Potential for Significant Wind Energy Utilisation at Antarctic Stations

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INTRODUCTION

Since the 1950s, the remote and inhospitable Antarctic region has seen the establishment of many permanent scientific stations. Highly reliable, continuous power is required for both the continuity of research activities and a satisfactory level of comfort for the expeditioners. Although continually improved, the stations' energy systems still rely on conventional, fossil-fuelled generator sets and boilers. Technical difficulties and reliability concerns have limited the use of renewables to small-scale, field installations and prototype or demonstration units.

Environmental and logistical concerns, along with technological evolutions, have recently provided an incentive for a move away from the reliance on imported fuels to using renewable systems. A cooperative French-Australian project is aimed at evaluating the possibilities of, and developing plans for, such a move at the two nations' Antarctic research stations. Preliminary studies identified wind power as the most promising solution for immediate implementation (Guichard, 1994) and field trials of a 10 kW turbine at Casey Station provided encouraging results (Brown et al., 1996a).

Current work now focuses on the detailed evaluation of the wind power potential and on the identification of suitable installations and implementation plans. After a brief discussion on possible turbines, this paper gives an overview of the wind energy production potential at the stations and outlines the options considered for implementation.

POSSIBLE WIND TURBINES

The problems of finding suitable turbines for Antarctic sites have been discussed in Guichard et al. (1996). In brief, the strong, consistent, gusty winds, combined with high maximum gusts and relatively cold temperatures, impose high stresses on rotors, causing frequent mechanical failures for most turbines, especially larger machines.

The two main approaches to these problems have been to develop specific prototypes or to adapt the stronger and more reliable existing products. This latter approach has led to the successful operation, since 1984, of 3 kW Northern Power Systems turbines on Black Island in McMurdo Sound and to the ongoing,

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satisfactory validation tests of 5 and 10 kW Vergnet turbines at Kerguelen Islands and Casey Station.

In order to provide a significant amount of the stations' power requirements (which are of the order of 70 to 250 kW average - electrical only), it is crucial to be able to move to larger turbines. The next step will be to identify potentially suitable machines of 50 to 100 kW, assess the possible adaptations and strengthening required, and evaluate and test the reliability of the units. A machine of such size is the Lagerwey LW18/80 (18m diameter, 80kW, rated survival wind speed of 60 m/s). The production potential of the LW18/80 has been estimated, along with the potential of the successful Vergnet GEV 7.10 (7m diameter, 10 kW, rated survival wind speed of 90 m/s).

WIND ENERGY PRODUCTION POTENTIAL

The interior of the Antarctic continent sees extremely low temperatures and light winds, whereas the Antarctic coastal sites and subantarctic islands, where most stations are located, are usually characterised by relatively mild temperatures but powerful, gusty winds. The favourable wind speeds hold good promise for wind energy capture providing that the high gusts do not affect the turbines'reliability. A summary of Air Temperatures and Wind Speeds at selected sites can be found in Guichard et al. (1996).

The kinetic power of the wind is proportional to the density of the air and to the cube of the wind speed. As air density is inversely proportional to temperature, cold regions usually have high air density which results in an increase in the power recoverable at a given wind speed.

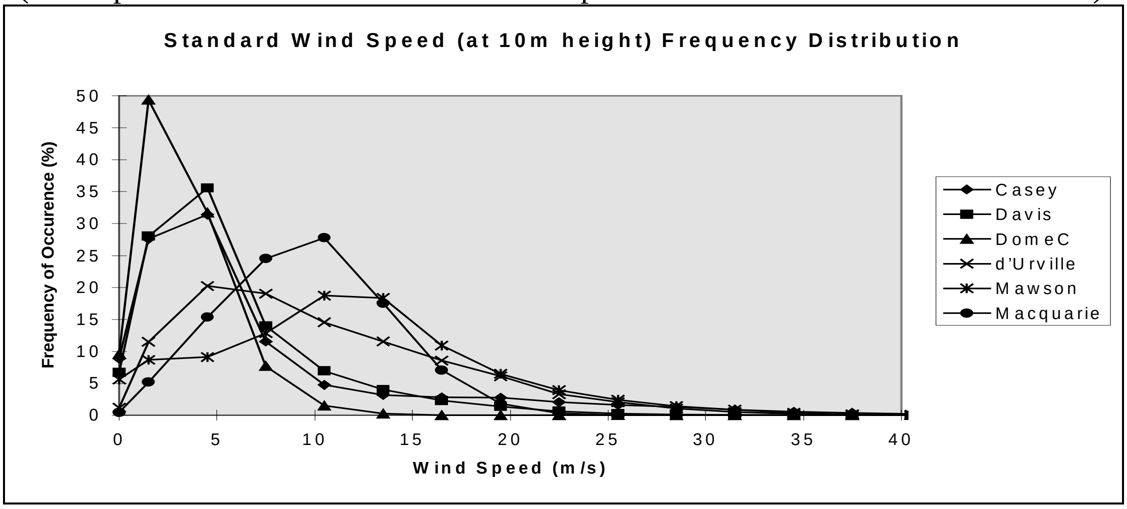
But in the Antarctic, this effect is partially offset by lower atmospheric pressure, as air density is also proportional to pressure. Standard 3-hourly pressure (P), temperature (T) and wind speed (V) data was used to correct actual wind speeds (V) to equivalent 'Standard' speeds (Vs) producing the same power in a standard atmosphere of Ps=1013 hPa and Ts=15°C.

Principal characteristics of six stations are summarised in Table 1 and the frequency distribution of Standard Wind Speeds (Vs) are illustrated in Figure 1. Casey, Davis, Dumont d'Urville and Mawson are coastal stations located around 66 to 68°S between 62 and 140°E. Dome C is an inland site around 75°S, 124°E and 3200m elevation. Macquarie is a subantarctic island at 55°S and 159°E.

Table 1: Principal Characteristics of Selected Antarctic Station Sites
(Averages based on 3-hourly data for full years -no seasonal bias-)

Station	Average Temperature T (°C)	Average Pressure P (hPa)	Maximum Wind Speed at 10m V (m/s)	Average Wind Speed at 10m V (m/s)	Average Standard Wind Speed at 10m Vs (m/s)
Casey	-09.25	982	80.8	6.46	6.56
Davis	-10.11	986	57.1	5.10	5.19
Dome C	-50.80	644	17.4	3.03	2.84
Dumont d'Urville	-10.89	982	90.0	9.60	9.80
Mawson	-11.27	987	50.9	11.22	11.44
Macquarie	+04.70	998	28.8	9.45	9.51

Figure 1: Frequency Distribution of Standard Wind Speed (Vs) at 10m Height
(wind speed corrected to the standard atmospheric conditions of 1013 hPa and 15°C)



The "Standard Wind Speeds" can then be used in combination with the manufacturers' characteristic output curves (at standard atmospheric conditions) of given turbines to evaluate power output. Table 2 indicates the results obtained for the 10 kW Vergnet GEV 7.10 and the 80 kW Lagerwey LW 18/80. Height corrections follow the "Power Law Method" [V/Vo=(H/Ho)^α] using a coefficient α=0.1 (Gipe, 1995). The annual fuel savings (per 100 kW of installed capacity - equal to 10x GEV7.10 units or 1.25x LW18/80 units) are based on an electrical efficiency of 0.35 for a generator set using diesel fuel of 9.8 kWh lower heating value per litre (Guichard, 1994). The relative capital cost index is based on the current listed price of the wind turbines with their masts and does not take into account any projected installation and maintenance costs. Therefore, although it is legitimate to infere from those results that larger turbines should be cheaper 'reliability permitting', the index should be used mainly for comparisons between stations. As expected, the inland site of Dome C has a low potential in terms of wind turbine utilisation factor, but the extremely high costs of delivering fuel to such a location could still make wind power viable.

Table 1: Output Estimates for Two Selected Turbines
(Long term average, corrected for height, temperature and pressure, turbulence factor 0.85)

Station	GEV 7.10 on 18m mast			LW 18/80 on 30m mast		
	average utilisation factor	annual fuel savings per 100kW (l)	relative capital cost index	average utilisation factor	annual fuel savings per 100kW (l)	relative capital cost index
Casey	0.230	58 780	1 222	0.170	43 450	529
Davis	0.214	54 690	1 313	0.183	46 770	492
Dome C	0.050	12 780	5 620	0.049	12 520	1 837
Dumont d'Urville	0.530	135 450	530	0.414	105 810	217
Mawson	0.678	173 280	414	0.526	134 430	171
Macquarie	0.643	164 330	437	0.541	138 260	166

INTEGRATION OF WIND POWER

Typical, major steps towards the integration of wind power into the stations' generation systems are, in ascending order of capital cost: (1) direct connection (with no additional regulation on the diesel generator sets, wind power limited to 40% penetration); (2) addition of limited power regulation to allow 100% penetration and intermittent operation of the diesel generators; and (3) the inclusion of energy storage with two way inverters sized to take all excess wind power and supply all station load. Preliminary modelling (Brown et al. 1996b) seem to indicate that step 2 (limited power regulation) at the windy sites of Mawson and Macquarie is optimal, with installed capacities of 250 and 70 kW respectively meeting 60% of the station electrical needs, and step 1 (direct connection) at the less windy sites of Casey and Davis provides the most cost effective results.

CONCLUSIONS

There is considerable potential for the application of wind power at Antarctic station sites. Space available for wind farms within the stations is usually limited and a high level of replacement of diesel power by wind power generation would require either a dramatic decrease in station requirements or larger-sized wind generators. The key is to be able to move to larger turbines. Although it might be unrealistic to find a turbine of several hundreds of kilowatts which would resist the highest wind speeds ever encountered at Dumont d'Urville Station (90m/s or 324 km/h), resistant medium-sized turbines could meet a significant proportion of the power required by the scientific stations.

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