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Cycle Costing of Wind Generation System

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ABSTRACT

Life Cycle Costing (LCC) is a methodology used first time by the Department of Defense of United State, it's an economic calculation of all costs propagated during the life span of any technical system. For Renewable Energy (RE) systems, LCC is a good methodology, which shows the cost-effectiveness of using RE as an alternative source compared to conventional power generations. A LCC model was introduced for Wind generation system. Data collection was done through four different cost data sources. The results shows that the capital investment cost is $1.968/W. For a 20 years PV project life-time, the operation and maintenance cost forms 19% of the total LCC of the system.

1. Introduction

Alongside with the growth of renewable energy (RE) market, the need for an accurate and precise evaluation for an economic feasibility of these technologies is a pressing issue. Accordingly, all costs regarding the project should be taken into consideration from the conceptual to disposal phases, or what it was called life cycle costing (LCC). The concept of LCC was firstly introduced in 1970s by the U.S. Department of Defense (DoD) [1]. Since the LCC concept was widely adopted in a wide range of industrial sectors including energy, construction, manufacturing, transportation and healthcare [2]. LCC is a process driven by the nature, quality, amount and characteristics of the collected data, henceforth, it determines the methods and models followed for LCC calculations.

1.1. Global Renewable Energy Status

Renewable Energies (RE) jumped a high pass in the last few years as a result of the declared polices that bolstered energy security and manageability. By the end of 2015, the global harnessed renewable power is 1,985GW extended at its quickest rate to date. However, 8.3% is the total RE augmented in 2015 translated to 152GW installed capacity at that year [3]. Experts expected that REs will represent very nearly to 66% of the generated power energies extensions by 2020 [4]. According to the published statistics [3, 5, 6], and due to different reasons, wind energy is the most viable renewable energy source compared to others. The commitment of wind energy to the whole energy supply has achieved a considerable share on the worldwide level. Total global capacity utilizing wind energy reached

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approximately 432.5GW at the end of 2015 which represents approximately 21.8% of the total globally harnessed RE, Fig 1 shows the global annual installed wind capacity between years 2000 and 2015 [5]. However, year 2015 has achieved a 17% increased cumulative RE capacity compared with the year before.

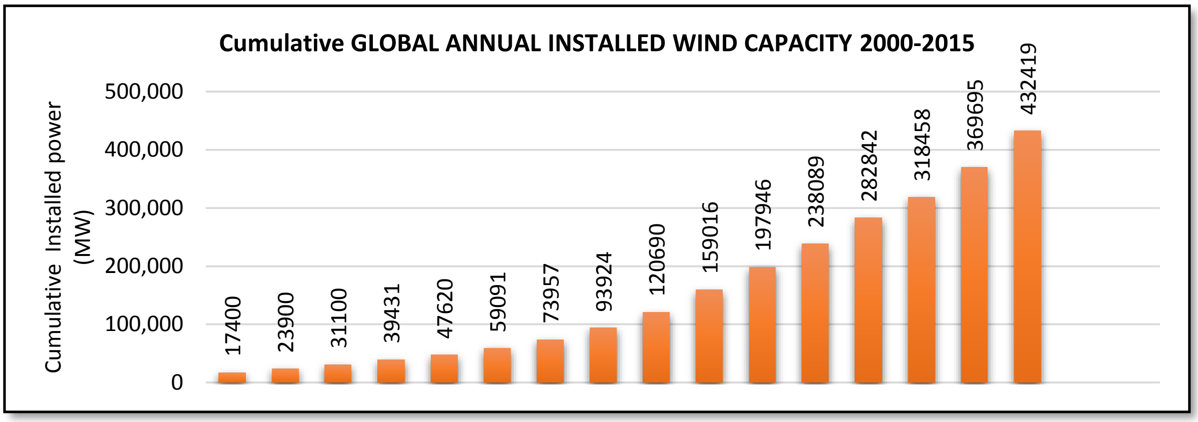

Fig 1. Cumulative global annual installed wind capacity 2000-2015 [5].

1.2. Levelised Cost of Electricity (LCOE)

LCOE, also called Levelised Cost of Electricity is a more accurate energy cost calculation that is accepted and widely used technique and it has been adapted by many researchers and agencies [7-17]. LCOE is defined as the ratio between the life-cycle cost (LCC) of the PV system to the whole life produced energy [18] as shown in Eq. (1).

$$LCOE = \frac{Life\ Cycle\ Cost\ (LCC)}{Life\ Cycle\ Energy\ produced\ (LCE)} \tag{1}$$

The LCE produced can then be calculated on an annual bases discounted with *r* discount rate as shown in Eq. (2).

$$LCE = \sum_{i=0}^{n} \frac{AEP\ x\ (1-\mathrm{df})i}{(1-r)i} \tag{2}$$

Where *AEP* is the expected annual energy produced, *n* which is the estimated life of the project. With system life progress its output power yield will be degraded with a factor *df* in order to get a better energy harvest forecasting [19].

1.3. Life Cycle Costing (LCC) Model for Wind Farm

Depending on the availability of wind cost data, the LCC model of wind farm was developed. The developed LCC model distribute the LCC of the project into five categories; Development costs (C_{Dev}), Wind Turbines cost (C_{WT}), Civil work and installation (C_{civil}), Electrical apparatus (C_{Elec}) and operation and maintenance costs ($C_{O\&M}$) as depicted in Eq. (3).

$$LCC = C_{Dev} + C_{WT} + C_{Elec} + C_{Civil} + C_{O\&M} \tag{3}$$

Cost break-down structure for each cost category of the LCC is depicted in Fig 2.

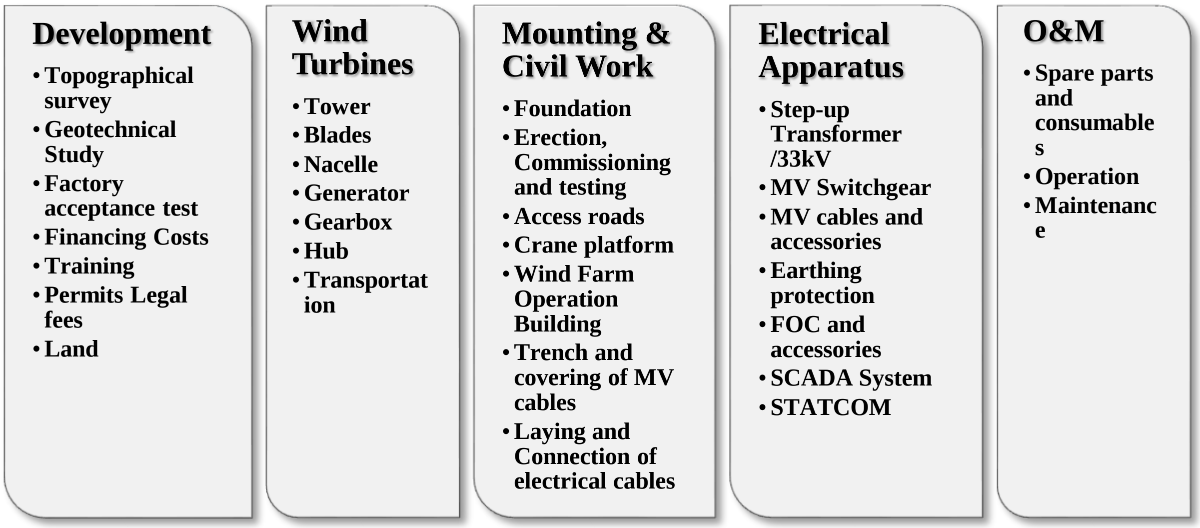

Fig 2. Life Cycle Costing (LCC) model for wind farm.

1.4. Wind Farm project Timeline

The development of wind farm passes through four time phases: Development, Implementation, Operation and Decommissioning phase [23, 24]. The Development phase start by finding suitable site that have good wind characteristics and site accessibility and far from natural reserves. After that starting the design of the farm which is an iterative process with Implementation phase which comes after taking the right permission and licenses. The project financing is very important in this phase so it contributes in cost reduction for the investor. The Implementation phase through which we actually buy the equipment and construct it where the whole capital is used. Next is the Operation phase, the longest phase, hence the design continues to last for 20 to 25 years during this the costs distributed on regular maintenance, spare parts and overheads. Finally, the Decommissioning phase where we have two choices either removing the turbines or repowering it with newer technology, Fig 3 summarizes these phases [25].

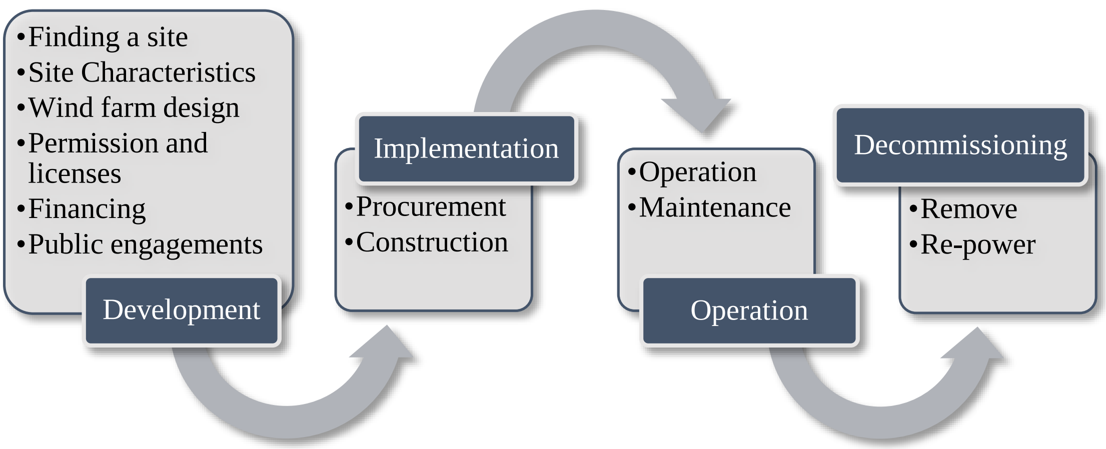

Fig 3. Wind farm project timeline.

2. Methodology

Based on our constructed LCC model of wind farm Eq. (3). The wind park cost data was collected from four sources as shown in Fig 4.

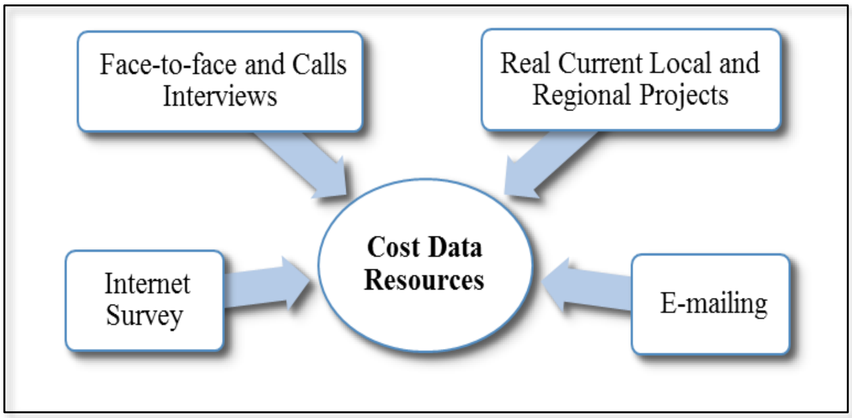

Fig 4. Cost Data Resources.

2.1. Real Current Local and Regional Projects

Endeavors headed toward the latest assigned PPA (Power Purchase Agreement) utility-scale wind projects in addition to the private sector projects with capacity greater than 1MW. The advantages of acquiring such project data give you a complete picture about the whole project costs with some details, which reflect the costs under local circumstances.

2.2. Face-to-face and Calls Interviews

We have conducted a face-to-face and calls interviews with some plants owners, EPC contractors' representatives, plants managers, consultants, expert engineers working in the field from both private and public sectors.

2.3. Internet Survey

An extensive deep Internet research about any available cost data for both wind and PV components. Especially, the specialized sites that presents the latest price lists for the main systems components and commercial shopping sites.

2.4. E-mailing

E-mailing is a complement task to the net survey where many products requires an enquiries for PO (Purchase Order). We have developed lists of globally leaders of wind manufacturer and international agencies with their contact information and we have e-mailed them along the thesis duration. Unfortunately, there were no price data available for public; cost data unveiled only for serious businesses and not for research purposes. Consequently, we headed toward emailing an international wind turbine manufacturers and EPC contractors in addition to wind energy agencies. The results was disappointed. We do not receive any response from many of them and a few of them replied with apology and inability to support such information for researchers.

3. Results and Discussion

Due to low number of utility-scale, wind projects locally and regionally, the high conservative on cost data regarding wind farms everywhere (considering it as a confidential information) and limited number and outdated utility-scale wind cost structure resources, all of these limits our acquired, real and updated data. The confidentiality of the gathered cost data mandate us to hide the identity of the source. Barely, we could get detailed cost data for two wind projects in Jordan, other projects' costs we got it either orally through interviews or through the already announced press information.

The summary of the total LCC of the collected up to date wind farm cost data normalized to dollar per watt is tabulated in Table 1 and for better visualization of cost structure see Fig 5. The average of the total investment cost is listed in the last. As we can see that the National Energy Research Center (NERC) project (1.65MW), the cost of wind turbine has approximately double of that of Ministry of Energy and Mineral Resources (MEMR) project (14MW) because it is a pilot project with only one gearless turbine. Additionally, the development cost of MEMR project is the lowest because it is an extension to already existing 66MW project.

Table 1. Summary of the wind farm LCC data normalized to ($/W).

<table>
<tr><td></td><td colspan="6">Total LCC ($/W)</td></tr>
<tr><td>Cost Data Source</td><td>Net Survey</td><td>14MW</td><td>1.65MW</td><td>100MW</td><td>117MW</td><td>Average</td></tr>
<tr><td>Wind Turbines</td><td>$0.80</td><td>$0.998</td><td>$1.974</td><td rowspan="3">$2.012</td><td rowspan="4">$1.906</td><td rowspan="4">$1.968</td></tr>
<tr><td>Civil Work & Installation</td><td>-</td><td>$0.291</td><td rowspan="2">$0.538</td></tr>
<tr><td>Electrical Apparatus</td><td>-</td><td>$0.450</td></tr>
<tr><td>Development</td><td>-</td><td>$0.016</td><td>$0.051</td><td>$0.046</td></tr>
<tr><td>Total Investment Cost</td><td>-</td><td>$1.754</td><td>$2.564</td><td>$2.058</td><td>$1.906</td><td>$1.968</td></tr>
<tr><td>O&M (1st year)</td><td>-</td><td>$0.016</td><td>$0.023</td><td>$0.048</td><td>$0.038</td><td>$0.031</td></tr>
</table>

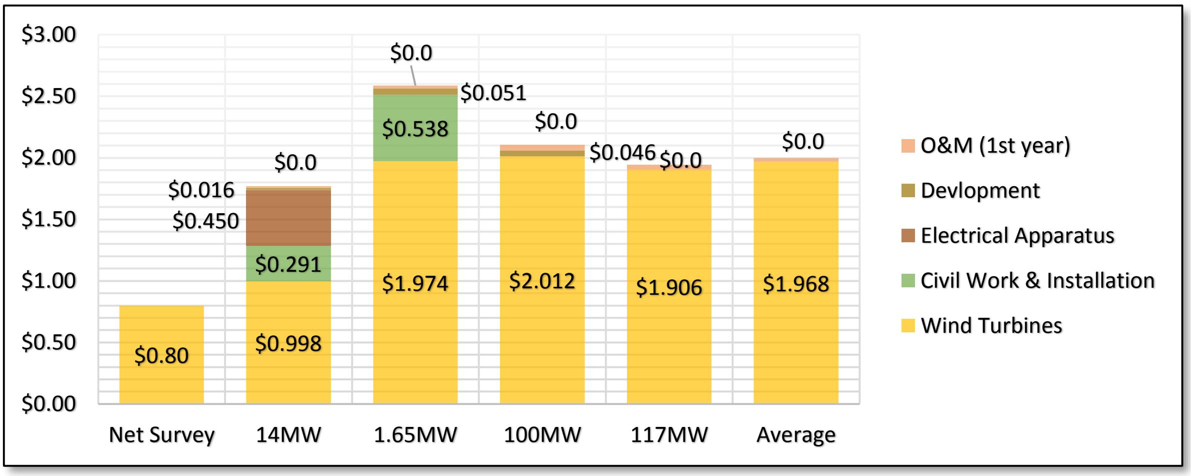

Fig 6. Stacked LCC components of gathered wind data for better visualization.

We can show that the $C_{O\&M}$ of 20 year discounted cash flow (at 5% interest rate and 2% inflation rate) forms a significant portion of the total LCC of wind farm system (approximately 19% of the total LCC) and about 24% of initial capital cost.

4. Conclusion

Life cycle costing is a good methodology especially for a Renewable Energy (RE) systems which shows the benefits of using RE as an alternative source compared to fuel incurred costs. A model for LCC was conducted, and a methodology for cost data acquisition was followed depending on four cost data sources. The results shows that the capital investment cost is $1.968/W. For a 20 years life-time Wind farm project, the operation and maintenance cost forms 19% of the total LCC of the system.

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