Selection of Suitable Wind Turbine for Wind Farm

Candidate Site Narakkalliya, Kalpitiya Peninsula, Sri Lanka

Sandagiri.C.A, Peiris.L.R, Perera.L.A.A.N, Siriwardena.K.A.P, Soysa.W.H.I.D

Supervised by: Dr. Nanayakkara D.P.N

Department of Electrical Engineering, University of Moratuwa, Sri Lanka

Abstract: **Out of the candidate sites feasible to construct utility scale wind farms in Sri Lanka, Kalpitiya peninsula is the ideal site. Wind Turbine NM 54/950 of NEG Micon AS of Denmark best suits site characteristics and could be used in first large scale wind farm in Sri Lanka. If the wind farm is to be constructed based on Build, Own and Operate basis a tariff rate should be negotiated with Ceylon Electricity Board.**

I. Introduction

According to the Wind and Solar Resources Assessment carried out by National Renewable Energy Laboratory (NREL), USA in collaboration with Ceylon Electricity Board (CEB) there are nearly 5000 km^2 of windy areas with good-to-excellent wind resource potential in Sri Lanka. About 4100 km^2 of the total windy area is land and about 700 km^2 is lagoon. The windy land represents about 6 % of the total land area (65,600 km^2) of Sri Lanka. Using a conservative assumption of 5 MW per km^2, this windy land could support almost 20,000 MW of potential installed capacity. If the windy lagoons are included, the total wind potential increases to approximately 24,000 MW. If areas with moderate wind resources potential are considered, the estimated total windy land area increase to approximately 10,000 km^2 or almost 15 % of the total land area of Sri Lanka. This amount of windy land could support more than 50,000 MW of installed capacity.

II. Site Selection

Candidate sites which we have identified to construct utility scale wind farms in Sri Lanka are as follows,

- South Coast – Hambantota to Buthawa
- West Coast – Kalpitiya Peninsula
- Northwest Coast – Mannar Island
- North Coast – Jaffna
- Central Providence – Ambewala
- Offshore – Great Basses to Little Basses (Along Great Basses Ridge and Little Basses Reef)

Out of these sites, after carrying out rigorous site screening process we have identified land strip near Narakkalliya in the west coast of Kalpitiya peninsula as the most suitable site to construct a wind farm at the moment. Wind farm of capacity about 25 MW can be easily constructed at the site.

III. Wind Climate

Wind resources at the site is analysed by wind resources data obtained form wind measuring installation of CEB at the site. The measuring installation comprises of three cup anemometers installed at 10 m, 20 m and 40 m above ground level, one wind direction sensor mounted at 40m, and a data logger installed at 40m high mast.

After analysing wind resources data for *year 2000* it was found that the site has an annual average wind speed of *7.08 m/s* and power density of *317.91 W/m^2*. Graph in figure 1 shows annual frequency distribution of the site with Weibull approximation.

Weibull approximation describes wind regime of a site attributed to two parameters, Weibull Shape factor (k) and Weibull Scale factor (c). This approximation is used in fluid dynamic models derived for assessing wind resources at a particular area.

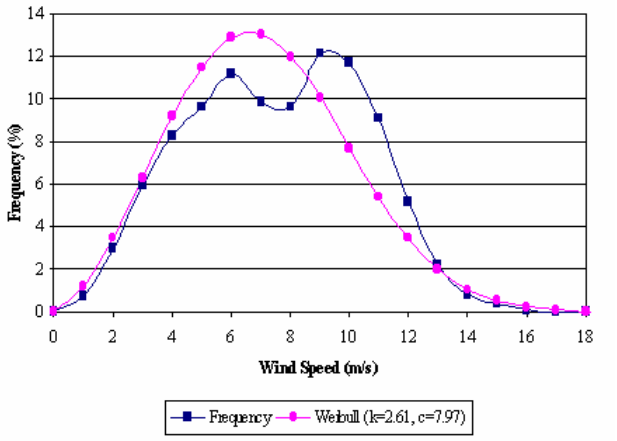

Fig. 1 Annual Frequency Distribution

We could observe in figure1 that the actual annual frequency distribution of Narakkalliya consists of two peaks (bimodal distribution) corresponding to approximate average wind speeds of the Northeast (NE) and Southwest (SW) monsoons. Also the Weibull approximation does not fit well with the actual distribution. The reason for this is that Weibull analysis is developed to describe European wind regimes, which are simple in nature as compared to Sri Lankan wind regime. Weibull approximation can only describes frequency distribution, which has single peak, and this approximation does not really explain the candidate site's wind regime. But Weibull approximation fits well with actual frequency distributions corresponding to twelve azimuth sectors.

Area around Narakkalliya is characterised by homogeneous flat terrain and we could assume that the measured wind data at the installation represents the wind regime in the area and could be used to determine the feasibility to construct a wind farm.

The site is well exposed to SW monsoon and NE monsoon, which are the dominant wind regimes in Sri Lanka. Availability of wind speed form sector 180^o – 270^o which is the direction of *SW monsoon* is about *63 %* with an average

wind speed of *9.23 m/s* and that for sector 0^o – 90^o which is the direction of *NE monsoon* is about *22 %* with an average wind speed of *4.96 m/s.*

After detailed wind data analysis we can conclude that the site has good wind resources that can be harnessed by a utility scale wind farm.

IV. Wind Turbine Selection

Turbine selection procedure was based on following factors,

- Plant factor
- Classes of wind turbines defied in IEC 61400 – 1, 2nd Edition dated 1999 – 02
- Manufacture's willingness to invest in Sri Lankan projects
- Technical and financial* viability of each turbine

Three brands of turbines provided by NEG Micon A/S, Denmark, ENERCON GmbH, Germany and TURBOWINDS SA/NV, Belgium were used in the turbine selection process. Financial and technical analysis was carried out assuming the farm to be constructed under Small Power Purchase Agreement** (SPPA). Table 1 presents summary of performances of each turbine.

V. Conclusions

After considering constrains in section IV and technical and financial performance of each turbine we can conclude that NM54/950 of NEG Micon Company is the most suitable turbine that can be used in a wind farm constructed in Narakkalliya area. Also it can be clearly seen that if the wind farm is to be constructed based on Build, Own and Operate (BOO) basis, the tariff rate applicable to the farm should be much higher compared to SPPA.

Finally we can conclude that the best site to construct a wind farm in Sri Lanka is Kalpitiya peninsula using NM54/950 wind turbines. Also if the plant is based on BOO basis an agreement should be made for a negotiable tariff rate.

TABLE 1
SUMMARY OF TECHNICAL AND FINANCIAL PERFORMANCES OF WIND TURBINES

Wind Turbine Type	**TURBOWINDS T600 - 48 (600 kW)**	**Enercon E - 40 (600 kW)**			**NEG Micon NM54/950 (950 kW)**
Wind Farm Details					
Turbine Capacity (kW)	600	600	600	600	**950**
Hub Height (m)	50	46	65	78	**60**
Rotor Diameter (m)	48	44	44	44	**54.5**
No of Turbines	16	16	16	16	**10**
Wind Farm Capacity (kW)	9600	9600	9600	9600	**9500**
Technical Details					
Net Energy (kWh)	30,176,590	26,779,306	27,943,441	28,562,197	**25,181,562**
Plant Factor	0.36	0.32	0.33	0.34	0.30
KWh/kW	3143.39	2789.51	2910.78	2975.23	2650.72
KWh/ m^2	1042.26	1100.74	1148.59	1174.02	1079.45
Financial Details					
Unit Costs					
Rs/kWh	7.35	6.37	6.71	7.22	**5.74**
Rs/kW	162,506.65	124,918.16	137,353.45	151,201.84	**108,778.62**
+IRR on Equity Under SPPA					
Base Case	2.75%	4.50%	3.86%	2.85%	**5.66%**
Case 1	1.44%	3.09%	2.48%	1.53%	**4.19%**
Case 2	1.04%	2.61%	2.03%	1.10%	**3.66%**
Case 3	1.80%	3.32%	2.76%	1.88%	**4.31%**
Worst Case	-0.84%	0.52%	0.02%	-0.78%	**1.40%**
***Required Levelised Tariff for Profit (Rs)**	10.06	8.94	9.33	9.96	**8.34**

* Financial analysis was carried out based on the conservative assumptions that turbine price represents 80 % of total wind farm coast and operation and maintenance cost represents 2.5 % of initial capital cost.

** SPPA tariff rate applicable for year 2004.

*** This tariff rate is calculated to have marginal profit i.e. tariff rate where IRR on equity equals bank-lending rate of 9.96 % ((Daily News Paper 09/08/ 2004).

\+ Five cases considered

- Base Case
- Case 1. Project cost overrun by 10 %
- Case 2. Power value reduced by 10 %
- Case 3. Construction period extend by 12 months
- Case 4. Worst case

REFERENCES

[1] Young.M, Vilhauer.R, 2003, 'Sri Lanka Wind Farm Analysis and Site Selection Assistance', Global Energy Concepts LLC, Kirkland, Washington, Page 4.

[2] Fernando.K.S, Kariyawasam.P.L.G, Alwis.A.M.A, 2002, 'Wind Energy Resource Assessment - Puttalam and Central Regions of Sri Lanka', Ceylon Electricity Board, Sri Lanka.

[3] Elliott.D, Schwartz.M, Scott.G, Haymes.S, Heimiller.D, George.R, 2003, 'Wind Energy Resources Atlas of Sri Lanka and Maldives', National Renewable Energy Laboratory, USA.

[4] Course notes of Wind Energy Training Program published by Espace Eolien Development, France.

[5] 'Wind Energy Resources Assessment Southern Lowlands of Sri Lanka', Ministry of Power and Energy, Ministry of Foreign Affairs, Sri Lanka.

[6] Thambyahpillay.G, 1958, 'Rainfall Fluctuation in Ceylon, Part 1', (Lecture delivered to the Ceylon Geographical Society on 17 th November, 1958).

[7] 'RFP for the Establishment of Wind Power Plant on Build, Own and Operate Basis Volume 1: Instruction to Project Proponents', Government of Sri Lanka, Ministry of Power and Energy, Sri Lanka, Ceylon Electricity Board, Sri Lanka.

[8] Danish Wind Industry Association, 'Wind Energy Reference Manual' (online),
Available From: www.windpower.org, (07/06/2003).

[9] AWS Truewind LLC, 'wind Mapping' (online), AWS Truewind LLC, 255 Fuller Road, Suite 274, Albany, NY 12203,
Available From:
www.awstruewind.com/inner/services/windmapping.htm,
(08/06/2003).