2014-04-14

Financial Appraisal of a Small Scale Wind Turbine with a Case Study in Ireland

Tony Kealy
Technological University Dublin, tony.kealy@tudublin.ie

Recommended Citation

Kealy, T. (2014) Financial Appraisal of a Small Scale Wind Turbine with a Case Study in Ireland. *Journal of Energy and Power Engineering*,Vol. 8 (4), 2014, p.620-627 doi:10.21427/D7PD1X

Journal of Energy and Power Engineering 8 (2014) 620-627

Financial Appraisal of a Small Scale Wind Turbine with a Case Study in Ireland

Tony Kealy

Department of Electrical Services Engineering, School of Electrical Engineering Systems, Dublin Institute of Technology, Dublin 8, Ireland

Received: November 11, 2013 / Accepted: December 12, 2013 / Published: April 30, 2014.

Abstract: This research seeks to evaluate the economic benefits to be gained by installing a small-scale wind turbine for a customer with a three-phase electrical supply requirement. The evidence for the claims made in this paper is obtained by using actual data obtained from the installed equipment over a three year period. The objective is to accurately appraise the financial investment using real data. There appears to be limited studies conducted into this type of research, possibly because the renewable energy sector is in the infancy stage in the host country, Ireland. There are some wind energy installations with financial appraisal techniques based on modeled data, which may, or may not, be accurate. The study concludes by claiming that the financial benefits of the wind energy turbine installation had disappointing results when compared to predicted benefits based on modeled data.

Key words: Wind turbine, financial appraisal, feed-in-tariffs, power loss in cables, preliminary load and wind tests.

1. Introduction

The majority of Ireland's generated electricity comes from fossil-fuel driven plants. In line with European Union directives, Ireland has committed itself to adjusting this policy by agreeing new climate and energy targets [1]. It is likely that there will be financial penalties to be paid by the Irish Government if the targets are not met. It is hoped by the year 2020 that the renewable contribution to electricity production will have increased to 40%. Of this figure, it is envisaged that 35% will come from wind energy. To aid and enhance this strategy, the Irish Government has put incentives in place to encourage small scale wind energy projects. It appears that now a significant number of small businesses and households have embraced these types of wind energy projects possibly without fully investigating the consequences of adopting such incentives.

Corresponding author: Tony Kealy, researcher, research fields: renewable energy and sustainable business development. E-mail: tony.kealy@dit.ie.

Financial appraisals of small scale individual projects appear to be sparse, understandably because of the early stage of development of this industry life cycle. A paper by Kelleher and Ringwood [2] presents a method to estimate the economics of renewable micro-generation of electricity from wind and solar energy sources using a computer programme. Kelleher et al. [2] use variables such as a range of feed-in tariffs, government incentive schemes, and the cost of capital borrowing to determine payback periods. They concluded by claiming that payback periods can vary greatly depending on the location, installation and economic variables. Location is also seen as being a very important variable in an article by Al-Buhari and Al-Haydari [3]. They highlight the importance of carrying out preliminary analysis on potential wind turbine sites as they claim that the amount of energy that can be supplied depends on the wind resource available, the type of wind turbines used, and the nature of the load being supplied. The methodology used [3] involved analysing wind speed data collected over a seven-year period by the Yemen Meteorological Department. As stated by Kelleher and Ringwood [2], economic variable are likely to influence the level and attractiveness of feed-in-tariff available to the turbine owner(s). One such study was carried out by Walters and Walsh [4] who examined the financial performance of micro-generation wind projects in the UK with specific focus on the subsidy effect of feed-in tariffs. However, the benefits and cost savings of such projects in Ireland have yet to be clearly identified using empirical data from existing installations. A case study carried out in Pakistan by Awan et al. [5] questioned whether it is worth investing in infrastructure for wind energy alone, and proposes that hydro-electric power be used in conjunction with wind power to reduce the variation in the output. Awan et al. [5] mentioned the results of a survey of wind data in a range of potential sites. The proposed 600 kW wind turbine had a predicted energy output of 696,663 kWh units per year. While it is important to consider the economical outcomes of a wind turbine investment, it is worth noting that the decision may not be made on a purely financial basis only. The public perception of such energy sources is also important for energy policy. As stated by Burger and Gochfeld [6], while renewable energy must be cost-effective, monitoring human perceptions of energy sources is also important for energy policy. Human perceptions change over time and are influenced by population density, technologies and economic consequences.

This longitudinal research study on a 10 kW, three-phase wind turbine took place on a singular farm unit in County Meath, Ireland, in 2012/2013 where the electrical energy usage is 76,338 kWh's per annum.

2. Methodology

Initially, a site visit to the premises was arranged enabling relevant quantitative data to be obtained from the electrical equipment. Subsequently, a number of electrical utility bills were accessed on-line in agreement with the turbine owner.

- Evaluation criteria

The performance of the wind turbine installation was evaluated from the following perspectives:

(1) initial cost;
(2) power output;
(3) energy output;
(4) financial investment appraisal.

- Schematic diagram

The schematic diagram for the wind turbine installation is shown in Fig. 1. It indicates the single-phase AC output from the left-hand inverter connected to L_1 while the AC output from the right-hand inverter connected to L_2, via an isolating transformer. The inverters are programmed so that the left-hand inverter has priority over the right-hand inverter and therefore will produce an AC output at a lower DC input voltage level and will produce the largest number of energy units. The schematic indicates that a three-core, SWA (steel wire armour) cable, buried directly in the ground linking the turbine generator and the farm installation, is to be sized in accordance with BS7671 [7] or local regulations. The distance between these two points is 300 m. The generator is a three-phase, multi-pole, synchronous generator.

3. Evaluation Criteria

3.1 Initial Cost

The turbine installation cost was €22,000 plus VAT (valued added tax) at 21%, making the total price equal to €26,620. Maintenance of the installation is included in the initial cost. Due consideration must be given to maintenance of the turbine and it is suggested by Zaghar et al. [8] that analysis of the failure rate of each component is very important at the design stage as maintenance is generally difficult and costly. The specification for the turbine is shown in Table 1.

This price included the supply and installation of a three-phase 12 kW inverter for the interface between the turbine and the existing electrical installation. However, on a site inspection, it was found that the

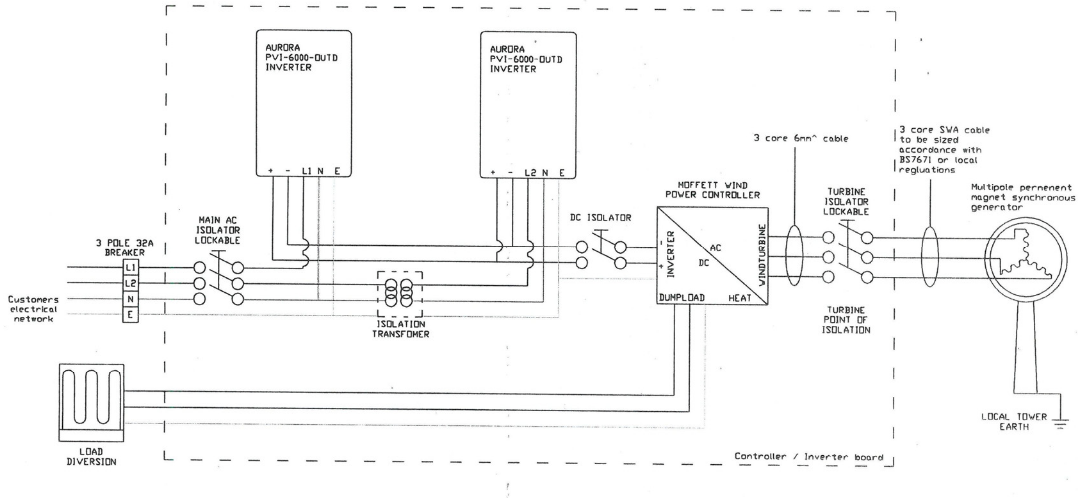

Fig. 1 Schematic diagram for turbine installation.

Table 1 Specification for wind turbine.

Turbine type	Upwind
Rated capacity	10 kW
Maximum capacity	12 kW
Rotor diameter	6.5 m
Number of blades	3
Rotor speed	0-260 RPM
Generator type	Permanent magnet
Cut-in wind speed	2.2 m/s
Rated wind speed	11 m/s (39 km/h)
Cut-out wind speed	30 m/s
Survival wind speed	58 m/s (200 km/h)
Yaw control	Active
Main brake	Winch yaw control
Tower height	10 m
Performance	900-2,100 kW per month

contracted installation company installed two single-phase 6 kW-rated inverters instead of the quoted three-phase version. The original quote also included installation of a 25 mm^2 Steel Wire Armour cable, costing €6.45 per metre, to carry the current from the turbine to the installation. The installation company was new entrants in the renewable energy industry. They made a strategic decision to enter the renewable energy market after successfully competing in a different industry for a number of years. Before installation began, there was no tests carried out to ascertain the suitability, or otherwise, of the site. This would have included wind speeds tests at the proposed location of the turbine. Also, there were no load (current) tests carried out at the clients existing installation to determine if the loads were balanced equally over the phases as recommended by Al-Buhairi and Al-Haydari [3]. The three-phase utility meter at the supply intake is equipped with both an Import and an Export facility. Any excess power generated from the turbine, and not used instantaneously on the farm, is exported onto the National Grid. The number of export units is 477 kWh units per annum. The farmer receives 9 cent per kWh for every unit of energy exported. The life-span of the turbine in this research is quoted as being 25 years. Zaghar et al. [8] suggest that the lifetime of turbines may be 20 years but a final statement cannot be made because they are in the infancy stage.

3.2 Power Output

The wind turbine has a rated capacity of 10 kW with a maximum output capacity of 12 kW. The generator is a multi-pole, permanent magnet, three-phase synchronous generator. The turbine has a rated wind speed of 11 m/s as specified in Table 1.

3.3 Energy Output

Each inverter has an energy output indicator on the front panel. This data is recorded and used in subsequent calculations for this research. Over a three-year period, the two single-phase inverters produced a combined total of 21,779 kWh units of energy. The left-hand inverter, Fig. 1, produced 13,307 kWh's and the right-hand inverter produced 8,472 kWh's of this total. This equates to an average yearly energy output, for the turbine, of 7,260 kWh's. Of this yearly total, 477 kWh units of energy are exported back to the National Grid at a feed-in-tariff rate of 9 cent per kWh. This gives a net import energy saving of 6,783 kWh's per annum. As a result of examining previous utility bills over a number of years, it is noted that the customer uses 55% of his electricity during the day and 45% at night. Therefore, the actual imported energy savings are 55% of 6,783 (3,731 kWh's) day units and 45% of 6,783 (3,052 kWh's) night units. Note that the performance specification shown in Table 1 predicts an energy output of between 900-2,100 kWh per month (10,800-25,200 per annum). A summary of the yearly savings are as shown in Table 2.

3.4 Financial Investment Appraisal

The turbine installation was a significant investment by the farmer. Given the importance of this investment decision, it is essential to screen the investment proposal. There are four main methods of evaluation used in this research [9]. They are (1) PP (payback period); (2) ARR (accounting rate of return); (3) NPV (net present value); (4) IRR (internal rate of return).

Payback period: (1) This is the length of time it takes for the initial investment of €26,620 to be repaid out of the net cash inflows from the turbine installation. We can derive the payback period by calculating the cumulative cash flows associated with the project. The cumulative cash flow becomes positive after year twenty-three as shown in Table 3.

The advantages of the PP method are that it is quick and easy to calculate and is easily understood by the manager making the investment decision.

Accounting rate of return: this investment appraisal method takes the average accounting operating profit that the wind turbine installation generates and expresses it as a percentage of the average investment made over the life-time of the project, i.e., 25 years. The average annual operating profit is the cash-flow (€1,142) plus the depreciation on the installation (€26,620/25 i.e., €1,064.80) giving a total value of €2,206.80. The average investment is the cost of the installation plus the scrap value, all divided by two [(€26,620 + €2,000)/2] giving a value of €14,310. The ARR of the turbine installation is calculated as 15.42% [(€2,206.80/€14,310) × 100%]. The ARR relates accounting profit to the cost of the assets invested to generate that profit. The problem with ARR is that it almost completely ignores the time factor. There are also problems concerning the approach taken to derive the average investment of the turbine.

Net present value: the NPV investment appraisal method considers all of the costs and benefits of the turbine installation, and makes a logical allowance for the timing of these costs and benefits. The time factor is an important factor as the farmer will not see €1,142 received now as equivalent in value to €1,142

Table 2 Savings made due to wind turbine installation.

Day units	Day rate	Night units	Night rate
3,731 kWh	€0.1815	3,052 kWh	€0.0897
	€677		€274
Plus VAT	€91	Plus VAT	€37
Sub-total	€788	Sub-total	€311
Export 477 kWh at 9cent per kWh = €43			
Total annual financial benefits = €1,142			

Table 3 Payback period.

Time	Net cash flow	Cumulative cash flow (€)
Immediately	-€26,620	
1 year's time	€1,142	-€25,478
2 year's time	€1,142	-€24,336
3 year's time	€1,142	-€23,194
4 year's time	€1,142	-€22,052
5 year's time	€1,142	-€20,910
-	-	-
21 year's time	€1,142	-€2,638
22 year's time	€1,142	-€1,496
23 year's time	€1,142	-€354
24 year's time	€1,142	€788
25 year's time	€1,142	€1,930
25 year's time	€2,000	€3,930

receivable in a years' time. The three reasons for this are: (1) interest lost; (2) risk; (3) effects of inflation. The NPV method makes a direct comparison between the sum of the inflows over time and the immediate €26,620 investment. The cash benefits over time are discounted, depending on the interest rate and the period (year) in which the benefits arise. The discount factor is taken as 13% and the discount factors are shown in Table 4.

The NPV of the wind turbine installation is -€18,215. The decision rule for NPV states that if the NPV is positive, the project should be accepted and if the NPV is negative, the project should be rejected. The NPV method seems to be a better method of appraising the wind turbine installation because it takes into account the following three criteria: (1) the timing of the cash flows; (2) the whole of the relevant cash flows; (3) the objectives of the business [9]. In this case, it would appear that investment in the project is not viable because the NPV is a negative value, indicating that the costs outweigh the benefits. This NPV value is based on an interest rate of 13%. Perhaps in the current economic climate, it may be more realistic to apply an interest rate of 7% as the rate is based on the cost of borrowing money from a financial institution. When the interest rate is 7%, the NPV for the installation is -€13,122, still indicating that the costs outweigh the benefits.

Internal rate of return: The IRR method of investment appraisal, like NPV, involves discounting future cash flows. The IRR of the wind turbine installation is the discount rate that, when applied to its future cash flows, will produce an NPV of precisely zero. In essence, it represents the yield from the turbine investment. From (3), we calculated the NPV of the installation at an interest rate of 13% as -€18,215. When the interest rate is set at 2%, the NPV is calculated as -€3,110. When the interest rate is set at 1%, the NPV is calculated at €80. Since the IRR is the discount rate that will give an NPV of exactly zero, we can conclude that the IRR of the installation is between 2% and 1%. A more accurate calculation is 1.025%. A table for the IRR calculation is shown in Table 5.

Table 4 Net present value.

Time	Cash flow	Discount factor (13%)	Present value (€)
Immediately	-€26,620	1	-€26,620
1 year's time	€1,142	0.885	€1,011
2 year's time	€1,142	0.783	€894
3 year's time	€1,142	0.693	€791
4 year's time	€1,142	0.613	€700
5 year's time	€1,142	0.543	€620
-	-	-	-
22 year's time	€1,142	0.065	€74
23 year's time	€1,142	0.060	€69
24 year's time	€1,142	0.053	€61
25 year's time	€1,142	0.047	€54
25 year's time	€2,000	0.047	€94
		NPV	-€18,215

Table 5 Internal rate of return.

Discount factor (2%)	Present value	Discount factor (1%)	Present value
1	-€26,620	1	-€26,600
0.98	€1,119	0.99	€1,131
0.961	€1,097	0.98	€1,119
0.942	€1,076	0.971	€1,109
0.924	€1,055	0.961	€1,097
0.906	€1,035	0.951	€1,086
-	-	-	-
0.647	€739	0.8	€914
0.634	€724	0.795	€908
0.622	€710	0.787	€899
0.609	€695	0.779	€889
0.609	€1,218	0.779	€1,558
NPV	-€3,110	NPV	€80

It is important to note that the methods described, and the values calculated, are not seen purely as a mechanical exercise. The results derived from this wind turbine installation investment appraisal are only one input to the decision-making process. Other, broader, issues that may be connected to the decision include the concern, by the farmer (client), for our natural environment which, according to much scientific evidence, appear to be under the threat of global warming. Each kWh unit of energy produced by the turbine saved 0.532 kg of CO_2 that would be emitted into the atmosphere as a result of burning fossil fuel to produce the same output. This environmental impact information is written on each electricity utility bill. It is hoped that we, at this present time, do not destroy the natural environment to be inhabited by future generations because of our heavy dependence on burning imported fossil fuels. This ecological evaluation of renewable energy sources is summarised by Burger and Gochfeld [6] who list seven objectives that must be met in order to make renewable energy effective. The authors claim that renewable energy must be protective of human health and the environment, protective of landscape and Earth systems, and be acceptable to the public. A summary of the results of the financial appraisal methods for the wind turbine installation are expressed in Table 6.

Table 6 Summary of financial appraisal methods.

Appraisal method	PP	ARR	NPV	IRR
Value	23 years	15.42%	-€18,215	1.025%

4. Findings

A potentially significant finding of the study was highlighted by measuring the load current at the DSO (distribution system operator) electrical supply intake of the installation. It was found that a possible inefficiency in the design of the installation may have negatively affected the potential for savings on the project. It was noted that the output from the left-hand inverter was connected to L_1 of the installation and from the right-hand inverter to L_2 as shown in Fig. 1. The only connection to L_3 was via the National Grid. However, on analysis of the loads connected to the installation, it was discovered that L_1 was the phase with the lightest loads connected to the supply. The problem was compounded because the left-hand inverter was programmed to give the highest output of the two inverters. The result was that the farmer could potentially be exporting electricity via L_1 at 9 cent per kWh and, at the same time, importing electricity on either L_2 or L_3 at 18 cent per kWh. As a result of this analysis, the output from the left-hand inverter was moved to L_2 and the output from the right-hand inverter was moved to L_3.

The author found that the cable buried directly in the ground, installation method D (British Standard, BS7671, Requirements for Electrical Installations) [7], linking the turbine with the installation is 3-core 25 mm^2 SWA. When the cable is carrying, for example, 30% of the rated output from the turbine, 3.3 kW, this equates to a current value of approximately 13 A. Under these conditions, the total volt drop between the start and the end of the cable is 5.85 V (1.5 mV × 13 × 300). When the full load is being generated, i.e., approximately 40 A, the volt drop in the cable is 18 V, a significant loss in the cable. A cable with a larger diameter would have reduced these losses considerably. For example, a similar cable with a conductor size of 35 mm^2 would have a volt drop on full load of 13.2 V (1.1 mV × 40 × 300).

5. Discussions

From this limited study, it appears that the expected economic benefits of investing in this micro-generation wind energy project did not materialise. The client made a significant financial investment, €26,620, to reduce the overall electrical energy bill by only 9.5% (7260/76338). The results of the values calculated by the financial appraisal methods are disappointing. A PP of 23 years is unlikely to be acceptable to shareholders in business. As a comparison to generally acceptable economic benefits from investment opportunities, some examples are now briefly discussed. The supermarket giant, Tesco, is in the process of installing voltage optimiser equipment at the DSO intake to nearly all of its 2,300 stores and warehouses in the UK [10]. The equipment reduces the voltage, if required, to allow connected loads run at optimum efficiency. Tesco expects a return on investment of approximately 20% and achieve a payback period of five years by installing the voltage optimizer equipment. Also, Marks and Spencers, the stores chain, has targeted an IRR of between 12% and 15% on any new investment programme [11]. Thirdly, Rolls-Royce in its 2010 annual report and accounts stated that all investments are subject to rigorous examination of risks and future cash flows to ensure that they create shareholder value [12]. Discounted cash flow (NPV) analysis is performed on a regular basis at Rolls-Royce.

The payback period of the turbine in this research is significantly longer than that predicted in the research by Kelleher and Ringwood [2]. For example, Kelleher and Ringwood predict a 3.65 years payback period for a Proven 2.5 kW micro-wind turbine in an open rural area. It must be noted, however, that the range of sizes used in Ref. [2] are smaller than the turbine used in this research.

There appears to be several factors contributing to the indication that financially the wind turbine project does not perform well in this case.

Firstly, the competencies of some companies' operating in this specialised area would seem to be somewhat questionable. It appears that the installation company in this research did not have the expertise needed to design and install such an installation. They did not complete any pre-connection wind speed and/or electrical load tests on the installation, as suggested by Al-Buhairi and Al-Haydari [3] and they did not inform the client of the potential pit-falls, or advantages, that his investment might hold. This conclusion concurs with Walters and Walsh [4] who claimed that how the equipment is installed contributes to the success, or otherwise, of the project. In the installation of the wind turbine for this research, two single-phase inverters were installed instead of a three-phase inverter, which may contribute to a lower energy output than specified by the manufacturer. Also, the SWA underground cable linking the turbine generator and the installation appeared to be lower than that needed to efficiently transfer the power between both, considering the distance is significantly long at 300 m. This leads to high power loss in the cables.

Secondly, the renewable energy feed-in tariff, at 9 cent per kWh, is low compared to UK tariffs. Walters and Walsh [4] concluded that the proposed feed-in tariff of 30.5 (UK) pence per kWh (approximately 25.9 cent per kWh) would not boost the economic attractiveness of some sites in the UK. There seems little benefit, in Ireland, of customers exporting electricity at significantly lower price per unit than the UK when the higher price is deemed unattractive in the UK. The customer in this study is better advised, from an economic point of view, to use all of his generated units in his installation rather than export any to the National Grid. Table 7 shows the benefits to the consumer if all the electricity generated by the turbine is used on-site in the installation. We can compare these results with the figures in Table 2.

When the financial benefits are analysed, allowing for 477 kWh units to be used on-site rather than be exported to the National Grid as shown in Table 2, it can be concluded that there is a small financial benefit to be gained by using all the generated kWh units on the installation, as shown in Table 7. The difference in monetary terms is €14 per annum.

Thirdly, it may be significant that the specialized, and new, nature of these wind energy projects are such, that in many cases a clients' understanding of the venture, its terminology and the technology involved is somewhat limited and therefore the potential for exploitation is great. The investor in this research used his "gut feeling" in making this investment decision. Larger businesses can afford to employ financial experts to appraise any such potential projects.

However, on the positive side, this investment saved a total of 3,862 kg of CO_2 being emitted into the atmosphere every year as a result of "green" generation of electrical energy instead of burning fossil fuels to obtain the same output. This will help to meet Irish energy targets as set by the European Union Directives with respect to CO_2 emissions and possibly reduce the

Table 7 All kWh units used on-site.

Day units	Day rate	Night units	Night rate
3,993 kWh	€0.1815	3,267 kWh	€0.0897
	€725		€293
Plus VAT	€98	Plus VAT	€40
Sub-total	€823	Sub-total	€333
Total annual financial benefits = €1,156			

fines to be paid by the Irish government if the targets are not met.

6. Conclusions

The financial analysis of the wind turbine investment identified poor results. A long pay-back period and a negative NPV value would seem to indicate that the cost of the investment outweighs the financial benefits to be gained by making the investment. There were no preliminary tests carried out on the suitability of the site or on the load characteristics of the installation. However, the Irish Government are keen that such renewable energy projects are implemented as it contributes to reducing CO_2 emissions. This will help the country to meet pre-defined targets; otherwise financial penalties may be incurred.

The main contribution of this research is to provide an appraisal of a small-scale wind turbine installation using actual data collected over a three year period and the results of which can be used for future, potential, investors in their investment decisions. There is a lack of such research in the host country, Ireland. These results will assist in the decision-making of other potential investors.

The author feels that there is merit in carrying out an investigation on a similar project where the designer/installer is an expert in the wind energy industry. The results of such an investigation would possibly highlight more favourable economic results with regard to a small-scale wind turbine investment.

Acknowledgments

Thanks to Gordon Evans for allowing his data to be utilised in this research project.

Thanks to Dr. Malabika Basu, Dublin Institute of Technology, for her encouragement and guidance in the writing-up of the proceedings.

References

[1] Energy and Natural Resources Home Page, http://www.dcenr.gov.ie.

[2] J. Kelleher, J.V. Ringwood, A computational tool for evaluating the economics of solar and wind micro-generation of electricity, Energy 34 (4) (2009) 401-409.

[3] M.H. Al-Buhairi, A. Al-Haydari, Monthly and seasonal investigation of wind characteristics and assessment of wind energy potential in Al-Mokha, Yemen, Journal of Energy and Power Engineering 4 (2012) 125-131.

[4] R. Walters, P.R. Walsh, Examining the financial performance of micro-generation wind projects and the subsidy effect of feed-in tariffs for urban locations in the United Kingdom, Energy Policy 39 (9) (2011) 5167-5181.

[5] S. Awan, M. Ali, M. Asif, A. Ullah, Hydro and wind power integration: A case study of dargai station in Pakistan, Journal of Energy and Power Engineering 4 (2012) 203-209.

[6] J. Burger, M. Gochfeld, A conceptual framework evaluating ecological footprints and monitoring renewable energy: Wind, solar, hydro, and geothermal, Journal of Energy and Power Engineering 4 (2012) 303-314.

[7] British Standard BS7671: 2008 Requirements for Electrical Installations, 7th ed., IEE Wiring Regulations, The Institution of Engineering and Technology and BSI, 2008.

[8] H. Zaghar, M. Sallaou, A. Chaaba, Preliminary design support by integrating a reliability analysis for wind turbine, Journal of Energy and Power Engineering 4 (2012) 233-240.

[9] P. Atrill, E. McLaney, Accounting and Finance for Non-specialists, 7th ed., Financial Times/Prentice Hall, 2011.

[10] R. Jaggi, Case study: Power efficiency [Online], Nov. 25, 2009, http://www.ft.com/intl/cms/s/0/c882555a-d9e6-11de-b2d5-00144feabdc0.html#axzz312a14MVA.

[11] Marks and Spencer plc, Annual report, Marks and Spencer, London, 2011.

[12] Rolls-Royce plc, Annual report, Rolls-Royce, London, 2010.