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FALKLAND ISLANDS:
WIND POWER EXPLOITATION

A FEASIBILITY STUDY

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SUMMARY

This report was commissioned in order to study again the economics of generating electrical power using Windmills on the Falkland Islands.

Examination of weather records for the islands shows clearly that the potential for wind power generation is very favourable. The wind pattern is very steady, with neither appreciable diurnal variation nor appreciable variation in mean monthly values of windspeed. In addition the Falklands rarely experience serious gales.

At present the generation of electricity on the Falkland Islands is almost exclusively performed by diesel powered generators, the size of which varies from one to hundreds of kilowatts. Because of the relatively high delivered cost of diesel fuel, it is shown that well-proven windmills could begin to offer a return on investment after about five years, depending on the future diesel price, if installed into the Port Stanley network.

The economics of installing medium-sized (about 40kW) machines in the larger settlements would follow similar trends to the case of Port Stanley. Small machines, for installation where requirements may be below 20kW for example, cannot be summarised because of the unique requirement for each individual circumstance. However it can again be stated that, especially for locations where the wind resource is well documented, it may be advantageous to install wind powered generators.

It is concluded that a single 50kW wind turbine machine should be installed into the Port Stanley network and such an installation should show a payback of about five years.

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1.0 INTRODUCTION

Interest of the Falkland Islands Government in the possibility of using the abundant wind energy of the islands has been long standing and led to two earlier pieces of work (1, 2). The most recent study, undertaken in 1978 by the ERA recommended the introduction of a prototype machine of 1MW capacity into the Port Stanley electricity network, there being no alternative suitable machine on the market at the time. The resulting proposal was felt to be uneconomic by the Government and there were misgivings expressed over the introduction of an untried machine into a fairly hostile and isolated environment.

Since 1978 the manufacture of wind turbines has become widespread and products have matured to a commercial stage, particularly in machine capabilities of up to 250 kW. (The current world scene is discussed in Section 2.0). Machines, particularly in Denmark and the USA, have been in operation for several years and those of many manufacturers have accumulated considerable machine-years of electrical generation into local electrical utility networks. There has been an associated maturing of autonomous units which operate with diesel generators or into battery storage.

The main energy demands of the island communities were, when the study was conceived, at Port Stanley (the capital) and at the larger settlements of Goose Green and North Arm. There are understood to be generators of 100kVA and 30kVA respectively at these two settlements. Smaller settlements and isolated homesteads have a variety of small diesel generators from 1.5 to 25kVA. (3). The recent war has caused a substantial garrison to be added to the island population, with power demands reported to be about 10MW, but for the purposes of this study it is assumed that civilian generation systems will be operated separately to the military systems.

If recommendations of the Shackleton report (4,5) are implemented, the general camp environment may be subject to redevelopment into some smaller units and additional small generating units may be required. Reference (5) suggests that funding be made available for these decentralisation proposals.

Other developments have been discussed in (5) for possible introduction in the near future which will require an electrical or heat input, (horticulture, for example). Such developments are being operated in Europe using significant wind generated energy as an input and experience may be read across to the islands. With peat as the sole local energy resource, fuel oil has been imported until recently from South America and the U.K. Current supplies are through Ascension Island. Reference (5) reports that local energy costs have risen by 20% in real terms in the period 1979 to 1982, and there is a wide disparity in fuel costs between the capital and the camp. Current oil prices are reported to be 17.2p/l in Port Stanley (retail).

2.0 THE CURRENT WINDPOWER SCENE

Drawing on an ancestry of several hundred years, prewar experiments to harness the energy in the wind took place in France and Russia, among several countries, with the intention of generating electricity. Prior to and during the last war, a USA project sought to harness mountain top wind energy in Vermont using a wind turbine capable of producing 1.25 MW of electrical power for the local utility network. During the same period Denmark was exploiting their much lower wind regimes with many machines providing network quality electrical power, thereby conserving diesel fuel.

In the 1950's a significant programme of wind power research was underway in the UK, culminating in proposals for three test machines which were subsequently installed. Other countries were also active in the field. However, the advent of proposed cheap nuclear power brought much of the work into decline, but with Denmark being an exception. A 200 kW machine at Gedser which still stands and is operational, produced network quality electric power for 25 years.

Following the oil crisis of 1973, several countries looked again at alternative resources and wind energy was reconsidered.

In the UK the national programme has taken time to mature, but concurrent with Energy Paper No. 21 (dealing with electrical energy generation from the wind) (6) several projects were underway and some were initiated. In the medium machine field, two projects were using hydraulic fluid as the power transfer medium, to provide in one case, high quality electricity and the other, heat for horticultural use. Research and academic institutions began to investigate small scale vertical and horizontal axis machines, (the former three arrangements; Darrius, gyromill and the Musgrove type, the latter four arrangements; two-bladed, three-bladed, a sail wing and a multiblade). Two commercial organisations developed different types of horizontal axis machine; for water heating and high reliability electrical generation. In total a wide spectrum of wind turbines were being developed with a variety of end uses.

A large machine to generate utility quality electricity was conceived in 1976/7 and a scaled down version proposed for installation on the Falkland Islands and St. Helena in the earlier study.

The UK programme has gelled with the thrusts directed towards the horizontal axis and a vertical axis machine capable of utility quality electrical generation, perhaps using offshore sites. Smaller units are being planned and built for the initial evaluation and these units form the basis of possible machines for installation in the Falklands. Ratings are around 250 kW. The horizontal axis machine is expected to be running in mid-1983. UK commercial concerns continue to plan and develop machines in the small and medium range and these will be considered in the evaluation.

Compared with some other countries the UK scene did not have the benefit of (i) a large home market, (ii) a utility willing to purchase excess electricity, or iii) vigorous political interest (muted perhaps by the advent of North Sea Oil). Other countries have these advantages and with the addition of tax credits a fertile environment for development was the result.

ERDA, the USA Energy Authority, laid down a long-term programme and commercial Danish manufacturers began to market machines based on the Gedser design. By 1978 many countries had formulated programmes for wind energy exploitation. Against this background a few small machines continued to be marketed-mainly water pumps-but including a few electrical generators, in Australia, Switzerland, France, the USA and the UK.

These national programmes are coming to maturity but generally are related particularly to large machines, greater than 1 MW, although machines of suitable size for some Falkland installations have been used in the first stages of programmes. Activities relating to smaller and medium machines has been intense in the USA and Denmark and these sizes of machine have been put into production, gaining field operational experience. The USA and Danish programmes have been testing commercial machines run at special test sites and more reliable machines have resulted with improved safety aspects, with some being withdrawn from production. Other countries are developing similar sites.

A result has been that the most viable small and medium machines are found in the US and Danish markets with some individual machines from other countries.

3.0 FEATURES OF WEATHER PATTERNS AROUND THE FALKLAND ISLANDS

This region of the South Atlantic has a weather pattern which results from a steadily declining pressure southwards from the subtropical anti-cyclones. The pressure does begin to rise again near Antarctica. Because of the pressure gradient, the region experiences mainly Westerly Winds. Occasionally depressions from the North West round to South West can give rise to winds from other quarters. The islands lie in the lee of South America, separated by about 500 Km of (relatively) cold sea. This, and the influence of the Andes, leads to a fairly dry climate in the islands. Frequent passages of fronts means that the weather in the islands is very variable, and the range of pressures experienced over the Falkland Islands is similar to that in the region between Iceland and Great Britain. Both regions are subject to a continual procession of more-or-less regular low and high pressure systems. However, an important difference is that the pressure near the British Isles is often stabilised by prolonged anticyclones over the continent or over the Atlantic Ocean. The anticyclones affecting the Antarctic region are nearly always short-lived.

Ships observations to the West and South of the islands indicate (even moreso than observations at Stanley) that the predominant wind direction is virtually always between 225^0 and 360^0. This feature, at sea, is not seasonally dependent to any great extent. Wind roses for the sea area West of the Falklands can be found in (2).

4.0 POWER REQUIREMENTS FOR THE FALKLAND ISLANDS

4.1 Port Stanley

Port Stanley has a population of around 1100 and is served by a modern power station with a maximum capacity of just under 1300 kW. This is shortly to be augmented by a 320 kVA diesel set.

The power used in 1977 was 2.7 GWh with a peak winter load of about 1 MW. The minimum load is about 200 kW, in the Summer. Future peak demand was anticipated to be up to 1.5 MW before the war. The load is dominated by a heating demand (resistive) in houses, government buildings and the hospital. In all, about 600 consumers are connected, by overhead lines, with a total system length of 10 kms. Almost half the total power consumed is taken by the hospital, radio services, water supply, heating and street lighting. Domestic consumption of energy absorbs a little over a quarter of all power generated. Most houses are equipped with the usual domestic appliances, although there is little domestic electric cooking or space or water heating.

Because of the nature of most of the load, it is likely that the Power Factor will run close to unity.

Per capita installed capacity is about 750W (shortly to be increased to about 900W) and the average annual consumption is about 1700 kWh. For comparison, the U.K. figure per capita consumption is 4,200 kWh/annum. These figures are 1976 levels, but the relative comparison is probably still valid and demonstrates that purely domestic power demand in Port Stanley is barely 40% of the U.K. levels. Reference (4) (page 278) notes that the domestic sector share of power usage is unusually low and reflected the relatively high cost of electricity compared to other fuels. At that time (1976) unit heating costs for peat:gas:electricity were about 1:6:48 and it is usual to find that peat is used for domestic heating. Large buildings tend to use oil-fired equipment for heating.

There has been some recent development in Stanley (for example, an 80-children hostel nearby) which has warranted the extra generating capacity shortly to be installed. (7)

Information concerning the garrison at Stanley suggests that the extra generating capacity required will be wholly self-generated and no appreciable use of power produced by Stanley B power station by the garrison is anticipated.

With the proposals for development and expansion of facilities in Port Stanley it is to be expected that the energy requirements will, in future, be increased from their current level.

4.2 Camp Settlements

There are a total of about 35 settlements containing a total of 900 persons throughout the Falkland Islands and these are listed in Appendix 8. Virtually all of them can be considered as isolated communities, and links with the remainder of the islands are principally by sea(cargo) and air(people). All are coastal,with perhaps a third of the settlements being islands off West Falkland; figure 1 shows most of the settlements.

Each settlement is a sheep farm of between 5,000 and 400,000 Acres with its own electrical generating capacity serving the immediate dwellings. The farms are generally well equipped although some new jetties are required. Most remote outhouses have their own (usually diesel) generating sets. As reported in (4) (pp 282-283), the cost of electricity generated in these remote situations was very high compared to Port Stanley. The output from these centralised diesel generators is between 4 and 25 kVA, with voltages at 110 or 230, A.C or D.C. The smaller outhouses are served with air-cooled diesel sets of between 1½ and 4 dVA at 240 V.A.C. 24-hour power availability is not normal; the general policy is to restrict the running of the generation equipment so that a high load factor can be maintained for short periods. During certain seasonal periods (e.g. shearing) then some settlements may generate power all day. There are two of the larger settlements (Fox Bay East and Port San Carlos) where diesel generators are connected to batteries to give D.C. power at 110V. In addition it is noted that Goose Green has about 100 kVA available for its 140 inhabitants and that North Arm has a 30 kVA set. Battery storage is not wholly suitable for domestic-type loads (special electrical equipment or D.C/A.C converters are required) and the batteries require some maintenance and have operational lives of about 10 years (4 , p 282).

Other requirements for power within the camp include the major seasonal load of sheep shearing. It is policy to extend the shearing over as long a period as possible, because of the energy availability (early November - mid January). In addition, regular sheep husbandry (spraying, dipping) does require small amounts of power, as does the electric fencing which has been introduced as a cost-saving over conventional fencing. Power to run such fences has come from batteries or wind generators of up to perhaps 300W.

5.0 GENERAL WIND TURBINE REQUIREMENTS FOR THE SETTLEMENTS

There are three levels of demand required by the settlements; large scale in Port Stanley, medium scale at the larger settlements and small scale in many of the camps and isolated homesteads.

The Falkland wind resource is excellent, but there will be times of low wind with insufficient energy to operate a wind turbine generator. An example of power available from a medium sized wind turbine operating in a small utility network is shown in Fig.2, the wind regime being similar in mean value to the Falklands. Clearly, if a firm supply is required a diesel generator must be included in the system, particularly to cover the periods of low wind speed.

Figure 3, showing a typical performance curve, can be used to define the terminology used. Wind turbine sizes and ratings for the various communities are discussed in detail in the following sections.

5.1 Port Stanley

In order to establish the general requirement for a machine (or group of machines) best suited to Port Stanley's power demands, a series of notional wind turbines of various ratings (both in size and power) have been matched to the known demand (Table 1) and the wind data (Table 2). The result of this matching is shown in Figure 4, where seven wind generator ratings are depicted along with seven diameters. It should be noted that the indicated diameter could represent the total rotor area of a multiple installation.

At given rated wind speeds wind turbine contributions increase as rotor diameters are increased and as generator ratings are increased, as may be expected. However, for a given generator rating the contribution to the system increases as the rated wind speed decreases, as additional energy is extracted from the more frequent lower speed winds. The penalty for the increased contribution is an increased rotor diameter, which for larger contributions to the system increase markedly for smaller increases in contribution.

If given diameter machines are considered, as rated wind speeds are increased, contributions rise to a maximum with increased generator ratings, and then begin to fall away. The higher rated wind speed machines fail to harness the more frequent lower speed winds, and because output powers are large at higher wind speeds the wind contribution is at times in excess of demand.

It may be noted from the curves that a turbine with a generator rated between 300 kW and 400 kW provides the most substantial contribution, with contributions increasing with rotor diameter,(but to a lessening amount).

For a given diameter, the careful selection of rated wind speed is crucial, especially when larger diameter machines are considered, in order to give the maximum penetration, although if the cost of fitting slightly larger generators is not significant, a larger than optimum wind speed does not give rise to large penalties.

If several machines are to be considered for the wind power station, there will be a small advantage in rating each machine at the optimum level for the group. This increases the contribution by 1%, worth 2.7 MWhr/annum.

5.2 Large Settlements

Some are reported to have diesel generators in the range of 30-100 kW rating and a similar matching of wind energy to power demand as that used for Port Stanley can be constructed. A minimal overnight demand has been assumed, along with an idealised daytime demand.

Fig. 5 shows such a series of curves where again each point on the graph represents a particular turbine. A minimum diesel operational limit has not been included in the computation. The general character of the curves is similar to those for Port Stanley, and the general discussion of the last section applies.

In these cases the optimum rating for the wind power of plant is around 100 kW, for an 8.1 m/s mean wind site, with contributions increasing as rotor diameter (or an equivalent total) are increased. A multiple machine approach would again entail the ratings of machines being set to that of the equivalent single machine to give the optimum output.

5.3. Small Settlements and Individual Dwellings

A range of diesel generators are reported to exist for these sites, from 1.5 KVA to 30 KVA. At this stage it is impossible to produce a set of generalised curves for wind energy and load matching because of the variety of applications.

Using a mean wind speed similar to that of Stanley, the performance of a variety of small wind generators has been calculated and compared to the performance of small (3 hp, 2.25 KVA) diesel generators providing the same total output assuming that all the wind generated output is useable. The wind turbines are a selection of those currently available in the West and four notional base line designs with a common diameter, but different ratings have been included for comparison. Machine details are given in Appendix 2.

Two criteria have been considered :-

(a) Operational cost
(b) Energy output

Alongside these, firmness of the output is important. Firmness, which is based upon the wind availability, can be increased by employing a large diameter rotor or a generator which provides an output at low rotational speeds. A value relating to rotor area has been computed to highlight the smaller machines' performance and an absolute value of 500 watts output to highlight the larger sizes performance.

Considering the 6m diameter notional machines first of all, the most cost effective is the machine with the highest generator rating, (6kW) and the highest rated speed, (11 m/s). However, the supply is not firm at 58% for the 500 watt output level. Electricity is predicted to cost 4.4p per unit compared to power provided by two diesel units using 17p/l oil giving equivalent total power (kW hr) at 7.8p/ unit. A firmer supply is given by a 6m diameter machine with a 3.5 kW generator with the turbine rated at 9.0 m/s, but at a cost of 6.0p/unit.

Of the selected commercial machines, the Swiss made Electro WVG 50G with a generator rating of about 5 kW is predicted to provide power at 5.9p/unit, but the firmess of the supply is less that 50%. The annual output is estimated at approximately 15,000 kW. If firmness of supply is a criteria, the Aerowatt 4100 can provide 500 watts for 84% of the time and gives a substantial output of 24500 kWhr, but to be economic when compared with two 2.25 kWhr diesels the local oil price must be in excess of 24p/l.

Full details of the predictions for twelve machines with outputs varying from 200 watts to 5.0 kW ratings are given in Appendix 1. Ratings for the notional machines ranged from 1 kW to 6.5 kW.

6.0 POSSIBLE WIND TURBINES

6.1 Windmatic and other medium/large machines

The Windmatic range of wind turbines are based on the design of the long run Gedser machine which were introduced in the mid-1970's by Riisager, this company subsequently being taken over by Windmatic. At the present, Windmatic are part of the Holec group, and have approximately 90 machines in operation in Denmark. Machines in the product range have been tested at the Danish wind turbine test site at Riso and at the German test site at Pellworm, At the latter site high winds subjected the machines under test up to their limits.

Windmatic machines are available in Great Britain, being marketed through NEI Clark Chapman (now IRD) and have been installed on South Ronaldsay (Orkney), Fair Isle, off the Irish coast and at other sites. The island sites are subject to mean wind speeds similar to that of the Falkland Islands.

It has been found that the equipment, although conceptually good, is lacking in welding quality and some dimensional shortcomings have been noted. The machine destined for the Orkney Islands was subject to some remedial work prior to installation. During installation of the Tristan da Cunha machine several parts had to be redrilled in order to line up with the mating part.

In addition to the Windmatic range of machines rated around 50 kW there are several comparable machines produced in Europe. Details of some of these machines are presented in Appendix 2 , from which it is apparent that, because of the diverse operating régimes which can be encountered and the varying machine ratings it is necessary to choose carefully for optimum matching. Although no direct experience of the machines has been gained (except for Windmatic) it is known that examples of the various makes are in abundance, particularly in mainland Europe. It is also noted that there is a marked price difference between similar machines.

Machines of more than about 100 kW rating are more scarce, but it is known that this larger type of machine is being actively pursued by several European manufacturers.

Among the known examples, Howden market a machine of about 300 kW (see Appendix 2) and Polenko are producing similar machines (but at a lower price).

6.2 Small Machines (<20 kW)

There are many machines in production with outputs from a few watts through the range up to 20 kW or so. In addition, many organisations market tailor-made packages comprising a wind-turbine matched to battery storage and diesel backup, with electronic packs giving automatic control for stand-alone situations.

The choice of which machine would best serve a particular requirement is perhaps not so crucial as when considering the large machines. Nevertheless, care should be taken to ensure that the site candidates are evaluated diligently in order that advantage can be taken of the localised conditions.

Reliability and (for example) a feature which automatically restarts the machine after a shut-down due to high winds may be very important features when considering a remote, stand-alone case. Although windmills are not especially complex machines it is usually found that some attention is necessary at least every month.

7.0 SYSTEM COST ANALYSIS, PORT STANLEY

The brief for the study (8) identified a Wind Matic wind turbine for particular consideration and the relevant performance data and costs have been used in the analysis. A British machine is expected to be available in the near future and this also has been considered in the analysis. The wind resource employed is that at Port Stanley.

7.1 Unit Detailed Costs

Each machine installation will incur freight, installation and instrumentation costs and for the higher levels of power generation from a multi-machine installation or a larger machine, a dump load (which could harness excess energy usefully) must be included to protect the system from sudden surges of power onto the grid and absorb energy in the event that the diesel generators are becoming underloaded. In consideration of a multi-machine installation, some costs can be spread over several machines; for example spares, technical back-up and transmission components.

The costs of small machine installation are as follows and are based on the Tristan da Cunha installation, with latest manufacturers costs and quotations.

Model	Price	Delivered and fully installed
WM 14S (x1)	£ 25,500	£ 39,050
(x2)	£ 51,000	£ 80,350
(x3)	£ 76,500	£117,900
(x5)	£127,500	£193,000
HPW 200	£230,000	£300,000 (9)

WM 14S Installed costs include:

Transport & packing	£6,000	
Installation & foundation	£3,300	
Spares	£1,000	for first m/c
	£2,000	for five m/c's
Maintenance allowance	£1,250	each machine (annual charge)
Dump Load	£5,500	for second m/c + £50 for each additional machine
Local labour and equipment hire	£2,000	covering commissioning problems
Contingency charge (for first m/c only)	£1,250	

HWP 200 Maintenance allowance of 2½% of basic machine cost assumed per annum

7.2 Contribution to the Stanley Network

	WM 14S				HWP 200
	1 off	2 off	3 off	5 off	
Mean Contribution (%)	6.0	11.75	16.4	23.75	15.41
Diesel-generated units saved (kWhr)	164759	322653	450342	652172	423157
† Fuel saved, gallons	9513	17925	25019	35232	23509
Cost saving (£) 1)Fuel £.73 per gallon	6944	13085	18264	26449	17161
2)Fuel £1.00 per gallon	9513	17925	25019	36232	23509

† See Appendix 3 for discussion of fuel oil conversion to power at 18.0 kWhr/gallon.

7.3 Long Term Machine Operation

The economic potential for wind turbines needs to be measured in the light of inflation and rising fuel prices. Figure 6 shows the effect of various discount rates and fuel price increases in real terms on fuel savings. These savings are made non dimensional by dividing the fuel cost saved in present value terms in a particular year by the nominal yearly savings. Higher discount rates reduce the effect of savings and offset fuel price rises in real terms.

Installed costs of particular machines are plotted in Figure 6 including an allowance for maintenance and an annual charge. These costs are also non-dimensionalised by dividing the costs by the nominal fuel savings predicted for each model. These costs, in present value terms, rise with time because of the maintenance charge.

	WM 14S				HWP 200
	1 off	2 off	3 off	5 off	1 off
Initial m/c values £	39050	80350	117900	193000	300000
Cost savings of fuel @ £0.73/gallon	6944	13085	18264	26449	17161
non dimensionalised	5.62	6.14	6.46	7.30	17.48
Cost savings of fuel @ £1.00/gallon	9513	17925	25017	36232	23509
non dimensionalised	4.10	4.48	4.71	5.33	12.74

Referring to Figure 6 the break-even running period is indicated by the intersection of the machine cost curves and the fuel savings for the relevant discount rates and fuel price rises.

Simulations were also run in the 10.8 m/s Sapper Hill wind régime where the higher rating of the HWP.200 may be expected to show some benefit and the contributions of that machine and the equivalent small group are given. An allowance for running a transmission line to Sapper Hill is omitted.

Installed m/c	HWP 200	W/M type (3 off)
value £	300,000	197,000
Contribution %	22.81	22.61
Fuel savings, gallons	34800	34500

Although the contributions are increased by over 40%, there is only a marginal improvement in comparison to an installation of three machines at the same site.

7.4 Sensitivity Analysis (Fig. 7)

It is not possible to undertake an analysis for the various sites on the islands, but it is helpful to consider the effects of various parameters acting individually on the economics of a 30 kW machine operating in a 100 kW small diesel powered utility.

Changes in the levels of spares and maintenance as a proportion of machine first cost have little effect of pay back periods, but increasing the machine size to be installed and reducing the installed cost begin to show significant effects. A reduction in wind speed or an increase in discount rates both have dramatic effects on pay back times. A windspeed at .8 of the base value shows the 30 kW installation to be completely uneconomic. Raising the windspeed does not have such a marked effect, although it is significant. The discount rate reduction or rise in fuel price in real terms is very significant.

8.0 SITE INSTALLATION AND SUGGESTED PROGRAMME (PORT STANLEY)

The large machines available from Europe (Denmark, Holland) are for direct network connection and are fitted with extensive protective features from both the user and utility points of view. Appendix 4 gives details of the requirements which are laid down for Danish machines connected to their grid.

The Windmatic type of machine produces 3 phase, 380V, 50Hz power and connection to the Stanley network would need to be through a step-up transformer to the normal 3,300V. Circuit breakers must be incorporated at the wind turbine and at the main transmission line. A power meter, logging the total power produced, should be fitted alongside each turbine control unit.

A schematic pictorial view of the installation is shown in Fig.8. A possible installation for a group is shown in fig. 9.

P.W.D. are expected to have general electricians competent to undertake some local installation work, but there appears to be no manufacturing capability for galvanised steel towers for example, which could have given a substantial local input.

Ideally, installation should start at the beginning of Summer (September/ October). Figure 10 is a bar chart which suggests the timing of the project, assuming that the design stage and associated consultations lead to the order of a single unit, even if a multiple-unit installation is the final object.

There will need to be a site visit unless more details can be made available and several other candidate machines will need to be examined, apart from the Windmatic machines.

Shipping is assumed to be via Ascension Island.

It is concluded that an elapsed time from go-ahead to machine operation is about 9 months, given a wind turbine delivery of about 3 months.

9.0 DISCUSSION

Wind energy has been harnessed to a small degree on the islands for water pumping and for powering electric fences. Much larger means of harnessing the abundant wind energy have been explored in this study, although small devices have not been ignored.

Port Stanley

The capital, with its well established diesel generating station and distribution network is well able to absorb wind generated electricity up to a significant level. Consumption data available for the analysis have been based on 1977 values for the demand. While it is known that the maximum levels have increased, it has not been possible to establish the current demand pattern. The optimum predicted levels of wind energy contribution are likely to be a little higher than anticipated because the estimates are conservative for two reasons. Firstly, a higher demand is expected for 1982 and beyond and secondly, a prediction has been made in the wind energy available to simulate a lower-than-average wind speed year.

A simple machine of the Wind Matic type (induction generator), installed in the Murray Heights region and connected into the network is predicted to pay for itself in terms of fuel saving in 4½ to 7 years, (depending on the fuel price) at a discount rate of 5% and real fuel price rise of 5%. For a wind powered station consisting of a given type of machine (particularly the rated speed) the optimum contribution will be given by a value of installed power of slightly in excess of 300 kW. A group of five Wind Matic type machines rated at a total of 275 kW shows a cost advantage over that needed to match the optimum rating. Also a pay back period of between 6 and 9 years is predicted, (dependent upon fuel costs) at a discount rate of 5% and real price rise of 5%.

Details of two machines have been provided with ratings close to the optimum predicted for the network. A type similar in output and cost to the Howden machine was predicted to have a pay back period in excess of ten years at the higher fuel price, but a type similar to the Polenko WPS 24, with a higher predicted contribution to the network and a lower installed cost, is estimated to have a pay back period of less than 7 years at the lower fuel cost.

For a given machine availability, output being to a finite network, it is slightly more advantageous to consider a multi-machine arrangement than a single machine arrangement. More significant is the firmness of supply, which falls to zero in the case of a single large machine failure.

Predictions have assumed the wind régime at Port Stanley because this is well documented and based on long-term averages. A turbine installed in the Stanley area will operate at a greater height than that used to measure the wind resource and there may be some increased wind energy as turbine height increases, but velocity profiles on such a rounded ridge as Murray Heights are not simple to predict. Sapper Hill, 3 km away from Stanley, does show a markedly higher wind speed than Stanley (by 24%) and a group of 5 Wind Matic type machines installed at that site provide an increased contribution of 32% and a single Howden type machine an increased contribution of 48%.

To exploit this higher speed regime, 2 km of transmission line must be installed and the machines will need to withstand a much harsher environment. Ready access will be more difficult especially in conditions likely to cause machine problems.

It must be noted that the prediction for contributions from five Wind Matic machines installed on Murray Heights is similar to that of a single Howden type machine installed on Sapper Hill.

Large Settlements

Where a large diesel generator is currently in operation, fuel could usefully be saved by the incorporation of a wind turbine in the 40 kW range, although the addition of a load dump to the system may be necessary to absorb energy surges from the turbine and maintain a reasonable output level from the diesel engine.

Demand levels and fuel costs were not available to make detailed predictions, but with the expectation of higher fuel costs in Camp and bearing in mind the recent installation of the Tristan da Cunha wind turbine (10) a wind powered generator is anticipated to be an economic proposition.

Small settlements and isolated homesteads

These will have a variety of requirements and a range of generating plants. To provide a general impression of the benefit of introducing wind generating plant, the operation of a variety of small machines has been predicted, and the generating cost compared with the operation of a small diesel generator (2.2 kW each). Results are discussed in Section 5.3. A requirement for a relatively firm supply can be met by a comparatively large diameter turbine providing the rated power at a low rated wind speed, but a larger output may be expected from a machine with a higher rating, giving this at a higher rated wind speed.

The analysis included the costs of an inverter or small battery pack in the wind turbine package.

10.0 CONCLUSIONS

10.1 Port Stanley

- A single wind turbine rated at around 50 kW in an 11 to 12 m/s wind is estimated to have a pay back period of 4½ years assuming a 5% discount rate, a 5% price rise in fuel costs in real terms, at a fuel cost of £1.0/gallon. This is for a Port Stanley installation. It is predicted to provide 6% of the electrical energy demand.

- A group of five turbines rated in a similar manner to the single machine is estimated to have a pay back period of 6 years assuming a 5% discount rate, a 5% fuel price rise in real terms at a fuel cost of £1.0/gallon. 23.7% of the electrical energy demand is estimated as the contribution.

- A single machine rated at around 300 kW in a 16.5 m/s wind is estimated to have a pay back period in excess of ten years and contribute 15% of the electrical energy demand. An alternative machine with a similar generator rating but with a larger diameter rotor and a lower cost which may be available is estimated to contribute 19.8% of the demand with a pay back period of less than 10 years.

- Exploitation of the higher energy wind régime at Sapper Hill will provide a greater return to the Stanley network in energy terms. The site, however, is more remote and at the current stage of wind turbine development it would be unwise to install machines at this site. The results of extended operations of machines at similar sites should be awaited before the resource is considered further.

10.2 Larger Settlements

It is likely that a single machine in the 40 kW range would pay for itself within ten years, provided the wind régime at the site was similar to that at Stanley.

10.3 Smaller Settlements

With higher fuel costs being likely away from the capital, a number of small installations should be viable in the 60 watt to 10kW rating range.

11.0 RECOMMENDATIONS

1. Following a detailed review of currently-available machines (including those of Windmatic) a single wind turbine in the 50kW range should be installed at Port Stanley, and connected into the existing supply network.

2. The provision of a higher contribution from wind energy to Stanleys' power requirements is viable. A detailed review is necessary to optimise the installation. A range of machine powers must be considered for the package because the economics of scale argued for the large machines are not yet apparent.

3. Provision for wind speed measurement for settlements other than Port Stanley has been made. The instruments should be read more frequently and regularly to give confidence in the total island wind resource.

4. Electrical demand and generator operation should be established in detail for the larger settlements and selected isolated dwellings as a precursor to undertaking wind resource/energy demand studies for optimum system design.

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC
0100	198	182	196	208	240	252	263	270	227	220	193	188
0200	193	177	189	206	231	237	250	257	218	212	188	178
0300	187	171	181	201	224	231	244	252	216	209	185	173
0400	175	162	181	188	222	229	243	247	214	206	178	157
0500	165	157	176	184	218	226	241	246	216	205	166	153
0600	173	167	183	212	235	241	255	260	227	202	177	162
0700	200	189	212	238	266	283	289	296	257	234	210	186
0800	296	285	338	339	376	391	411	421	357	354	317	267
0900	346	334	363	412	473	504	495	520	475	409	355	301
1000	363	362	410	426	492	523	515	545	486	435	381	324
1100	350	356	405	411	475	505	504	524	472	411	362	305
1200	325	308	367	375	432	470	467	487	430	374	335	288
1300	261	253	299	318	382	419	416	439	378	317	279	241
1400	284	274	318	331	415	457	454	479	406	346	307	264
1500	289	273	325	360	436	478	477	489	420	349	309	268
1600	281	267	315	354	443	502	483	477	404	340	293	256
1700	249	237	271	333	434	487	473	451	347	284	247	224
1800	238	232	279	399	436	462	479	480	410	277	236	215
1900	245	243	316	400	429	446	470	477	419	302	246	222
2000	256	272	254	388	423	441	464	475	423	352	277	238
2100	278	321	344	359	397	415	435	447	394	373	325	273
2200	302	304	312	323	355	376	397	398	351	345	312	283
2300	245	243	252	272	306	324	340	350	310	284	257	236
2400	211	201	210	231	256	267	289	290	249	233	207	201

TABLE 1 . Mean Power Demand (kw) for Stanley (1977)

HOURS	JAN	FEB	MAR	APR	MAY	JUN	JLY	AUG	SEP	OCT	NOV	DEC
0100	6.9	7.45	7.25	7.65	8.15	7.95	8.3	8.0	7.9	8.0	7.75	7.65
0200	7.1	7.35	7.35	7.45	8.1	7.95	8.3	7.95	7.8	7.95	7.7	7.65
0300	7.2	7.25	7.4	7.55	8.0	7.95	8.25	7.85	7.85	7.8	7.7	7.75
0400	7.2	7.25	7.35	7.45	8.15	7.95	8.35	7.75	7.95	7.75	7.7	7.7
0500	7.25	7.25	7.45	7.55	8.15	8.05	8.15	7.65	7.8	7.7	7.65	7.75
0600	7.3	7.15	7.55	7.45	8.1	7.85	8.15	7.75	7.8	7.85	7.75	8.1
0700	7.85	7.35	7.75	7.4	8.0	7.95	8.1	7.75	7.85	8.15	8.65	8.8
0800	8.45	7.85	8.05	7.45	7.9	8.0	8.0	7.75	8.15	8.65	9.0	9.0
0900	8.85	8.5	8.65	7.85	8.05	8.15	7.95	7.9	8.8	9.35	9.5	9.25
1000	9.05	8.8	9.2	8.15	8.5	8.2	8.15	8.15	9.4	9.5	9.0	9.5
1100	9.25	9.1	9.5	8.85	8.85	8.5	8.5	8.55	9.4	9.85	9.85	9.45
1200	9.35	9.3	9.7	9.0	9.1	8.7	8.95	8.9	9.65	9.95	10.1	9.55
1300	9.5	9.5	9.85	9.1	9.3	8.75	9.0	9.05	9.8	10.1	10.15	9.6
1400	9.5	9.6	9.85	9.2	9.2	8.7	9.0	9.0	9.85	10.25	10.25	9.5
1500	9.4	9.5	9.6	9.0	8.9	8.4	8.9	8.9	9.85	10.25	10.2	9.7
1600	9.25	9.7	9.4	8.7	8.6	8.15	8.65	8.45	9.45	9.55	10.2	9.7
1700	8.9	9.5	8.95	8.25	8.45	8.1	8.35	8.15	8.95	9.45	9.8	9.4
1800	8.65	9.05	8.45	7.85	8.35	8.1	8.3	8.0	8.4	9.0	9.35	9.0
1900	8.25	8.4	7.9	7.75	8.3	8.1	8.3	8.1	8.1	8.5	8.6	8.35
2000	7.7	7.9	7.65	7.75	8.3	8.1	8.2	8.1	8.15	8.15	8.05	7.9
2100	7.25	7.65	7.55	7.7	8.2	8.1	8.2	8.0	8.15	7.8	7.75	7.45
2200	7.15	7.55	7.35	7.65	8.2	8.05	8.2	8.0	8.2	7.8	7.75	7.35
2300	7.1	7.45	7.35	7.55	8.25	8.0	8.3	8.0	8.05	8.0	7.65	7.3
2400	6.75	7.45	7.2	7.45	8.15	8.0	8.3	8.0	8.0	7.7	7.65	7.4

TABLE 2 . Mean Windspeed (m/s) for Stanley (1951-1970)

These figures are plotted as fig. 11.

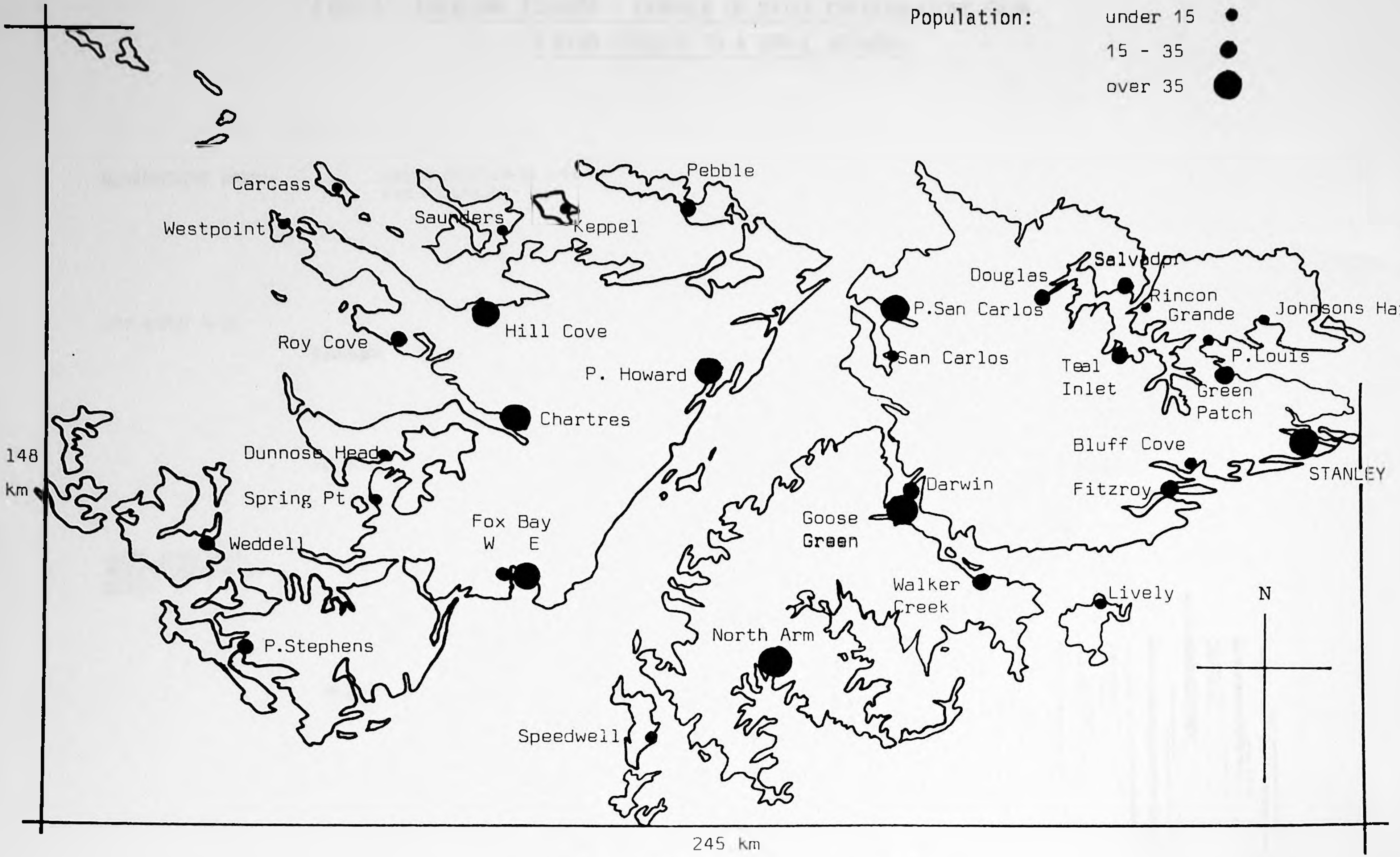
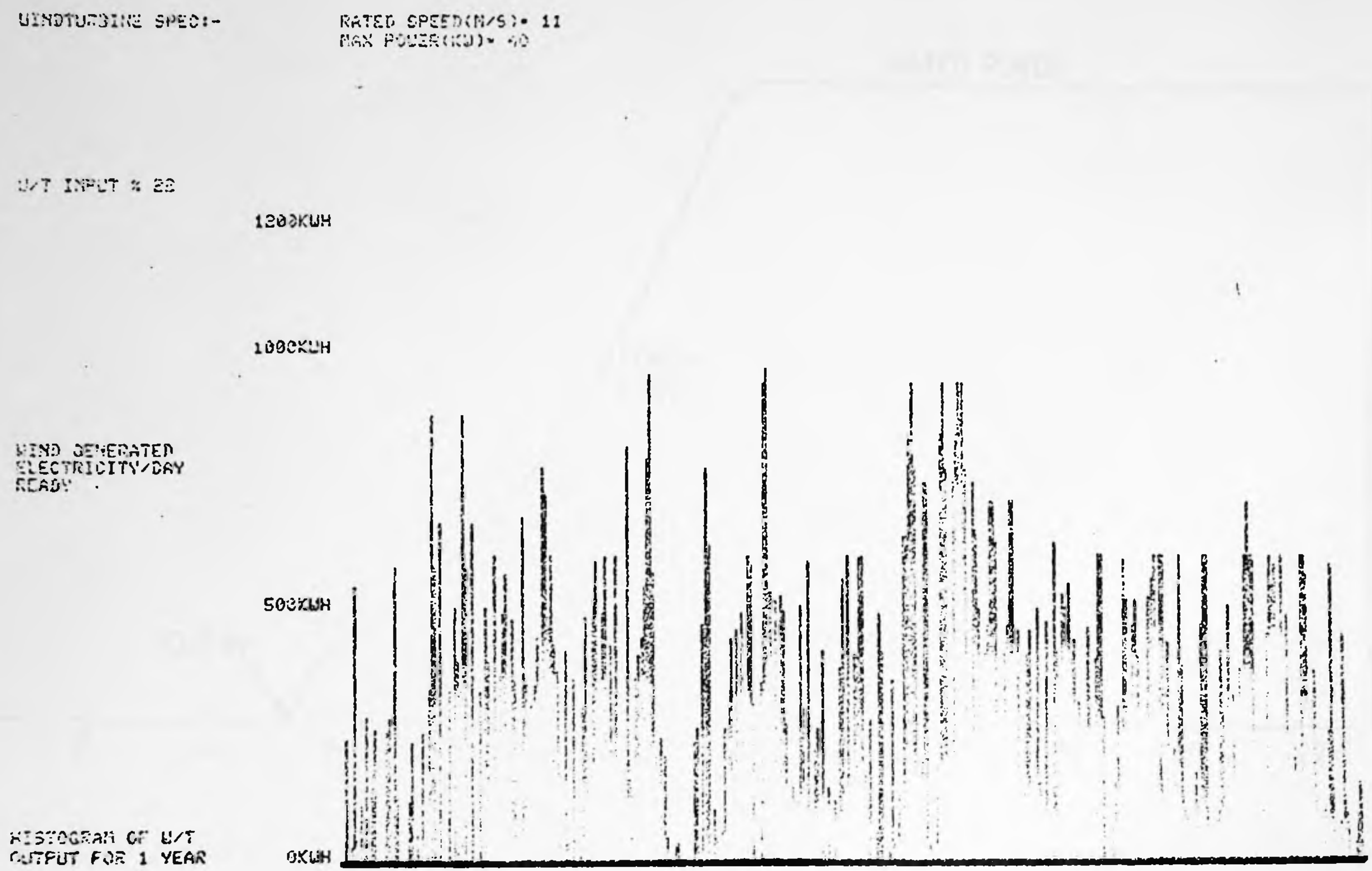


FIG. 1 FALKLAND ISLAND SETTLEMENTS

FIG. 2 FALKLAND ISLANDS - EXAMPLE OF DAILY CONTRIBUTIONS FROM A WIND TURBINE TO A SMALL NETWORK



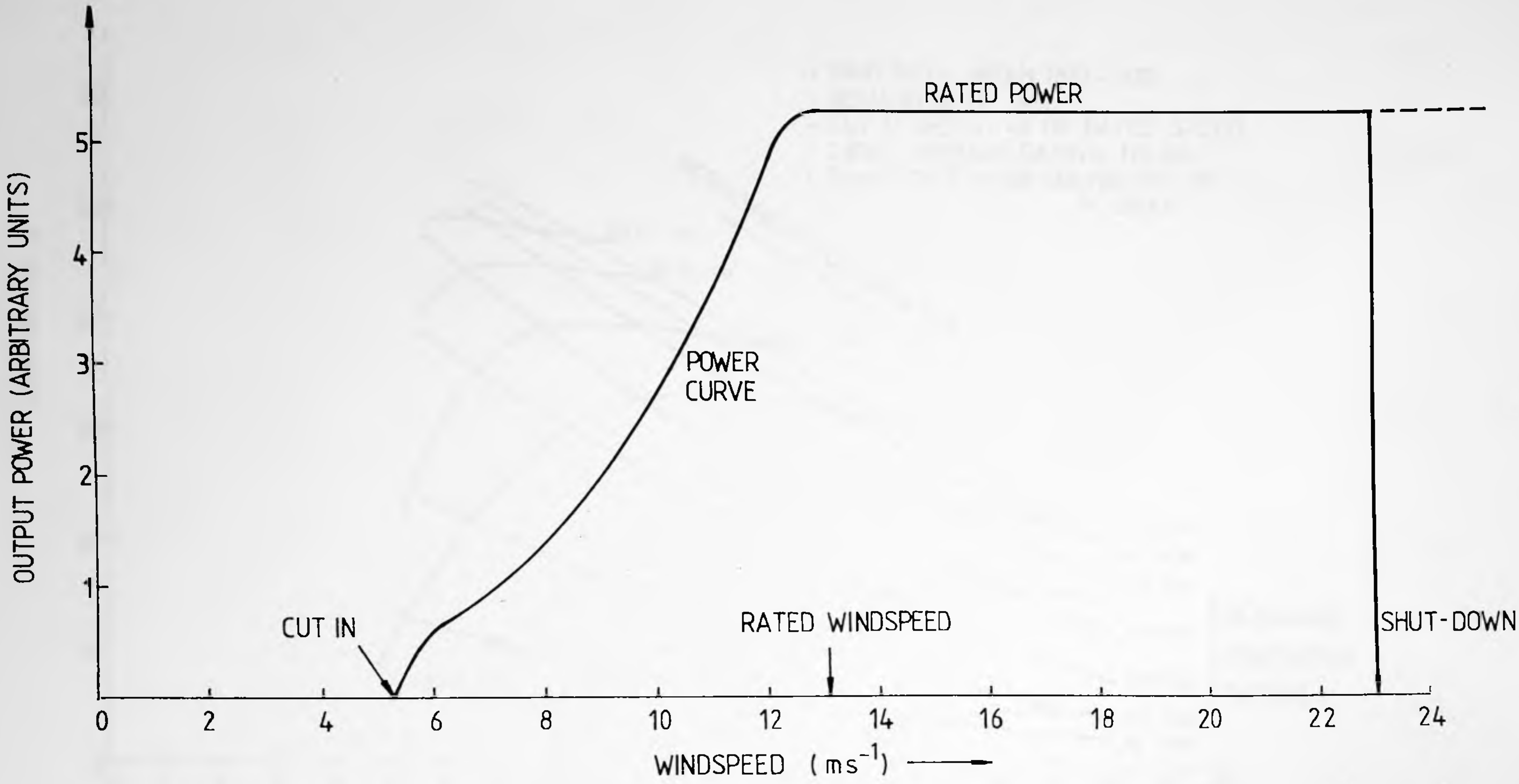


FIG. 3 TYPICAL WINDMILL PERFORMANCE CURVE

FIG. 4 FALKLAND ISLANDS - STANLEY; CONTRIBUTIONS OF VARIOUS WIND TURBINES TO THE ELECTRICITY NETWORK

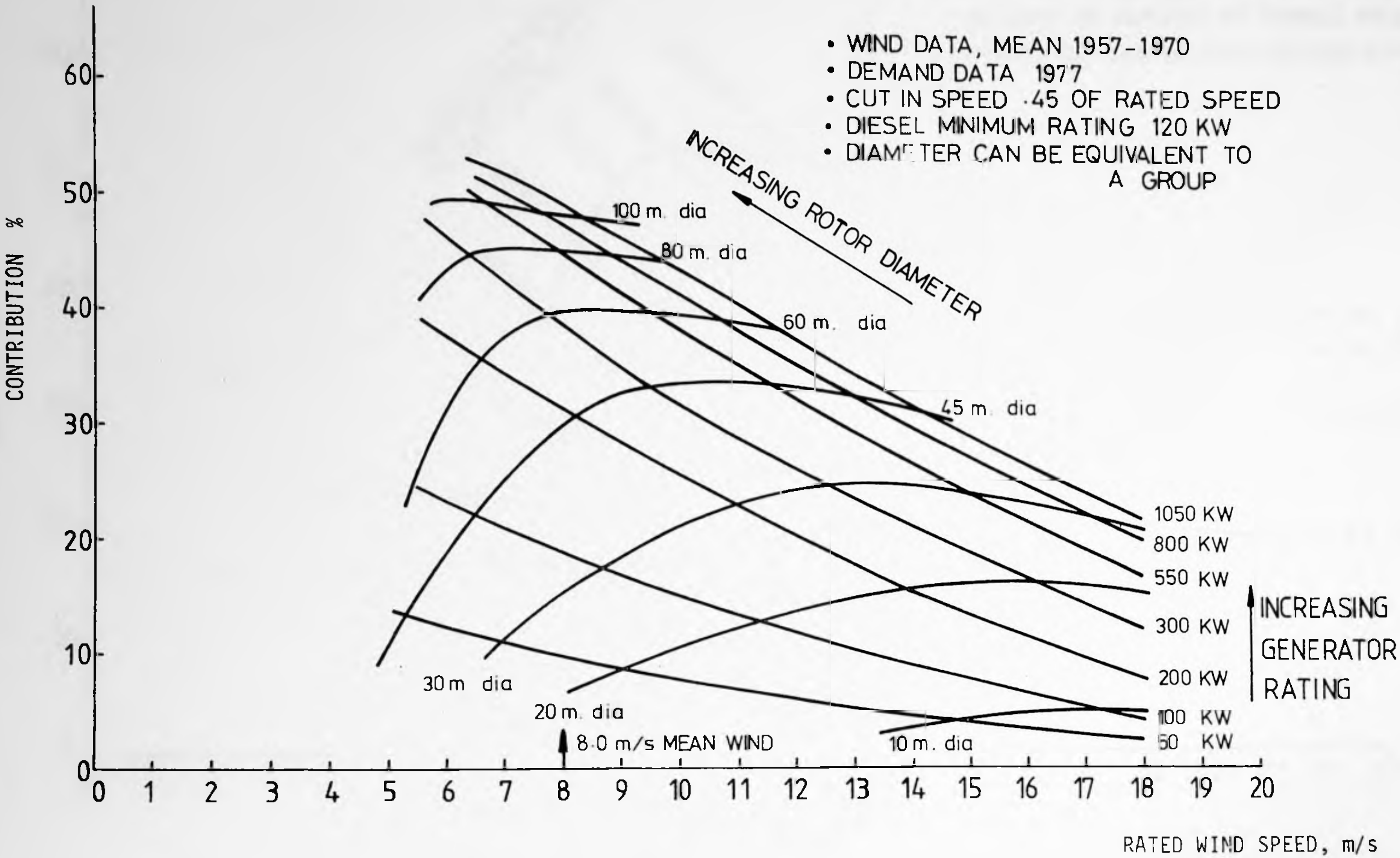


FIG. 5 FALKLAND ISLANDS - WIND TURBINE CONTRIBUTION INTO A SMALL NETWORK

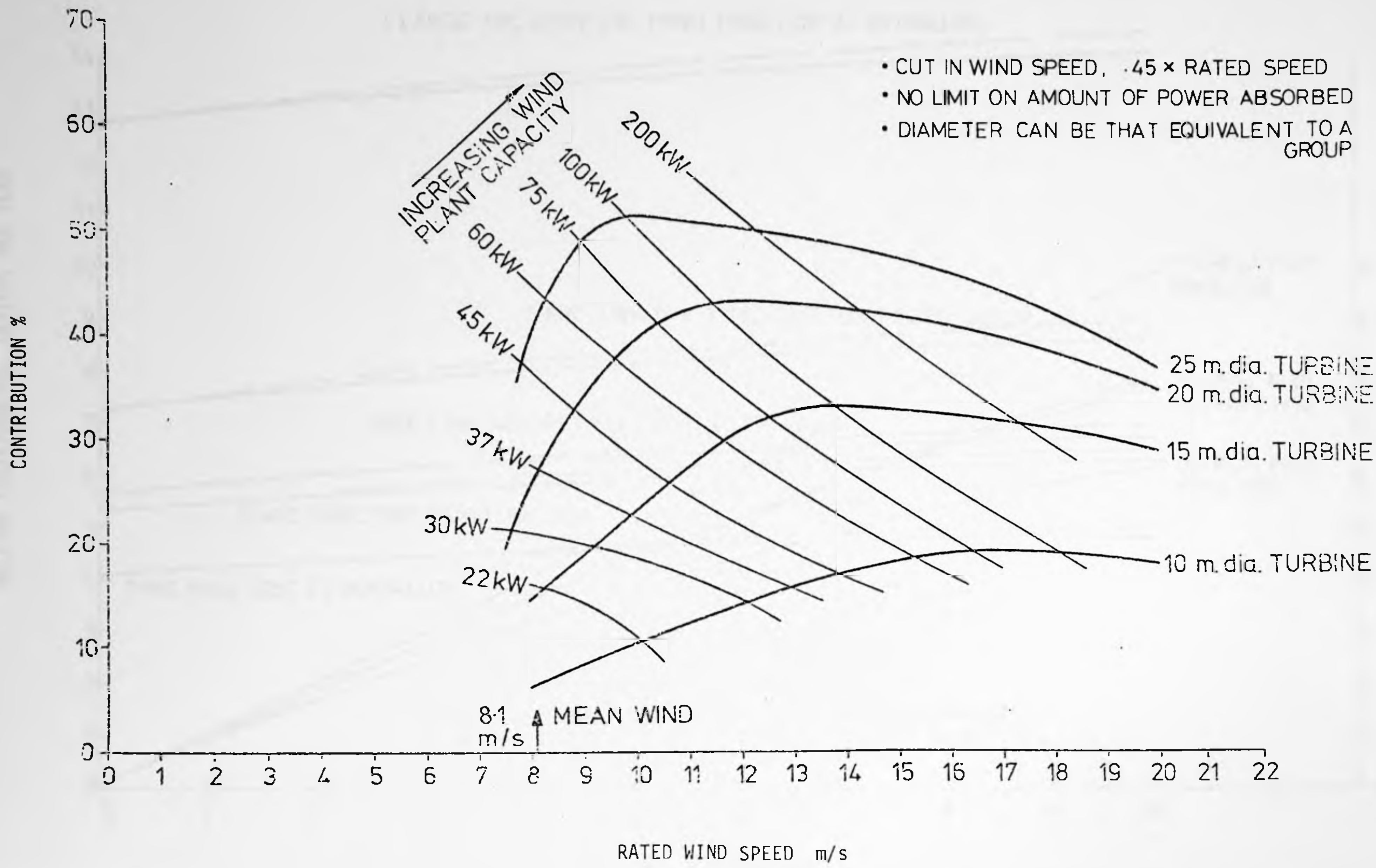


FIG. 6. RELATION OF ENERGY SAVED AND MACHINE RUNNING COSTS IN RELATION TO TIME, IN PRESENT VALUE TERMS

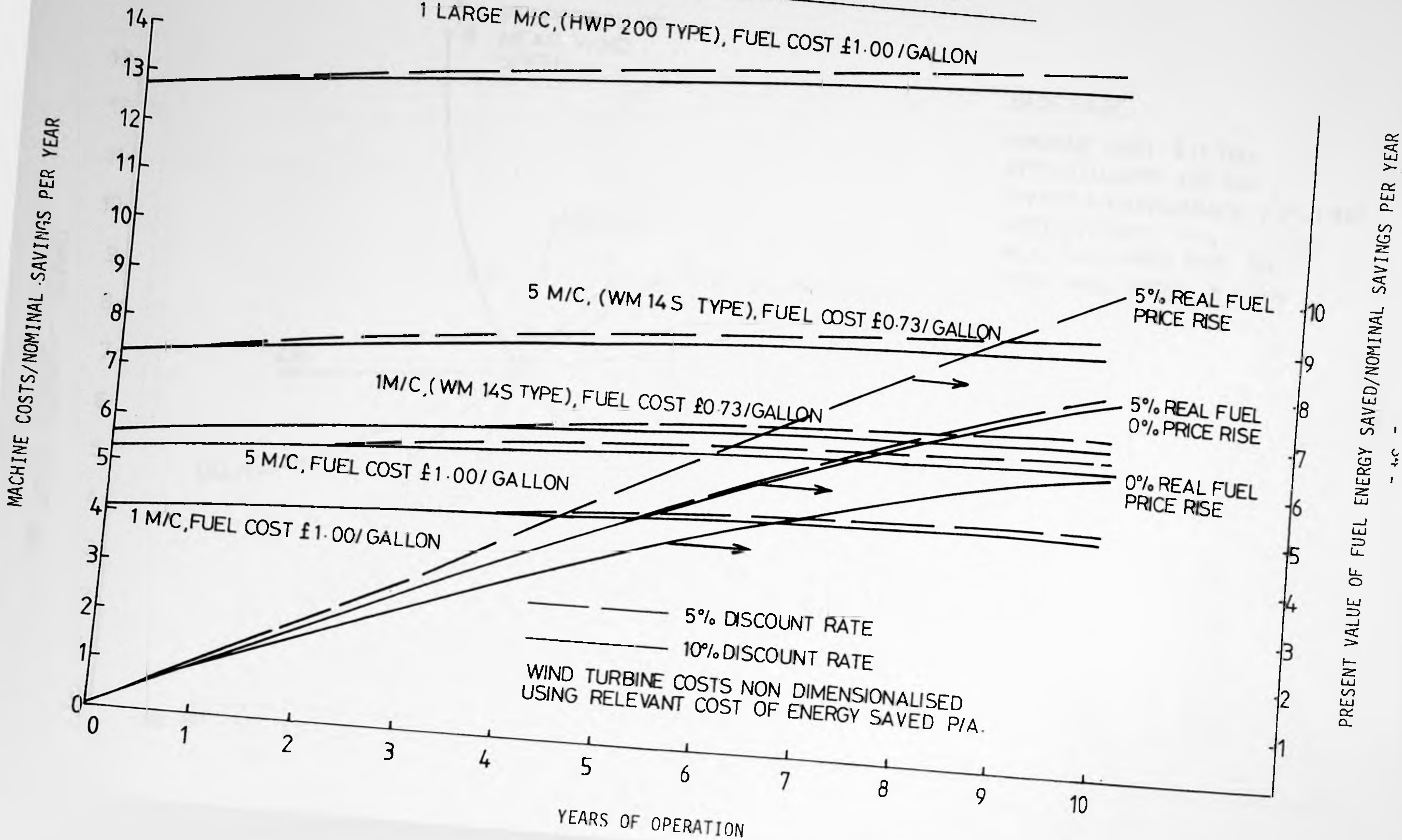
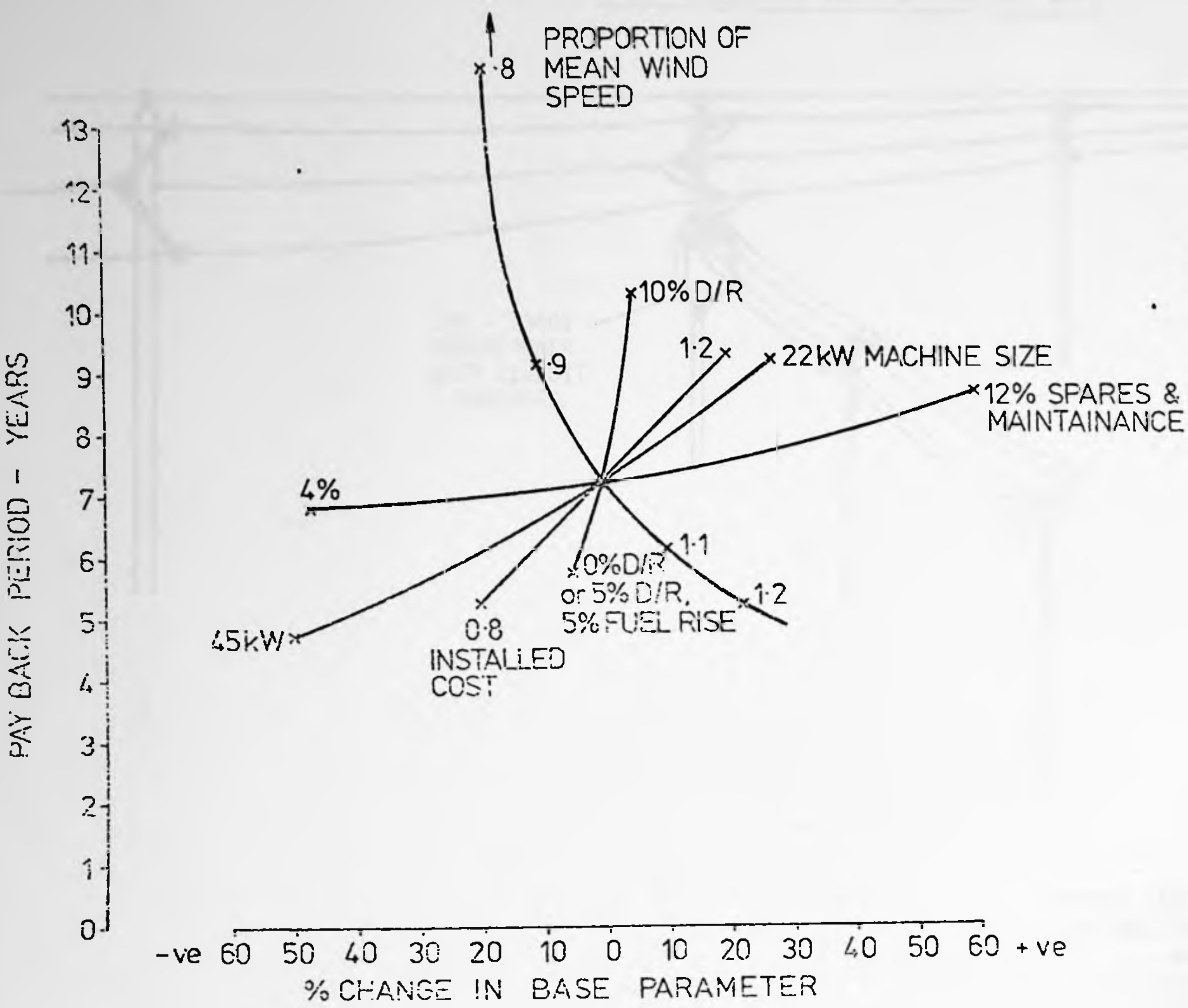


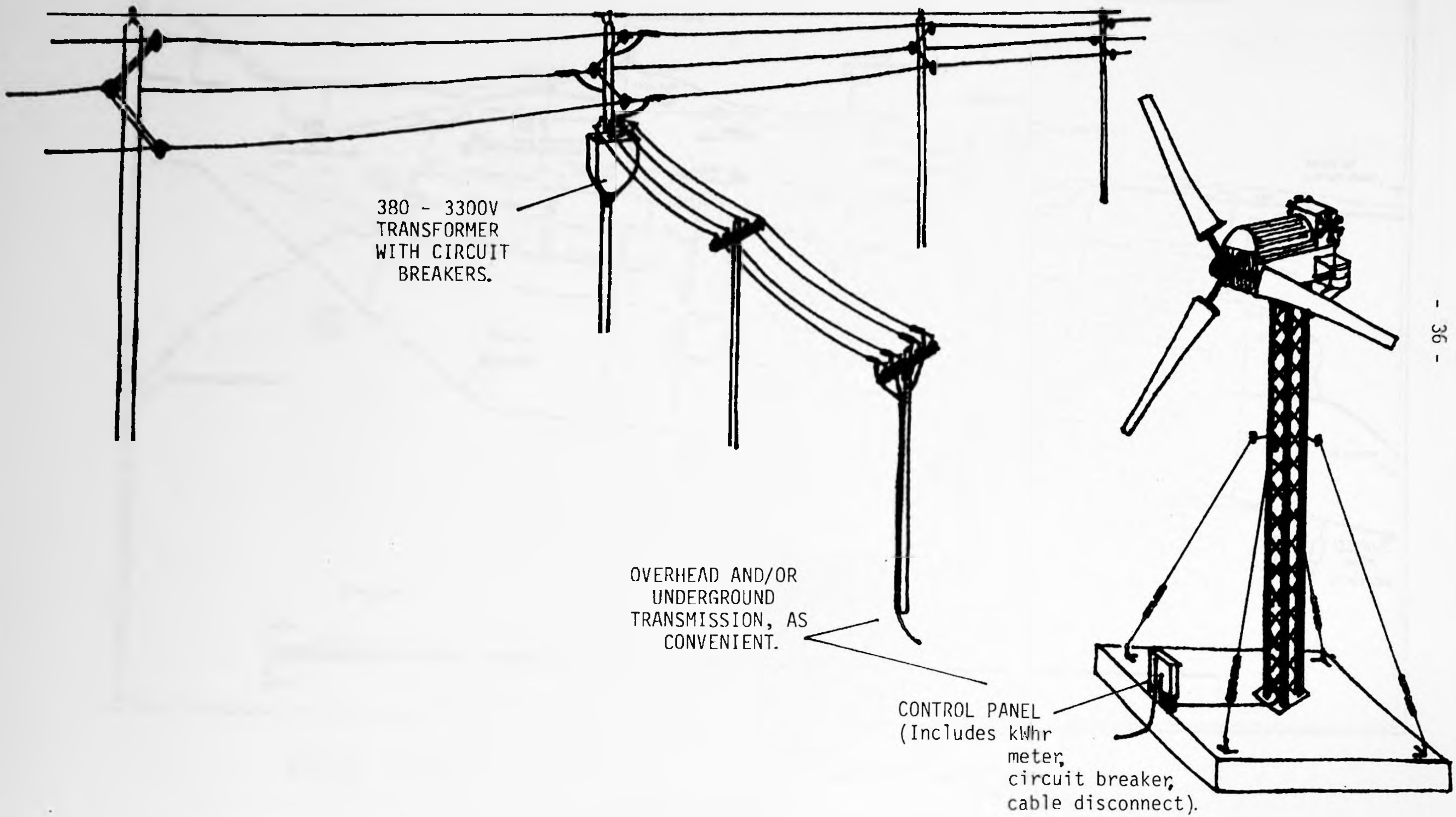
FIG. 7 FALKLAND ISLANDS - SENSITIVITY OF THE PAY-BACK PERIOD ARISING FROM VARIATIONS IN THE BASE CASE; 30kW WIND TURBINE



BASE CASE:

MACHINE COST £11,700
INSTALLED COST £25,500
SPARES & MAINTAINANCE, $7\frac{1}{2}$% £880
DISCOUNT RATE 5%
REAL FUEL PRICE RISE 0%
MEAN WIND SPEED 8.1 m/s

FIG. 8 TYPICAL WINDMILL INSTALLATION ONTO GRID



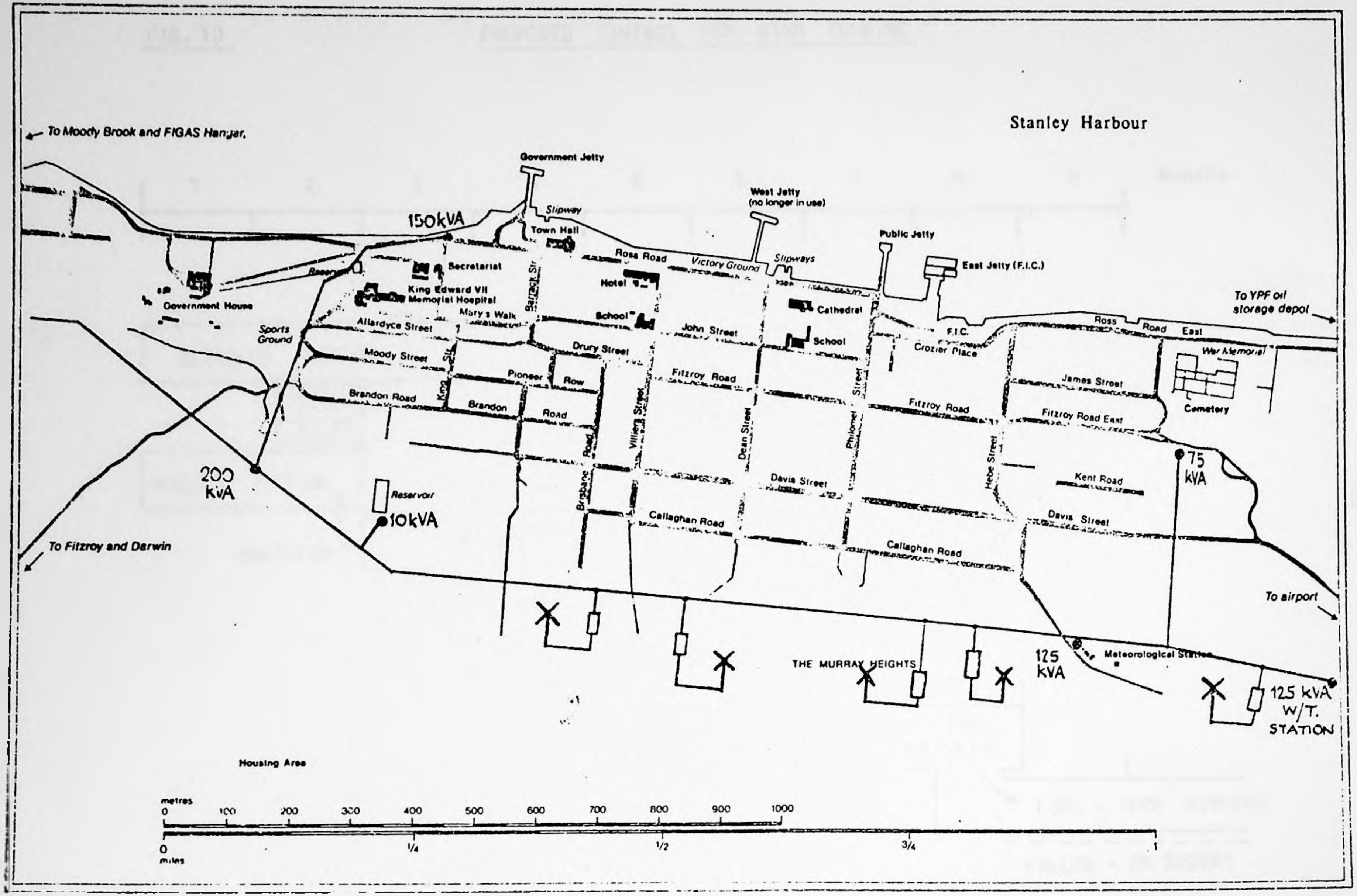


FIG. 9 POSSIBLE POSITION FOR WINDMILL GROUP ALONG MURRAY HEIGHTS

FIG. 10 PROPOSED TIMINGS FOR WIND TURBINE

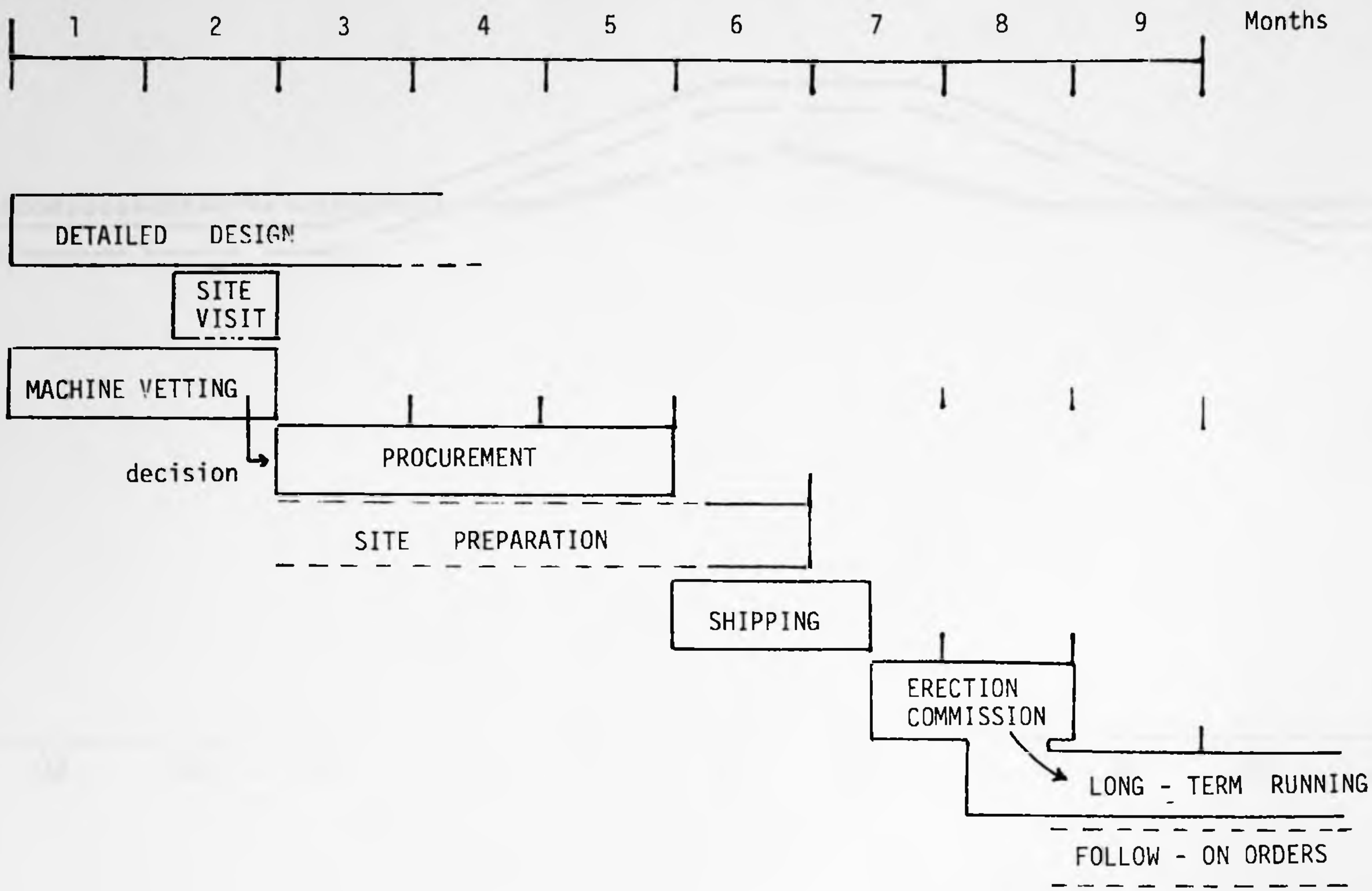
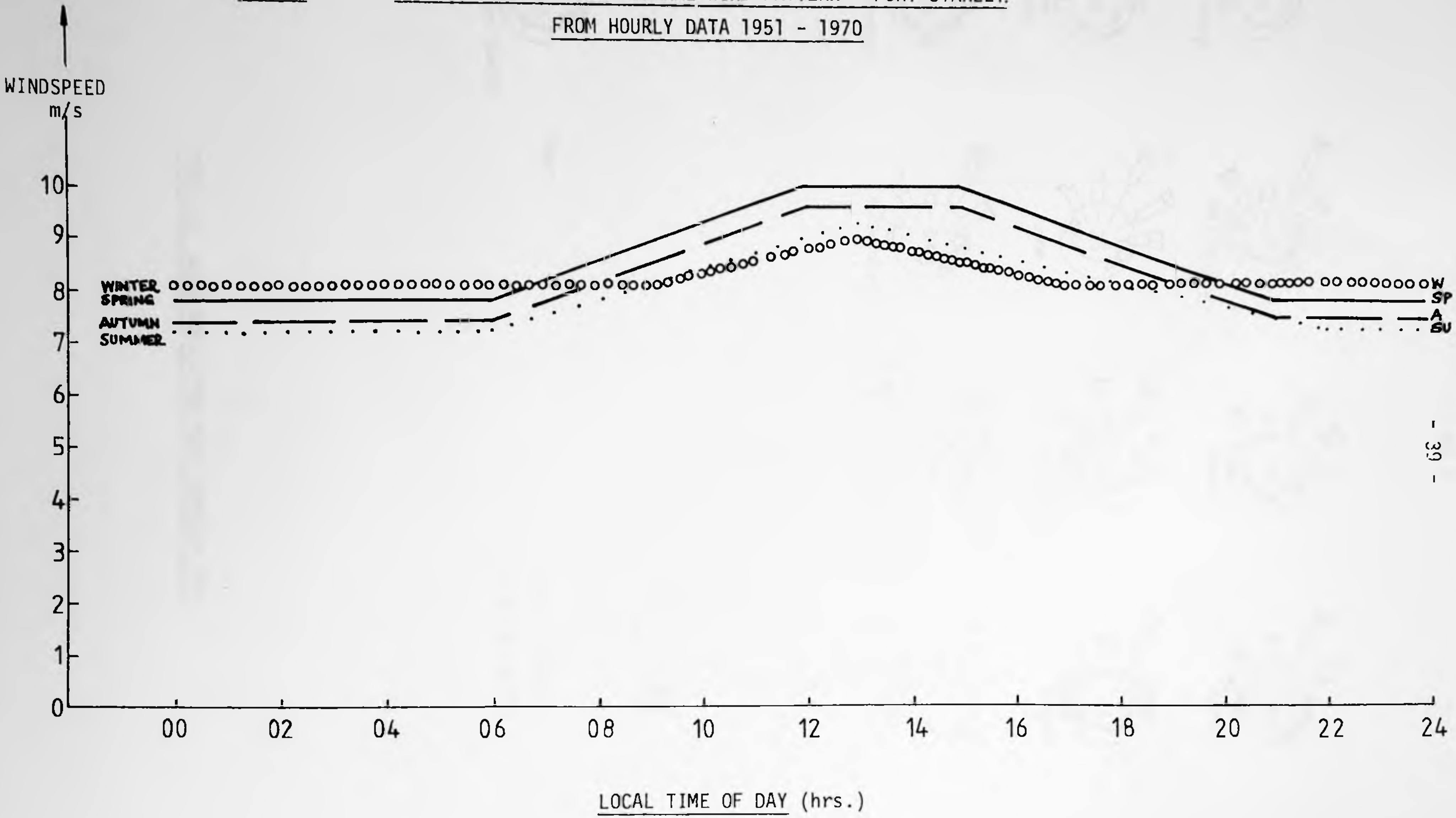


FIG.11 SEASONAL CHANGES IN DIURNAL WIND PATTERN - PORT STANLEY.

FROM HOURLY DATA 1951 - 1970



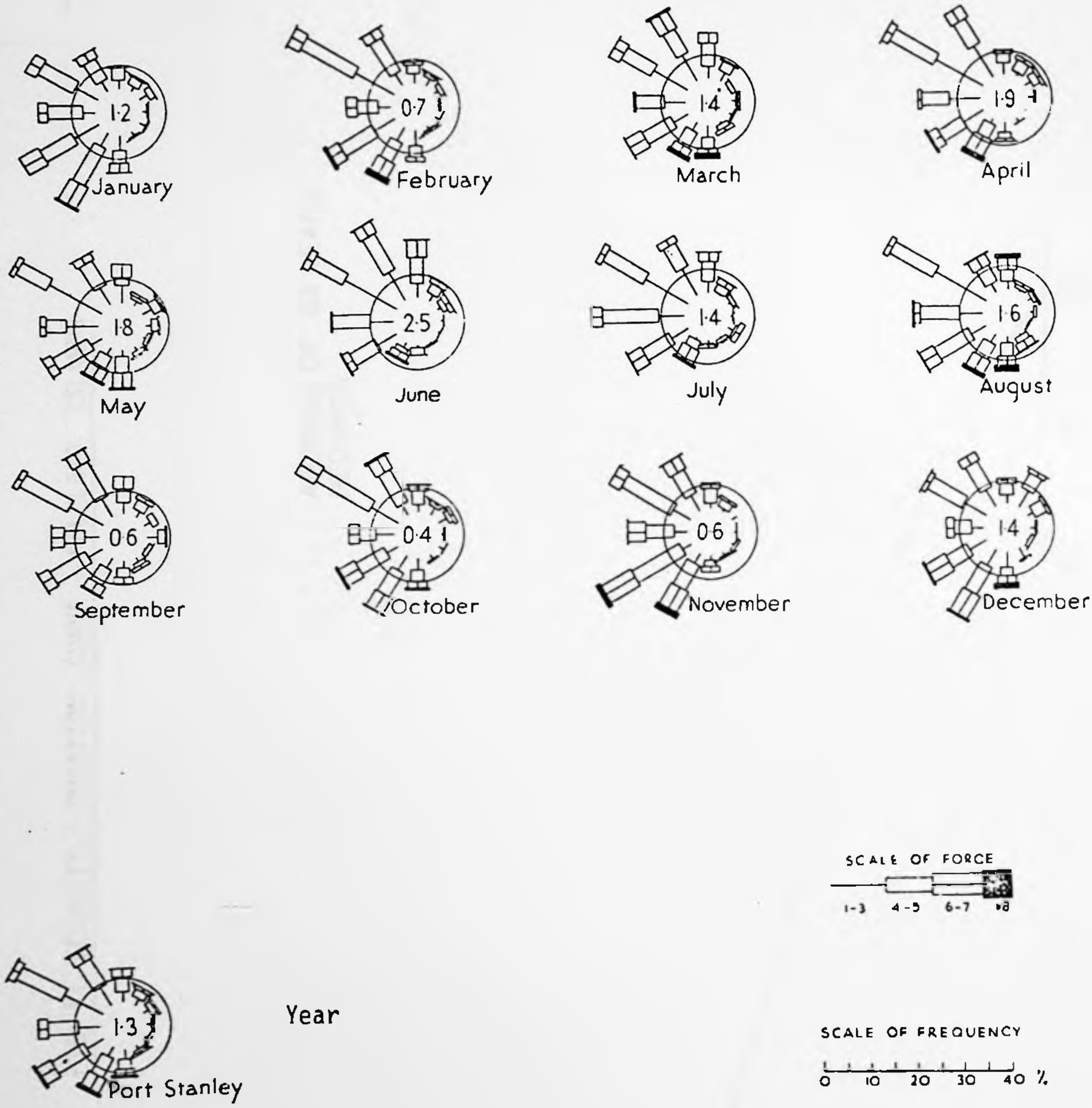
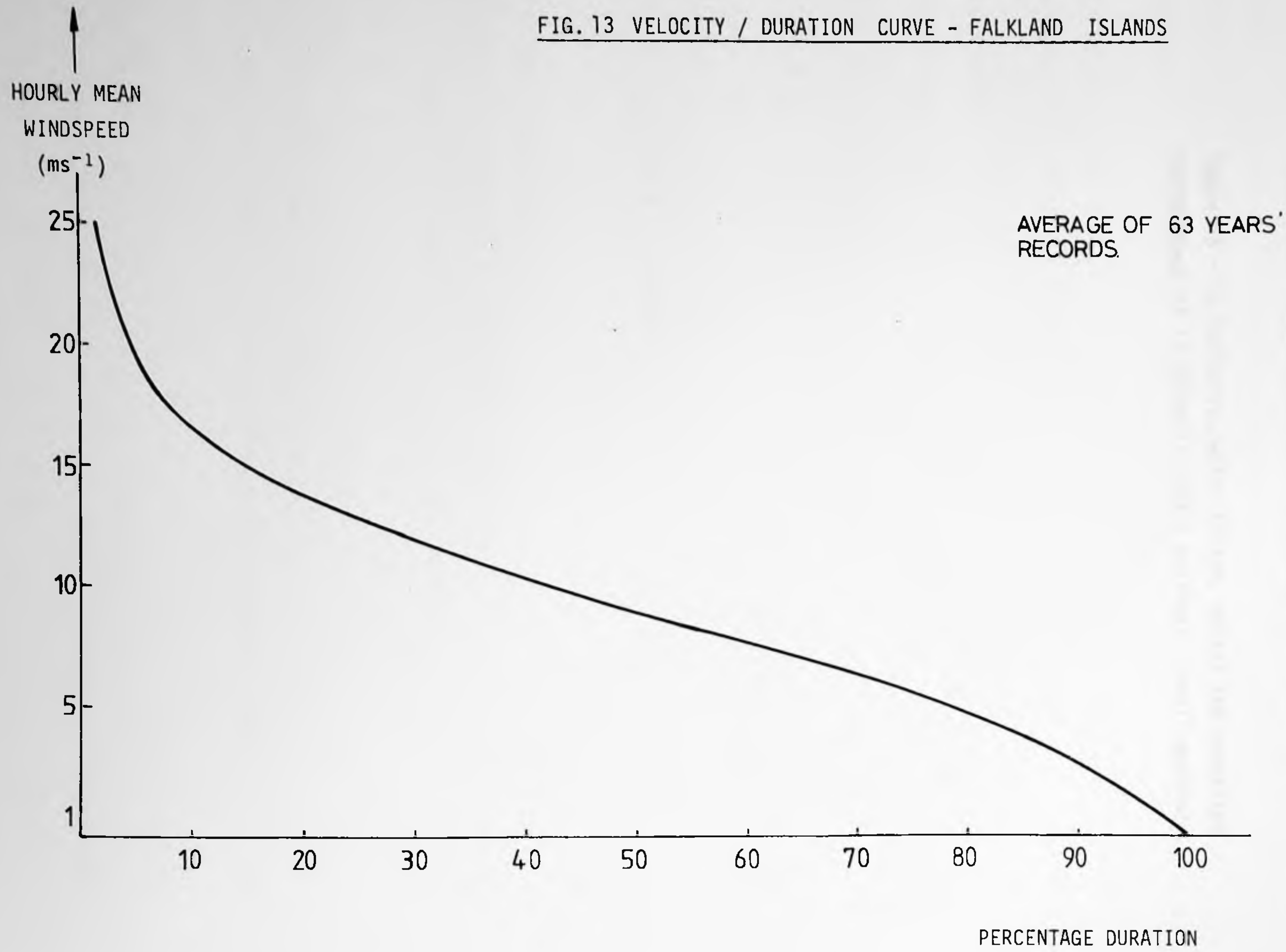


FIG. 12 WIND ROSES FOR PORT STANLEY (11)

FIG. 13 VELOCITY / DURATION CURVE - FALKLAND ISLANDS



APPENDIX 1 PREDICTIONS FOR SOME SMALL MACHINES FOR FALKLAND ISLANDS

Pages 43 - 50 inclusive, which follow, detail the predicted performance of 13 windmills and 4 notional "ideal" machines.

COST OF WIND TURBINE INCLUDES TOWER AND NOTIONAL SYSTEM CONNECTIONS.

WEIBGV82
DIESEL GENERATOR PRICE ASSUMED IS,STERLING, 724.
INPUT DATA FOR WEIBULL WIND REGIME
TYPE OF WIND CHARACTERISTIC(SHAPE FACTOR) IS 1.86
ENTER MEAN WIND SPEED(SCALE FACTOR 1.11*MEAN) 8.12
ENTER THE WINDMILL TYPE NUMBER FROM THE FOLLOWING LIST:-

DUNLITE 2KW	1	ENAG NO 1	11
AEROWATT 1100 FP5G	2	P.I. 3KW (VERT. AXIS)	12
AEROWATT 1200 FP10G	3	DUNLITE 5000 (5KW)	13
AEROWATT 4100 FP7G	4	ODM 66 1KW TEST MILL	14
WINCHARGER 200W	5	ODM 672 1.8KW TEST MILL	15
NORTH WIND POWER EAGLE 3KW	6	ODM 69 3.5KW TEST MILL	16
ELEKTRO WV 25G (2.2 KW)	7	ODM 611 6.5KW TEST MILL	17
ELEKTRO WVG 50G (5 KW)	8		
KEDCO 1200	9	ALL ODM MILLS	19
LUBING	10	ALL MILLS LISTED	20

TYPE NUMBER OF WINDMILL IS 20

COSTING INFORMATION
$$$$$$$$$$$$$$$$$$$

DISCOUNT RATE REQUIRED, % , IS 5

LIFESPAN OF MACHINE , IN YEARS , IS 10

LOWEST USER PRICE OF GAS OIL, PENCE PER LITRE, IS 17

EXPECTED OIL PRICE INCREASE, PER YEAR, REL TO INFLATION, %, IS 5

(THIS IMPLIES A RETAIL COST FOR DIESEL
OIL OF 27 PENCE PER LITRE
IN TEN YEARS TIME, IN TODAYS TERMS)

$$

WINDMILL TYPE :-

DUNLITE 2KW
****

TOTAL POWER GENERATED IS 7524 KWH.

NET PRESENT COST OF GENERATED POWER IS 11.10000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 58 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 58 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.799999 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 13.70000 HRS/DAY)
25 12.50000
PENCE/KWH
34 16.29999
PENCE/KWH

AEROWATT 1100 FP5G
****

TOTAL POWER GENERATED IS 8221 KWH.

NET PRESENT COST OF GENERATED POWER IS 29.50000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 91 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 84 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.700000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 15 HRS/DAY)
25 12.40000
PENCE/KWH
34 16.09999
PENCE/KWH

AEROWATT 1200 FP10G
****

TOTAL POWER GENERATED IS 5192 KWH.

NET PRESENT COST OF GENERATED POWER IS 21 PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 67 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 49 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 9.500000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 9.400000 HRS/DAY)
25 13.20000
PENCE/KWH
34 16.89999
PENCE/KWH

AEROWATT 4100 FP7G
****

TOTAL POWER GENERATED IS 24521 KWH.

NET PRESENT COST OF GENERATED POWER IS 10.60000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 84 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 84 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 7.799999 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 44.70000 HRS/DAY)
25 11.50000
PENCE/KWH

34 15.20000
PENCE/KWH

WINCHARGER 200W
****

TOTAL POWER GENERATED IS 849 KWH.

NET PRESENT COST OF GENERATED POWER IS 10.90000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 67 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 0 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 20.20000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 1.500000 HRS/DAY)
25 23.89999
PENCE/KWH

34 27.59999
PENCE/KWH

NORTH WIND POWER EAGLE 3KW
****

TOTAL POWER GENERATED IS 9002 KWH.

NET PRESENT COST OF GENERATED POWER IS 8.400000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 51 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 51 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.599999 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 16.39999 HRS/DAY)

PENCE/KWH	25	12.30000
	34	16 PENCE/KWH

ELEKTRO WV 25G
****

TOTAL POWER GENERATED IS	6151 KWH.
NET PRESENT COST OF GENERATED POWER IS PENCE/KWH	10.20000
FIRMNESS FACTOR (POWER >> 20 W/SQ.M) =	49 %
FIRMNESS FACTOR (POWER >> 500 WATTS) =	49 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 9.099999 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 11.20000 HRS/DAY)

PENCE/KWH	25	12.90000
PENCE/KWH	34	16.59999

ELEKTRO WV 50G
****

TOTAL POWER GENERATED IS	14833 KWH.
NET PRESENT COST OF GENERATED POWER IS PENCE/KWH	5.900000
FIRMNESS FACTOR (POWER >> 20 W/SQ.M) =	49 %
FIRMNESS FACTOR (POWER >> 500 WATTS) =	49 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.099999 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 27 HRS/DAY)

PENCE/KWH	25	11.80000
PENCE/KWH	34	15.50000

KEDCO 1620 3KW
****

TOTAL POWER GENERATED IS	10713 KWH.
NET PRESENT COST OF GENERATED POWER IS PENCE/KWH	6.400000

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 57 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 57 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.400000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 19.50000 HRS/DAY)
25 12.10000
PENCE/KWH
34 15.80000
PENCE/KWH

LUBING 400W
****

TOTAL POWER GENERATED IS 1843 KWH.

NET PRESENT COST OF GENERATED POWER IS 14.50000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 67 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 0 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 13.30000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 3.299999 HRS/DAY)
25 17 PENCE/KWH
34 20.70000
PENCE/KWH

ENAG £1 650W
****

TOTAL POWER GENERATED IS 3215 KWH.

NET PRESENT COST OF GENERATED POWER IS 6.900000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 75 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 40 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 10.80000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 5.799999 HRS/DAY)
25 14.50000
PENCE/KWH
34 18.20000
PENCE/KWH

P.I. ENGINEERS 3KW (VERTICAL AXIS)
****

TOTAL POWER GENERATED IS 12931 KWH.

NET PRESENT COST OF GENERATED POWER IS 6.500000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 67 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 67 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8.200000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 23.59999 HRS/DAY)
25 11.90000
PENCE/KWH

34 15.60000
PENCE/KWH

DUNLITE 5000 (5KW)
****

TOTAL POWER GENERATED IS 16212 KWH.

NET PRESENT COST OF GENERATED POWER IS 6.500000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 58 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 58 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 8 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 29.59999 HRS/DAY)
25 11.80000
PENCE/KWH

34 15.50000
PENCE/KWH

ODM TEST MILL:- 6M DIA, VO=6 M/S, 1KW
****

TOTAL POWER GENERATED IS 6904 KWH.

NET PRESENT COST OF GENERATED POWER IS 14.20000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M) = 84 %

FIRMNESS FACTOR (POWER >> 500 WATTS) = 75 %

NET PRESENT COST OF DIESEL POWER OIL= 17 P/LT 9 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF 12.60000 HRS/DAY)

```
                                               25          12.70000
PENCE/KWH

                                               34          16.39999
PENCE/KWH


ODM  TEST MILL:- 6M DIA, V0=7.2 M/S, 1.8KW
*****************************************

TOTAL POWER GENERATED IS                                   10851 KWH.

NET PRESENT COST OF GENERATED POWER IS                     9  PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M ) =                    84 %

FIRMNESS FACTOR (POWER >> 500 WATTS ) =                    75 %


NET PRESENT COST OF DIESEL POWER       OIL= 17  P/LT       8.400000 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF  19.79999  HRS/DAY)
                                               25          12.10000
PENCE/KWH

                                               34          15.80000
PENCE/KWH


ODM  TEST MILL:- 6M DIA, V0=9 M/S, 3.5KW
****************************************

TOTAL POWER GENERATED IS                                   17169 KWH.

NET PRESENT COST OF GENERATED POWER IS                     6  PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M ) =                    75 %

FIRMNESS FACTOR (POWER >> 500 WATTS ) =                    75 %


NET PRESENT COST OF DIESEL POWER       OIL= 17  P/LT       8 PENCE/KWH
(3HP UNIT(S) RUNNING TOTAL OF  31.29999  HRS/DAY)
                                               25          11.70000
PENCE/KWH

                                               34          15.40000
PENCE/KWH


ODM TEST MILL:- 6M DIA, V0=11 M/S, 6.5KW
****************************************

TOTAL POWER GENERATED IS                                   23443 KWH.

NET PRESENT COST OF GENERATED POWER IS                     4.400000
PENCE/KWH

FIRMNESS FACTOR (POWER >> 20 W/SQ.M ) =                    58 %
```

```
FIRMNESS FACTOR (POWER >> 500 WATTS ) =                 58 %


NET PRESENT COST OF DIESEL POWER      OIL= 17  P/LT     7.799999 PENCE/KWH
 3HP UNIT(S) RUNNING TOTAL OF  42.79999  HRS/DAY)
                                           25           11.60000
 PENCE/KWH
                                           34           15.30000
 PENCE/KWH


READY
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APPENDIX 2 DETAILS OF SOME AVAILABLE WINDMILLS

1. Medium and Large Machines (Possibilities for Port Stanley and Large Settlements)

Manufacturer	Model	Rated Power (kW)	Cut-in Windspeed (ms^{-1})	Minimum Windspeed for Max. Power (ms^{-1})	Diameter (m)	Tower Height (m)	Cost £
POLENKO (Netherlands)	WPS 11	40*	3.3	11.6	11	19.5	19,000
	WPS 16	60*	3.8	12.0	16	19.5	25,000
	WPS 18	100	3.5	14.0	18	30	39,000
	WPS 24	300	4.5	12.0	24	30	145,000
SONEBJERG (Denmark)	SM 22	22*	4.8	14.0	10	18	11,900†
	SM 30	30*	5.0	14.0	10	18	12,300†
	SM 45	45*	5.0	13.5	12	22.5	16,960†
	SM 55	55*	4.8	12.0	14	22.5	18,400†
WINDMATIC (Denmark)	WM 10S	22*	5.0 (WM 10S–14S)	15.0 (WM 10S–14S)	10	18 (WM 10S–14S)	16,350
	WM 12S	30*			12		19,500
	WM 14S	55*			14		24,500
HOWDEN (U.K.)	HWP 200	300	6.0	16.5	22	22	230,000
NORDTANK (Denmark)	-	22*	NA	NA	NA	18	16,750†
	-	45*				18	23,800†
	-	55*				18	24,650†

* These generators are fitted with a small additional generator.

† All prices were quoted in £ sterling except those marked † which have been converted using £1 ≡ 15.2 D.Kr.

COMPANY INFORMATION

Polenko — Part of the Holec group. British Agents are DP Enterprises, (North Sea) Ltd., Aberdeen. They are the largest Dutch manufacturer of Windmills; have installed 25+ rated at 60 kW or more in Holland. Currently contracted to build over 50 generators at 100 kW each for U.S. Two 60 kW machines are just being grid-connected in U.K. Details given are induction machines (40 and 60 kW machines) and AC-DC-AC fully microprocessor-controlled (100 and 300 kW machines). Price includes tower, delivery U.K.

Sonebjerg — Sonebjerg Maskinfabrik A/S, 6000 Kolding, Denmark. Employs 90, with in-house design. Special experience in steel structures.

Windmatic — The most experienced European windmill manufacturer in this range. Substantial order books, including 100 machines for U.S. Supplied 45 kW machine now installed on Tristan da Cunha. Several are in operation in U.K. and Eire.

Howden — The price given is a budget price as the machine is not yet commercially available. The company have their windmill experience from a recently-formed association with WTG (New York) and they have supplied a 250 kW machine at Camarthen Bay.

Nordtank — T. Rorbaek, Nyballevej 8, DK-8444 Balle. The machines appear to be conventionally built, although the use of a tubular tower is unusual for machines around this size (most tend to be of lattice type).

2. SMALL MACHINES (less than 20kW and suited to isolated settlements and stand-alone situations)

Manufacturer	Model	Diam. (m)	Rated Power (W)	Cut-in Wind-speed (ms^{-1})	Rated Wind-speed (ms^{-1})	Mast Height (m)	Cost £
WESCO (U.K.)	C3EAL	3.0	500 @ 12,24V d.c.	2.0	7.5		950
ALTERNATIVE ENERGY LTD (EIRE)	PHOENIX	8.0	10,000	3.6	10.7	11.3	N.A.
TORNADO (U.K.)	-	2.0	500	4.0	11.0	4.0	1,000
TRIMBLEMILLS (U.K.)	-	6.0	7,500	4.8	13.0	N.A.	7,500
RUTLAND (U.K.)	WINDCHARGER	0.9	60 @ 12,24V d.c.	1.8	12.0	Not Supp.	260
OSPREY (U.K.)	-	7.0	10,000	4.5	11.5	12.2	7,700
DUNLITE (AUSTRALIA)	2*	4.0	2,000	4.5	11.0	N.A.	3,900
AEROWATT (FRANCE)	1100 FP5G *	9.2	1,125	2.0	5.0	N.A.	16,500
	1200 FP10G*	3.2	1,200	2.0	10.0		4,900
	4100 FP7G *	9.2	5,000	2.0	7.0		16,600
ENAG (FRANCE)	No.1 *	2.4	650	4.0	9.0		1,280
LUBING (W.GERMANY)	M022-3G *	2.2	400	3.5	10.0	N.A.	2,300
P.I.ENGINEERS (U.K.)	VERTICAL AXIS *	6.0	3,200	4.0	10.0	N.A.	8,450
ELECTRO (SWITZERLAND)	WV25G *	3.6	2,200	3.0	13.0	N.A.	2,300
WINCO (U.S.A.)	1222H *	1.8	200	3.1	10.0	N.A.	600
EAGLE (U.S.A.)	III-110 *	4.2	3,000	3.6	11.6	N.A.	3,750
KEDCO (U.S.A.)	1,620 *	4.9	3,000	4.9	11.2	N.A.	3,300

In addition to the above list, where machines marked * are used in the economic survey, there follow four Notional machines which were first used in a previous study (8).

Power (kW)	Rotor area (m^2)	Cut-in Windspeed (ms^{-1})	Rated Windspeed (ms^{-1})	Cost £
1.0	28.3	3.3	6.0	9,900
1.8		4.0	7.2	9,900
3.5		4.9	9.0	10,500
6.5		6.0	11.0	10,500

These machines are included in the economic assessment in order that a guide to comparative machine performance can be obtained when referred to these "ideal" machines.

Manufacturer details

Wesco Windmills Limited - Bolney Avenue, Peacehaven, Sussex.

This particular machine is a Cretan type, with 6 sails and a horizontal axis, on a lattice tower. It outputs d.c. voltage at 12 or 24V, with a low rotational speed and inherent simplicity.

Alternative Energy Limited - Woodford, County Galway, Ireland.

The company has developed this machine since about 1977. It is produced to supply water heating primarily, but can be supplied to produce battery-charging voltages of 12 or 24V d.c. The shutdown speed is about 27 ms^{-1}, which would be expected to occur for about 1% of the time.

Tornado Wind Generators - (Hitchin 59457)

Produce one machine, with a special low speed alternator. Can produce up to 1000W, at 14.5 ms^{-1}. A timed brake is available which stops the windmill in high winds, then releases after a set period - say 2 hours - to allow the machine to run again.

Trimble Windmills - 55 East Parade, Harrogate, N.Yorks.

Produce a Cretan type machine with 2 sets of blades mounted on one axis (contrarotating).

Rutland Windcharger - Melecon, P.O. Box 10, Melton Mowbray, Leics.

Produce a small, 60W battery charging windmill which has a particularly low cut-in speed. High speed protection is by a thermally-operated device which limits the charge rate. The construction of the machine should give a reliable machine: only minimal maintenance is required.

Osprey - Wind and Water Power Limited, Huntly Street, Edinburgh

This machine, 3 bladed and available as single or 3-phase, mains excited or independent, is conventionally constructed. It is designed to withstand winds of 50 ms^{-1} (about 110 m.p.h.). Shut-down would occur before this speed.

APPENDIX 3

DIESEL FUEL COSTS FOR STANLEY POWER STATION

A diesel generator will produce 18.0 kWh/gallon of diesel fuel when operating at full load. This figure has been reached by reference to (2) and also to modern generating set specifications.

The annual power usage at Stanley (last available figure) is about 2.7 GWh (2700 MWh) and hence the annual diesel requirement is around 150,000 gallons.

If it is assumed that the cost of diesel to the Power Station is 0.73p. per gallon, then the annual cost is approximately £109,500. The table below shows how this annual cost varies with fuel price (65-100p. per gallon).

Unit Cost of Diesel p/gallon	p/litre	Diesel Cost to Produce 2.7 GWh electricity £
65	14.3	97,500
70	15.4	105,000
75	16.5	112,500
80	17.6	120,000
85	18.7	127,500
90	19.8	135,000
95	20.9	142,500
100	22.0	150,000

TABLE 3

COST OF DIESEL FUEL FOR STANLEY POWER STATION

APPENDIX 4

(1) Windmill Requirements

In order to avoid overspeeding of the rotor this should be equipped with aerodynamic brakes, such as pitching of the blade or of a part of the blade or spoilers (air-brakes). These devices should be governed by the rotational speed of the rotor, preferably by the centrifugal force, and should limit the rotational speed to a safe value at any windspeed.

Instead of the above-mentioned aerodynamic brakes on the rotor, the windmill could be of the kind in which the rotor is yawed out of the wind direction by means of a hinged tail vane. However, this should be accepted only as a safety procedure to avoid overspeeding of the rotor, if the yawing out of the wind direction is gradually increased with the wind speed as a part of the power control system, in order to ensure that the rotor is already somewhat yawed in case of failure in the power conversion system at some high wind speed.

The machinery of a windmill should be equipped with a brake which can bring the rotor to a full stop and to park the rotor in order to ensure that maintenance and service can be safely executed. This brake may not necessarily be sufficiently powerful to stop the rotor at full power. However, the mechanical brake should be capable of stopping the rotor if the power conversion system is disconnected from the power absorption system and the aerodynamic brakes are in action and the wind speed is below 8 m/sec.

(2) Electrical Considerations

A manually operated breaker must be available for disconnection of the generator from the network. Furthermore, the equipment must be designed in such a way that automatic disruption is performed in the case of a fault in the equipment and when faults occur on the power system. This requires that the equipment can only supply power to the public grid when this is fed from other sources, too.

For this reason of safety, the windmill should be equipped with relay systems regulating A, B and C as follows:

A. The frequency (50 Hz $\pm$ 1 Hz). In case of network dropout the windmill may go on producing power. However, the frequency will then differ from the nominal 50 Hz and relay A will then subsequently disconnect the generator from the network.

B. The voltage (nominal voltage + 10%, normally 220 + 10% = 242 V).

C. Phase symmetry (reacting to e.g. dropout in one phase).

If the generator has been disconnected in one of the cases A, B and C, the connecting shall be re-established only by manual operation after correcting the fault which caused the relay to function.

APPENDIX 5

WEATHER RECORDS FOR THE ISLANDS EXCEPTING THOSE FOR PORT STANLEY

The majority of long-term climatic records which are available for the Falkland Islands depend upon observations which have been made in the vicinity of Port Stanley. Some farms have kept rainfall records, showing in general that Port Stanley tends to be wetter than the areas to the West. Some wind data has been taken for other regions in the Islands, but not in a standardised way which would enable comparisons to be made. The wind strength does tend to increase with distance Westwards from Port Stanley, since the slowing effect of land is lessening. In addition, it would be expected that the persistence value - a measure of the directional consistency of the wind - would increase as the West Coast is approached from land.

Data from shipping to the West of the Falkland Islands is available (2, Fig.2.12) and shows monthly wind roses for a position 193 n.m. WSW of Port Stanley. These wind roses show, by comparing with those for Port Stanley given in Figure 12,that for all months there is virtually no contribution from wind in the E-S quadrant. In addition, the frequency of occurrence of given strength winds is more consistent through the year at sea than on land. The directivity is definitely more marked. Fig. 13 shows the long-term velocity/duration curve for the Falkland Islands (12).

It should always be appreciated that any given site will have its own particular wind régime which is very dependent upon local and distant topography. The effect of hills, mountain ranges and type of vegetation, for example, existing upstream of a given location can markedly affect its suitability as a windmill site. For that reason the best way to assess a site for its suitability is to erect anemometry at the site and record windstrengths and direction over a period of at least a year.

APPENDIX 6

WIND DATA FOR STANLEY 1961 - 1970

All Data All Hours (ex. per mille frequency tables)

Month	Windspeed Range (Knots) *										
	Calm	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	<47
J	24	35	48	173	283	219	138	60	19	2	0
F	28	45	61	170	251	224	139	62	19	1	0
M	19	40	49	185	287	216	137	62	21	3	0
A	28	39	59	206	271	195	111	61	24	3	1
May	25	35	48	183	265	215	137	66	23	4	1
Jn	20	35	69	188	295	190	129	50	17	5	1
Jy	22	44	51	199	281	193	127	61	19	2	1
Au	27	54	60	192	268	198	119	59	19	4	0
S	22	37	48	167	273	196	135	88	31	4	0
O	23	28	39	163	244	236	150	95	22	1	0
N	27	39	48	174	257	205	139	84	25	2	0
D	26	39	48	165	243	220	155	77	25	3	0
Year	24	39	52	181	267	209	134	68	22	3	0

* 1 knot ≡ 1.853 km/h ≡ 0.515 ms^{-1}

From the above table the monthly and annual mean windspeeds are (in ms^{-1}):

January	8.12	April	7.80	July	7.89	October	8.68
February	8.00	May	8.23	August	7.74	November	8.32
March	8.26	June	7.82	September	8.48	December	8.44

Average for year 8.12 ms^{-1}

In assessing any wind data gathered from normal anemometry it should be assumed that reading and instrument errors will be more likely at the lower ranges of windspeeds due to the reluctance of measuring anemometry to respond to low windspeeds. It is also found that a tendency for a recording instrument to stick or bind at low windspeeds can go undetected for long periods and this would lead to an underestimate in windspeeds being recorded.

APPENDIX 7

Installation of a 45kW Windmatic Machine on Tristan da Cunha (April, 1982).

A 45kW machine, purchased in Denmark, was shipped via Cape Town to Tristan da Cunha. The tower was of bolted construction, (which reduced shipping costs), and was to the specification for the longer machine in the range. Associated equipment to install the turbine and run it in parallel with the existing diesel generator plant was procured, together with a load dump system. This load dump could absorb 85% of the wind turbine output. This later was introduced to ensure that firstly, the diesel output did not fall below 30% of maximum (reducing carbonisation) and secondly, to absorb any power generated by the turbine in gusty conditions.

Build information provided was scant and inaccurate in some places and mis-drilled components caused some holdup in the build schedule.

A 40 foot crane and a caterpillar-based winch were used for the erection of the tower, using a hinged section at the tower base. The 12 meter tower and the 3.5 tonne nacelle assembly could not be erected by the crane alone, but the combination of equipment plus some shear legs made the task straightforward.

Commissioning has been lengthy. This has been mainly due to peripheral equipment problems rather than the turbine, but failures in the fan tail have been significant and replacements have been requested. On-site repairs have kept the generator running. Some excessive wear has been experienced on the disc brakes, but this could have arisen because of higher-than-normal use.

A production of 17kW per running hour has been achieved during the early part of operations.

APPENDIX 8

FALKLAND ISLAND SETTLEMENTS

Approximate Population	East Falkland	West Falkland	Islands
1,100 140	Stanley Goose Green	-	-
35-100	North Arm Port San Carlos	Port Howard Fox Bay East Chartres Hill Cove	-
15-35	Darwin Douglas Fitzroy Green Patch Salvador Teal Inlet Walker Creek	Fox Bay West Roy Cove Port Stephens	Pebble Weddell
less than 15	Bluff Cove Port Harriet Johnson's Harbour Port Louis Rincon Grande Port William	Dunmose Head	Beaver Carcass Keppel New Saunders Sedge Speedwell Westpoint

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