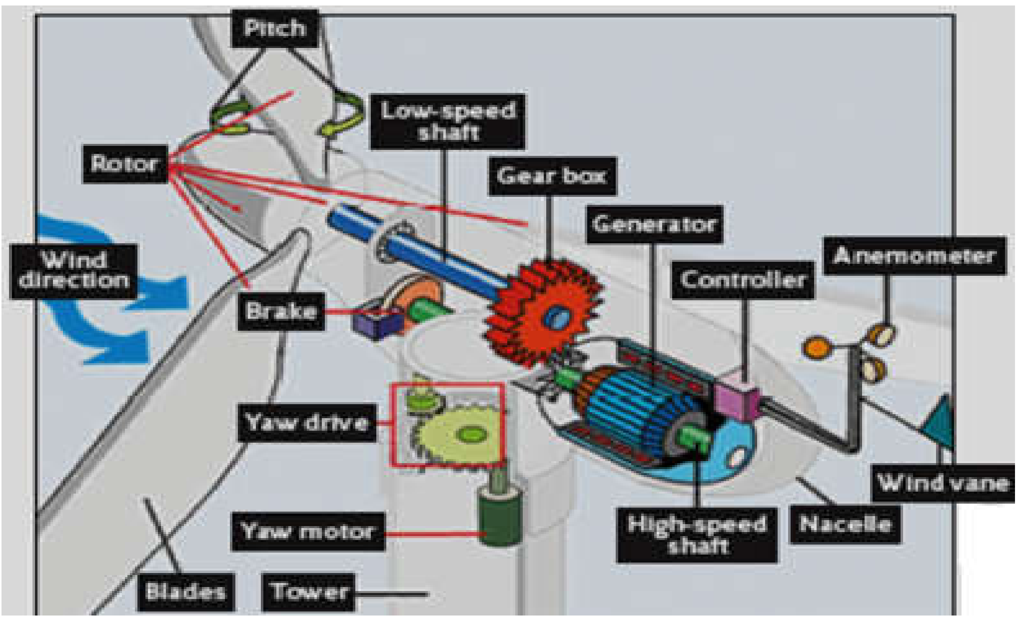

Figure 8. The parts of horizontal axis wind turbine

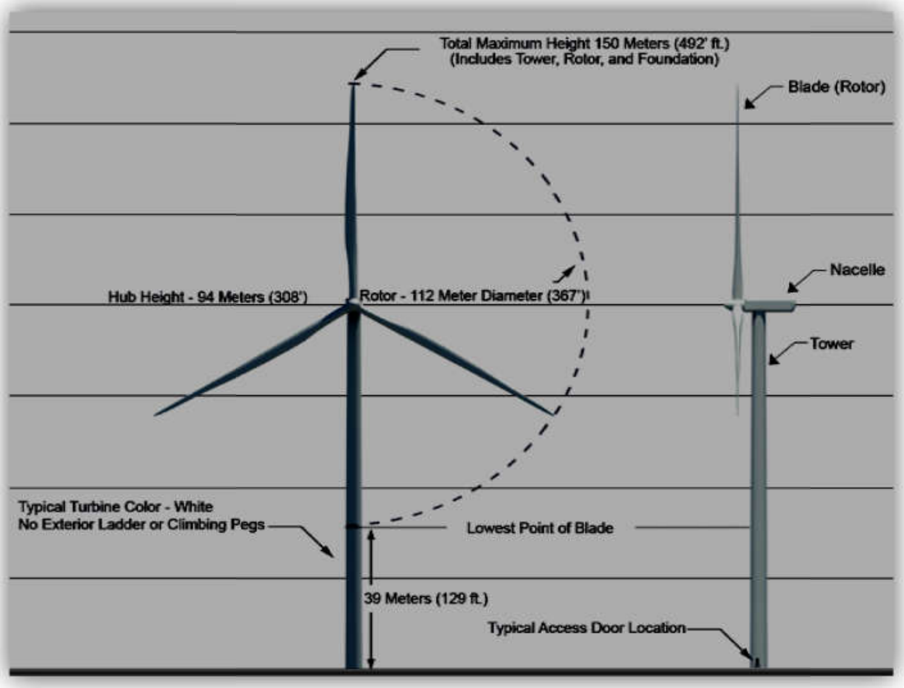

Figure 9. Vestas V112-3.0 MW tower and rotor (www.vestas.se/Brochure V112-3.0 MW)

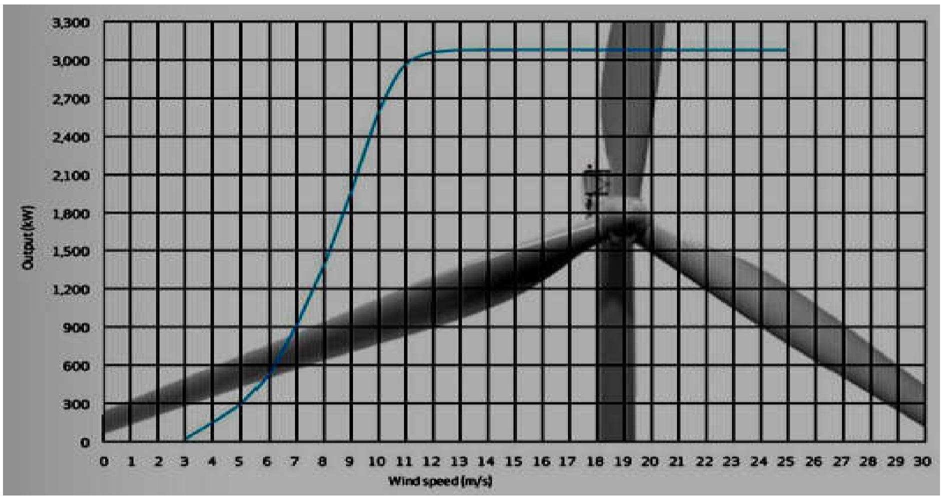

Figure 10. Power curve for V112-3.0 MW (www.vestas.se/Brochure V112-3.0 MW)

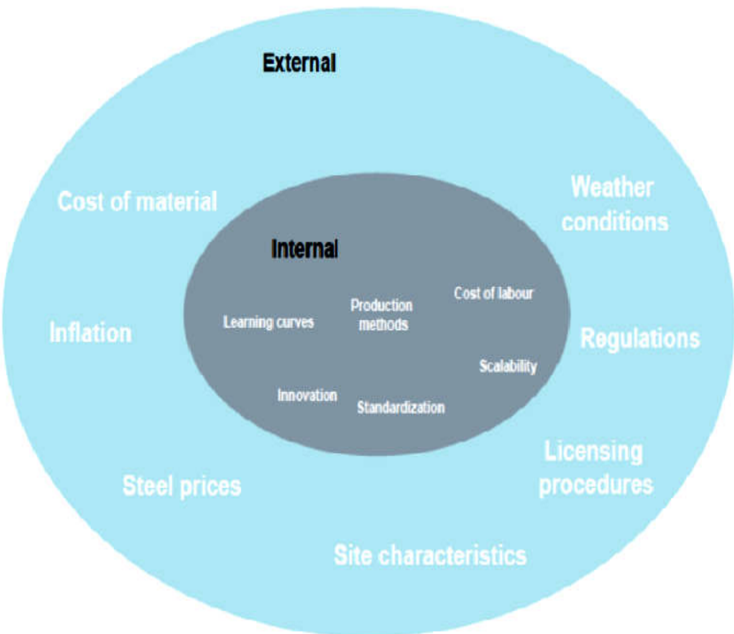

Figure 11. Factors influencing cost structure of the wind farms (Blanco, 2009)

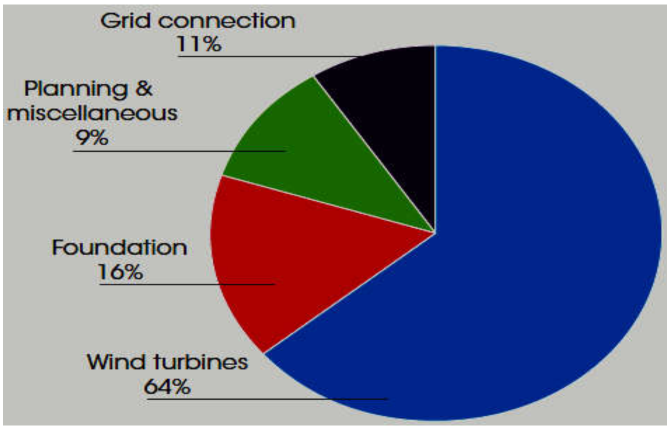

Figure 12. Capital cost a typical onshore wind power system and turbine (Blanco, 2009)

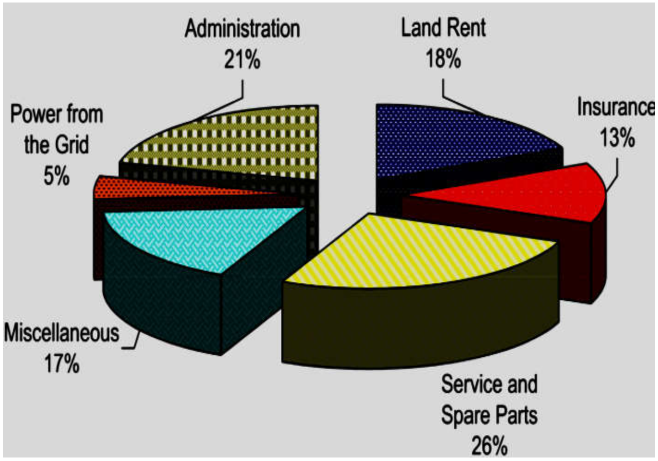

Figure 13. Typical distribution of onshore wind turbine maintenance and operation cost (M&O) (Kaldellis and Zafirakis, 2011)

- The selling price of electricity to the National Electric Power Company (NEPCO) = 0.085 JD/KWh
- The total selling price of the total production of the farm in Jordan Dinner = 400*1000*1000*0.085 = 34,000,000 JD/Year.
- The total selling price of the total production of the farm in US Dollar =
- 34,000,000/0.71 = 47,887,324 $/Year
- The expected operation time of the project is 20 years.
- AW of investment = 290,000,000 (*A*/*P*,10%,20) = 290,000,000*0.1175 = 34,075,000 $

Tafila wind turbines farm in terms of financial analysis

Benefit cost ratio calculation:

$$B/C = \frac{(Benefit - Disbenefit - M\&O)}{Initial\ Investement}$$

$$= \frac{47{,}887{,}324 - 4{,}800{,}000}{34{,}075{,}000}$$

= 1.26 ≥ 1. The project is satisfied.

Net future worth: Net future worth = -290,000,000(*F*/*P*, 10%, 20)- 4,800,000(*F*/*A*, 10%, 20)
+ 47,887,324(*F*/*A*, 10%, 20)
= -290,000,000(6.7275) -4,800,000(57.2750)
+ 47,887,342(57.2750)
= 516,852,513 $

Net present worth

Net present worth = -290,000,000- 4,800,000(*P*/*A*,10%,20) + 47,887,324(*P*/*A*,10%,20)

= -290,000,000 – 4,800,000 (8.5136) + 47,887,324 (8.5136)
= 76,828,242 $

Annual worth

Annual worth = -290,000,000(*A*/*P*, 10%, 20) - 4,800,000 + 47,887,324

= -290,000,000(0.1175) – 4,800,000 + 47,887,324
= 9,012,324 $

Payback Period:

$$payback\ period = \frac{First\ Cost}{Annual\ Benefit}$$

Table 1. Payback period of the project

Year	Σ Costs $	Σ Benefits $
	0290,000,000	-------------
1	294,800,00047,	887,324
2	299,600,000	95,774 648
3	304,400,000	143,661,972
4	309,200,000	191,549,296
5	314,000,000	239,436,620
6	318.800,000	287,323,944
7	323.600,000	335,211,268
Payback period = 7 years.		

Conclusion

The following is noted in Tafila wind turbines farmin terms of financial analysis:

- The benefit cost ratio for the project is 1.26 this means that the project is satisfied.
- Net future worth for the project is 516,852,513 $.
- Net present worth for the project is 76,828,242 $.
- Annual worth for the project is 9,012,324 $.
- The payback period for the project is 7 years.

In addition, the following is noted in Tafila wind turbines farm in terms of environmental and economic analysis:

- It is clear that Tafila is the best choice for the implementation of the wind farm power (highest average wind speed in Jordan is in Tafila location with a value of (8.54 m/s)).

- Contribute to Jordan's national strategy for energy as well as to regional targets in the field of clean energy (better to the environment). Reduce greenhouse gas emissions. reduce energy import dependency
- Produce about 4 % of the national electricity demand each year that is enough electricity to power 85,000 homes.

REFERENCES

Al-Nhoud, O. and Al-Smairan, M. 2015. "Assessment of Wind Energy Potential as a Power Generation Source in the Azraq South, Northeast Badia, Jordan". *Modern Mechanical Engineering*, 5, pp. 87-96.

AIMU Technical Services Committee, 2012. Wind Turbine Paper.

Blanco, M.I. 2009. "The Economic of Wind Energy, Renewable and Sustainable Energy Reviews, Elsevier, Vol. 13, Issues 6-7, pp. 1372-1382.

El-Tous, Y., Al-Battat, S. and Abdel Hafith, S. 2012. "Hybrid Wind-PV Grid Connected Power Station Case Study: Al Tafila, Jordan ", *International Journal of Energy and Environment*, Vol. 3, Issue 4, pp. 605–616.

Eminoglu. U., and Ayasun, S. 2014. "Modeling and Design Optimization of Variable-Speed WindTurbine Systems " *Energies*, *7,* pp. 402-419.

Kaldellis, J. K., and Zafirakis, D. 2011. "The wind energy revolution: A short review of a long history", *Renewable Energy*, Vol.36, pp. 1887-1901.

Sangroya, D., Nayak, J. K., 2015. "Development of Wind Energy in India", *Development of Wind Energy in India*, Vol.5, No.1, pp. 1-13.

Sarkar, A., and Behera, D. K. 2012. "Wind Turbine Blade Efficiency and Power Calculation with Electrical Analogy", *International Journal of Scientific and Research Publications*, Vol. 2, Issue 2, pp. 1-5.

Shrestha, S. 2015. "Design and Analysis of Foundation for Onshore Tall Wind Turbines ", Master's Dissertation, Clemson University.

Singh, A. K., Parida, S. K. 2013. "National Electricity Planner and use of Distributed Energy Sources in India", *Sustainable Energy Technologies and Assessments*, Vol. 2, pp. 42–54.

Srinivasan, C., Ajithkumar, G., Arul, S., Arulprasath, G., and Dharunbabu, T. M., 2017. "Design of Combined Savonius-Darrieus Wind Turbine", *IOSRJournal of Mechanical and Civil Engineering*, Vol. 14, Issue 2, pp. 60-70.

Svensson, H., 2010. "Design of Foundations for Wind Turbines", Master's Dissertation, Lund University. Sweden.

www.vestas.com.

www.vestas.se/Brochure V112-3.0 MW.

****