r 14-12-81

THE AUSTRALIAN NATIONAL UNIVERSITY

MEMORANDUM

FROM Deputy Vice-Chancellor's Office REFERENCE 14.4.4.32 DHF:MWH

TO Dr B. Martin, Applied Mathematics, Faculties DATE 11 December 1981

APPLICATION TO NERDDC

Medium Scale Wind Power for Isolated Communities

I regret having to inform you that your application to the Department of National Development and Energy for inclusion of the abovementioned project in the NERDDC Program has not been successful.

A copy of a letter of 7 December from the Acting Assistant Secretary, Research Policy and Programs Branch, regarding this year's applications, is ... enclosed.

D.H. Fraser
Graduate Assistant

111 14.4.4.32

DEPARTMENT OF NATIONAL DEVELOPMENT AND ENERGY

Tasman House–Hobart Place, Canberra City, 2601
Postal Address: PO Box 5, Canberra, ACT. 2600
TEL: (062) 45 8211. TELEX: 62101

Reference:

7 DEC 1981

Mr G.E. Dicker
Registrar
Australian National
University
PO BOx 4
CANBERRA ACT 2600

Dear Mr Dicker

NATIONAL ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

Reference is made to your response to the National Energy Research, Development and Demonstration Council's advertisements of 28 and 29 March 1981 inviting applications for energy research, development and demonstration grants.

I regret to inform you that those projects submitted by your organisation which are listed on the attached schedule have been unsuccessful. An outline of the assessment process is provided for your information in the following paragraphs.

Individual applications were assessed by one of seven Technical Standing Committees. The assessment took into account the merit of the proposal, the priority accorded to the particular research area and the total funds available. Competition for these was very keen. A total of 470 applications were submitted seeking approximately $88 million. This is about five times the funds available for the 1981/82 component of the program.

The assessments made by the Technical Standing Committees were reviewed by the full Council and the resulting recommendations were submitted to the Minister.

Unsuccessful projects will not be automatically reconsidered in 1982/83. However, they may be resubmitted in the next round of applications which is expected to be invited in February/March 1982.

Yours sincerely

A.J. Helling

A.J. Helling
Acting Assistant Secretary
Research Policy and Programs Branch

ENCL

14-7-81

14.4.4.32
GED

DEPARTMENT OF NATIONAL DEVELOPMENT AND ENERGY

JUL 10 4 01 PM '81

Tasman House-Hobart Place, Canberra City, 2601
Postal Address: PO Box 5, Canberra, ACT, 2600
TEL: (062) 458211, TELEG: NATDEV, TELEX: 62101

In reply please quote:

Project Numbers
as attached.

Dear Mr Dicker

NATIONAL ENERGY RESEARCH, DEVELOPMENT AND
DEMONSTRATION PROGRAM

I acknowledge receipt of your application(s) for Support Grant(s) as shown on the attached schedule.

It is expected that you will be advised of the outcome of your application(s) around October/November 1981.

Yours sincerely,

FOR
Assistant Secretary
Research Policy and
Programs Branch

MR G.E. DICKER
REGISTRAR
AUSTRALIAN NATIONAL UNIVERSITY
PO BOX 4
CANBERRA
ACT 2600

D FRASER Mrs 13/7

to file, please

SCHEDULE
DATE: 08 JULY 81

AUSTRALIAN NATIONAL UNIVERSITY

	PROJECT NO	SUPERVISOR	PROJECT TITLE
8.	811444	MARTIN,DR B	MEDIUM SCALE WIND POWER FOR ISOLATED COMMUNITIES

r 2-7-81

14.4.4.32 30 June 1981

DHF:MWH

The Assistant Secretary
Research Policy and Programs Branch
National Energy Office
Department of National Development
and Energy
Tasman House
Hobart Place
CANBERRA CITY, A.C.T. 2601

Dear Sir,

APPLICATION FOR SUPPORT GRANT 1981

I should be most grateful if you would accept for consideration the enclosed application from Dr Brian Martin seeking your support for research into medium-scale wind power for isolated communities which he proposes to undertake in collaboration with Dr Mark Diesendorf and Dr Jestse Kalma of CSIRO.

The project arises from the current work on large-scale wind power which has enjoyed your support.

Dr Martin's present appointment as Research Assistant in the Department of Applied Mathematics expires in January 1982. Because our resources available for staffing in 1982 cannot at the present time be determined it is not possible to affirm that Dr Martin will remain in that position. As soon as his future position is known I shall inform you.

This application had to be given unusually lengthy consideration within the University before it could be submitted and I regret the inconvenience you will have been caused by receiving the proposal so long after your closing date. I hope, nevertheless, that your Committee will be able to consider the application favourably.

Yours faithfully,

G.E. Dicker
Registrar

c.c. Dr Brian Martin ✓
Dean, Faculty of Science
Professor A. Brown, Applied Mathematics

1682/1976
31.5.1976
Revised June 1978

THE AUSTRALIAN NATIONAL UNIVERSITY

APPLICATIONS TO OUTSIDE ORGANIZATIONS FOR FUNDS

NAME: Dr Brian Martin DEPARTMENT: Applied Mathematics, SCHOOL/FACULTY: Science

NAME OF ORGANIZATION: National Energy Research, Development and Demonstration Council

A. Information for Vice-Chancellor

1. Is this in response to a general or a specific invitation for application? Which?
   General

2. Closing date, if any, for application 30 June 1981

3. Have there been previous approaches by the Department to the same donor? If so, with what result?
   No

4. Will commitments based on the funds sought terminate when the funds are exhausted?
   Yes

5. Where grant is sought to cover salaries or wages, is provision made for subsequent increase and salary-related costs?
   Yes

6. Have funds to cover the cost of computing been included or are they otherwise provided for?
   Included in normal Applied Mathematics Department computing budget.

7. What additional commitments for the University will be involved if the application is successful?
   Administrative support for one additional staff member.

8. Does the granting body propose conditions relating to patents which do not conform with University policy?
   No

9. Is the grant likely to be subject to any restriction on the publication of results?
   No

10. What responsibilities will be entailed for reporting, financially or otherwise, on the use of the grant and who will be responsible for ensuring that these reports are sent?
    Applicant will report to NERDDC as required.

11. Does the applicant's period of appointment in the University include the period for which support is being sought? If not the Head of Department should comment. Dr Martin's appointment is on an annual basis but we expect that he will be re-appointed when a renewal of appointment is required. I shall certainly be recommending this.

B. Recommendations

Head of Department A. Brown Date 25/6/81

Director or Dean [illegible] Date 25/6/81

NATIONAL ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION COUNCIL

Energy Research, Development and Demonstration Projects

1981 APPLICATION FOR SUPPORT GRANT

Project Title MEDIUM SCALE WIND POWER FOR ISOLATED COMMUNITIES

Applicant's Name DEPARTMENT OF APPLIED MATHEMATICS, FACULTY OF SCIENCE, AUSTRALIAN NATIONAL UNIVERSITY

CONTINUATION FUNDING

If this application seeks continuation funding of a project currently supported under the NERD & D Program, please list the existing project number(s) .....

OFFICE USE ONLY

Date received ..... File No .....

ONDOE 272 1 81

CERTIFICATE OF PUBLIC OFFICER/HEAD* OF ORGANISATION

I, being the duly appointed Public Officer/Head* of the organisation, declare that

(a) the information given in this application, including any attachments hereto, is true and correct in every particular;

(b) the organisation has the basic facilities required for the project and, subject to being awarded a grant, it will adhere to the program of activities set out in this application; and

(c) the salaries quoted for personnel are in accordance with the practice of this organisation.

** Delete whichever is not applicable.*

FULL NAME .....

SIGNATURE .....

DESIGNATION ..... DATE ...../...../.....

Applications to be lodged with:

The Assistant Secretary
Research Policy and Programs Branch
National Energy Office
Department of National Development and Energy
P.O. Box 5
CANBERRA, A.C.T. 2600

IMPORTANT

- *Original plus 9 copies of each proposal and supporting documentation are required.*
- *Please refer to Council's Explanatory Notes and Notes on the Preparation of Application Forms (Yellow Page) before completing this application.*
- *If space on this form is insufficient, supply details on separate pages.*

PART A -- BACKGROUND INFORMATION

1. ORGANISATION	Department of Applied Mathematics, Faculty of Science, Australian National University
2. BUSINESS ADDRESS	Box 4, P.O. Canberra ACT 2600
3. POSTAL ADDRESS	as above

4. (a) PERSON TO WHOM ALL CORRESPONDENCE SHOULD BE DIRECTED

Name:

Designation:

(b) PERSON TO WHOM TELEPHONE INQUIRIES SHOULD BE DIRECTED

	TECHNICAL	ADMINISTRATIVE
Name:	Dr Brian Martin	
Designation:	Research Assistant	
Telephone No.:	494445	

5. PROJECT DESCRIPTION (Brief summary of nature of project and general and particular objectives to be accomplished)

In several Australian townships which are isolated from the State electricity grids and are powered by diesel sets, medium-scale wind power is very close to economic competitiveness as a fuel saver. A basic question in planning such coupled wind-diesel systems is whether to install a single wind generator or several smaller, spatially dispersed wind generators. Advantages of dispersal include improved reliability, and the smoothing of gusts and other short-term wind variations. These should be quantified.

Therefore, this project aims to

i) obtain simultaneous measurements of wind speed from three similar but spatially dispersed sites, on time scales of several seconds to minutes;

ii) derive statistical models to describe the smoothing of fluctuations of total wind power in going from one to several sites (this is the principal objective);

iii) determine how much turbulent energy, over and above the energy estimated from hourly-averaged wind speeds, is recoverable by a wind generator;

iv) make preliminary assessments of the comparative economics of installing one larger wind generator versus several smaller wind generators into a town supply.

6. DURATION OF PROJECT 2 Years (insert number)

7. CHANCE OF SUCCESS (Indicate estimated chance of success of achieving particular objectives outlined in 5 in duration stated in 6)

(i) 95%; (ii) 90%; (iii) 90%; (iv) 80% %

8. R, D & D previously undertaken in this field by the Organisation (Brief summary)

See attachment.

9. PROJECT SUPERVISOR(S)

	(1)	(2)	(3)
Name:	Dr Brian Martin	Dr Mark Diesendorf	Dr Jetse Kalma
Qualifications:	BA, PhD	BSc(Hons), PhD	BScAg, MScAg, PhD
Designation:	Research assistant	Principal research scientist	Principal research scientist
Business Address: (Complete where "as above" is not appropriate)	as above	CSIRO Division of Mathematics and Statistics (DMS) P.O.Box 1965 ~~Canberra City 2601~~	CSIRO Division of Land Use Research (DLUR) P.O.Box 1666 ~~Canberra City 2601~~
Telephone No.:	494445	822011	465214
How much time in working days per month as an average will the Project Supervisor devote to this project?	2	1	1
Are any prolonged absences envisaged during the currency of this project which will affect its conduct?	No	No	No

What other major research projects are being undertaken and/or closely supervised by the Project Supervisor and what are their time demands? (Insert prefixes (2) and (3) and details if more than one project supervisor)

(1) Current DMS-ANU NERDDC project on large-scale wind power will expire around the time the proposed new NERDDC project commences.

10. SUPPORT FROM WITHIN ORGANISATION

		78/79	79/80	80/81	81/82 Estimate	82/83 Estimate	83/84 Estimate
A.	All related Energy R. D & D Activities wind only ($)	36,000	38,000	38,000	105,000	105,000	105,000
	Salary component included in above ($)	31,000	33,000	33,000	45,000	45,000	45,000
B.	This Project ($)				2,000	4,000	2,000
	Salary component included in above ($)				1,000	2,000	1,000

11. OTHER FINANCIAL SUPPORT
Give details of support separately for

(a) this project, and

(b) directly related energy R. D & D projects (show research field) from all sources.

Please indicate beginning and end of your organisation's financial year.

From 1/7.../... To 30/6.../...

DETAILS OF PROJECT/SOURCE OF FUNDS	AMOUNT ($) 80/81	81/82	82/83	83/84
		APPROVED OR REQUESTED		

PART B: ESTIMATED PROJECT EXPENDITURE REQUESTED AS A GRANT

12. SALARY AND RELATED EXPENDITURE

(a) Additional Project Staff

Employees	Annual Salary $	Period to be employed on project (i.e. dates)	Full-time man-months equivalent on project (incl. leave)	Estimated Cost ($)
(i) Professionally Qualified				
Research assistant grade 3	17383	1/1/82 to 31/12/83	24	37,000
		../../.. to ../../..		
		../../.. to ../../..		
(ii) Other				
		../../.. to ../../..		
		../../.. to ../../..		
		../../.. to ../../..		

(b) On-Costs

Items	Percentage of Salary		
(i) Payroll Tax			
(ii) Workers' Compensation Insurance			
(iii) Employers' Superannuation Contribution			
(iv) Holiday Pay Loading			
(v) Long Service Leave Allowance			
(vi) Others (Specify)			
TOTAL PERCENTAGE OF SALARY		TOTAL ON-COSTS	37,000

ESTIMATED TOTAL ADDITIONAL SALARY EXPENDITURE $

13. PLANT, EQUIPMENT AND MATERIALS	Estimated Date of Purchase	EXPENDITURE ($) (Include any installation costs)
(a) Description of Plant, Equipment and Materials for Project Costing More than $1000		
(i) Items to be purchased		
2 (two) Gill propeller vanes (Model 35003)	1/1/82	2,600
2 (two) Edas 2 microprocessor programmable data loggers	1/1/82	6,000
(ii) Items to be fabricated in-house (include cost of materials and labour)		
(b) Items costing less than $1000 (masts, batteries, solar panels)		1,000
(c) Maintenance*		–

ESTIMATED TOTAL EXPENDITURE ON PLANT, EQUIPMENT AND MATERIALS $9,600

Residual Value on Completion of Project* $ 4,500

* *Please supply details as an attachment*

14. CONTRACTED RESEARCH AND DEVELOPMENT EXPENDITURE

Name of Contractor and Period of Contract	Description of Tasks to be Contracted Out	Estimated Amount to be Paid $
ESTIMATED TOTAL CONTRACT EXPENDITURE		$

15. OTHER EXPENDITURE*	$
1. COMPUTING CHARGES	
2. TRAVEL	4,500
3. OTHER (SPECIFY)	
ESTIMATED TOTAL OTHER EXPENDITURE	$4,500

* *Please supply details as an attachment.*

16. TOTAL ESTIMATED PROJECT EXPENDITURE REQUESTED AS A GRANT

FINANCIAL YEAR	1981/82	1982/83		1983/84		TOTAL $
COST ITEM	Date of Approval to 31.12.81	DISTRIBUTION BY SIX MONTHS BEGINNING: 1.1.82	1.7.82	1.1.83	1.7.83	1.1.84	
SALARY AND RELATED EXPENDITURE (ITEM 12)		8,500	9,000	9,500	10,000		37,000
PLANT, EQUIPMENT AND MATERIALS (ITEM 13)		9,600	-	-	-		9,600
CONTRACTED R & D EXPENDITURE (ITEM 14)							
OTHER EXPENDITURE (ITEM 15)		1,125	1,125	1,125	1,125		4,500
TOTAL		19,225	10,125	10,625	11,125		51,100
CUMULATIVE LIMIT OF CLAIMS (OFFICE USE ONLY)							

PART C: SUPPORTING DETAILS

Applicants are requested to closely follow the seven headings outlined in the Explanatory Notes and listed below. Pages of the same size as this form should be attached as required and numbered consecutively

(a) Concept, proposed methodology and major problems
(b) Major stages of the project
(c) Significance of the project
(d) Awareness of related research in Australia
(e) Referees
(f) Facilities within the organisation available to the project
(g) Additional justification for expenditure

Attachment to Part A of NERDDC Application

Item 8:

Since 1978, the DMS-ANU wind research team has published or submitted for publication 15 scientific and technical papers on wind energy systems. Of these, 8 have had the financial support of NERDDC under Dr M. Diesendorf's grant to study the integration of wind power on a large scale into State electricity grids. The team has considerable skills in applied mathematics, computational mathematics and in statistical modelling, including the analysis of time series.

Dr J. Kalma, DLUR, is an applied climatologist with wide experience in wind measurement programmes. He has recently completed a consultancy with the PNG Department of Minerals and Energy on the potential for wind power utilisation in Papua New Guinea. A project to study the Australian continental distribution of wind speeds at fixed hours and of daily wind run throughout the year is near completion. Dr Kalma is also cooperating with the National Capital Development Commission on a regional airflow programme in the Canberra area.

Item 13:

Residual value on completion of project,

2 Edas data loggers (life expectancy about 6 years)	$4,000
2 Gill propeller vanes (life expectancy 3 to 4 years)	500
	$4,500

Attachment to Part A, item 9

The research assistant to be hired for the project (see B12) will be in addition to the three project supervisors. The additional staff member is vital to the project for undertaking data collection and reduction, statistical analyses, computer programming and report writing, and otherwise working with the three project supervisors. Thus the proposed project envisages a four-person team. The three project supervisors would be committed to spending a total of four working days per month between them on the project. The additional research assistant would spend full time on the project and could draw on the expertise of the supervisors and their colleagues and thus would be a key person in the team. A similar arrangement for the current DMS-ANU project has been quite successful: the appointee hired through NERDDC funds, J. Carlin, has done excellent and essential work and already has co-authored a number of papers (see publication list on wind energy).

PART C: SUPPORTING DETAILS

(a) CONCEPT, PROPOSED METHODOLOGY AND MAJOR PROBLEMS

Most existing wind speed data which are used for the assessment of wind energy potential are collected hourly and entail averaging the wind speed over periods ranging from 10 minutes to one hour.

The present proposal is to collect simultaneous wind speed data from three spatially dispersed sites with a time step and a time averaging period of several seconds. Data will be collected from a low-wind region (e.g. in or near the ACT) and a high-wind region (north-west Tasmania) and for each region the distance between the three dispersed sites will range from several hundred metres to several kilometres.

The principal objective of the project is to determine from this data, utilising statistical analysis and mathematical modelling, how much reduction will occur in the short-term fluctuations of total wind power output when a single wind generator of a given rated power is replaced by N spatially dispersed wind generators of the same total rated power. Hardly any work has been done previously on this problem anywhere in the world.

The answer to this question will depend on the value of N, the separation between the wind generators, the wind characteristics of the region and the response characteristics of the wind generators. We seek to provide simple, approximate mathematical expressions which will answer this question for many of the regions of Australia and its Territories which are suitable for medium-scale wind power, provided those regions do not contain major topographic inhomogenities (e.g. mountains and ravines). For this reason the sites chosen within each study region will have approximately the same altitude above sea level, and the same elevation above ground level.

The answer to our principal question above, taken together with consideration of the comparative reliability of wind power from N sites versus one site, will form the basis of a preliminary assessment of the comparative economics of installing one larger wind generator or several smaller wind generators into a town supply.

(The above project is analogous in some ways to the NERDDC-funded work which the DMS-ANU team has been doing on the capacity credit of large-scale wind power in State electricity grids. In that case,

wind speed data were analysed and simple mathematical expressions of considerable generality were derived for the capacity credit of wind power in the limits of small and large penetrations into the grid. The capacity credit results were then used as an input to an economic evaluation of wind power in a grid with optimal mix of conventional base and peak plant.)

In the present NERDDC proposal, the statistical analysis of data on short-term wind variations will also answer the following question: how much turbulent energy, over and above the energy estimated from hourly average wind speeds, is recoverable? The answer to this question will depend on the frequency spectrum of wind speed at a single site and the response characteristics of the wind generator. The former will be measured and the latter will be modelled mathematically by utilising published data on the response of existing wind generators.

The statistical analyses and modelling of wind speeds by ANU and DMS will utilise two methodological approaches: a static analysis of the distributions of wind power averaged over different time periods, and a time series analysis of power output.

Given the DLUR experience in monitoring wind data, the ANU-DMS experience in mathematical modelling, data analysis and wind energy systems, and the on-going DLUR-DMS cooperation on a Tasmanian wind energy assessment, we do not anticipate any major problems, once the necessary equipment and member of staff are obtained. The selection of a suitable, homogeneous region in or near the ACT will not be easy. However, in north-west Tasmania there is a known suitable region at Marrawah, where one anemometer mast has been erected for the Tasmanian project.

Lists of significant publications during recent years by the project supervisors and their immediate colleagues are attached.

The significance of this project and its relation to similar work elsewhere are discussed in sections (c) and (d) below.

(b) MAJOR STAGES OF THE PROJECT

(i) Purchase of recording equipment, site selection, initial collection of wind speed data both in the ACT and in north-west Tasmania: the local work should be achieved within 6 to 9 months of receipt of the grant; a further 6 months may be required to take a series of

measurements under different wind conditions in north-west Tasmania.

(ii) Mathematical models of the response of wind generators to fluctuations in wind speed. This work will be based on published measurements on existing machines. It will run concurrently with the first six months of wind data collection.

(iii) Static statistical models of wind power will be constructed concurrently with the initial one year of data collection.

(iv) Dynamic statistical models require a large body of data and may require developments in time series methodology, and so a full two years has been allowed for this stage of the project.

(v) All the early results from stages (i)-(iv) will be integrated in the second year of the project to determine:

- the turbulent energy, over and above the energy estimated from hourly averages, which is recoverable by a wind generator;
- the power output from a set of spatially dispersed wind generators, separated by various distances in various wind regions, on a time scale of the order of several seconds;
- any supplementary wind measurements which might be needed to provide useful information (such measurements would be performed and the data collected would be analysed during the last six months of the project);
- the economics of one large wind generator versus several smaller ones.

(vi) Publication of results. This would commence in the second year of the project and would probably continue after NERDDC funding of the project ceased.

(c) SIGNIFICANCE OF THE PROJECT

The project will provide essential information for the "substitution of alternative energy sources for liquid fuels in fixed installations" (paragraph 4 of explanatory notes of NERDDC application form). It will also assist the "economically feasible applications of solar, wind energy and other renewable resources" (paragraph 4).

There are several communities in Australia and its Territories which are situated in locations which are both windy and isolated from the State electricity grids. These include King and Flinders Islands (Tasmania), Esperance, Hopetoun and Bremer Bay (WA), and the Australian Antarctic Bases and Lord Howe Island (NSW). In these communities, the cost of electricity generation from the town diesel

sets is high (e.g. a total generation cost of 12c/kWh is now common) and is likely to rise in real terms in the foreseeable future.

In some of the above communities, it is further likely that medium-scale wind power will be economically competitive as a fuel-saver in the very near future (within two years).

Medium-scale wind power can be roughly described as the supply of electricity from one or more wind generators rated at 50 to 500kW each. The wind generators are coupled in parallel with the community's diesel set to produce fixed-frequency AC power. Storage is not necessary. Medium-scale wind power systems are already operating at several towns and islands in the USA, France and Canada, and are proposed for the UK and several other countries.

(d) AWARENESS OF RELATED RESEARCH

In Australia, the Tasmanian Directorate of Energy and the Hydro-Electric Commission (HEC) are investigating the possibility of medium-scale wind power for King and Flinders Islands. The State Energy Commission of WA (SECWA) is collecting wind data at Esperance, Hopetoun and Bremer Bay and is already operating a 50kW and a 22kW wind generator as a demonstration project on Rottnest Island. The University of NSW is measuring wind speeds on Lord Howe Island.

To the best of our knowledge, none of these projects is concerned with the main objective of our proposed project: namely, determining the effect of spatial dispersion of wind generators on the short-term fluctuations of power output (on time scales of a few seconds) of a set of wind generators separated by distances ranging from a few hundred metres to tens of kilometres. It is possible that one of our minor objectives (item (iii) of part A.5) could be achieved by the SECWA measurements.

The results of our project will provide essential data for studies by electrical engineers of the stability of town electricity supplies fed by wind power, and the constraints on the installed wind power capacity entailed by stability requirements.

The maximum installed wind capacity which a town supply could accommodate under stability constraints could be, for example, one single machine rated at 500kW or N spatially dispersed.100kW machines, where N is greater than 5. The purpose of our project is to provide the information which enables N to be determined. Thus our project

is complementary to the NERDDC project proposed by Dr Hugh Outhred, School of Electrical Engineering, University of NSW, which focuses on the stability aspects of medium-scale wind power from the viewpoint of power engineering. We believe that both projects are necessary for the proper development of medium-scale wind power in Australia and we would keep in close contact with Dr Outhred to ensure that the results of our project are presented in a form which is suitable for his project.

We are also aware that the UK Electrical Research Association (ERA) is preparing to study the stability of medium-scale diesel-wind supplies, again with the emphasis falling on power engineering aspects rather than data collection and statistical analysis.

Attached is the summary of a final report from the US Electric Power Research Institute (EPRI), entitled "Wind power generation dynamic impacts on electric utility systems". This report demonstrates that there is a great need for the NERDDC project we are proposing, not only in Australia, but also in the international scientific and engineering domain. For instance, the report concludes that

> "There is little representative minute-to-minute wind data presently available for assessing dynamic impacts of large clusters of wind turbines"

and that

> "The conclusions of this study are considered as preliminary due to the present lack of suitable site specific wind data".

The actual wind data used by the EPRI study are extremely limited. Although taken at one second intervals from three sites, the data spanned a total time of only six hours, were not taken simultaneously from the three sites and were not utilised for constructing statistical models which could then be applied to a wide range of sites.

In contrast, our project will record simultaneously from three sites with different separations in different regions. We propose to collect orders of magnitude more data than the EPRI group and to construct statistical models from the data which can be applied widely to different regions.

(e) REFEREES

Professor Bent Sørensen
Roskilde University Center, Energy Group, Building 17.2
P.O.Box 260
DK-4000 Roskilde
Denmark

Professor Peter Schwerdtfeger
Flinders Institute of Atmospheric and Marine Sciences
Flinders University
Bedford Park SA 5042

(f) ORGANISATIONAL FACILITIES AVAILABLE

The project needs NERDDC funding for a temporary position, wind speed monitoring equipment and travel.

ANU will provide mainline computing facilities at no charge, and DMS will provide minicomputer facilities at no charge. ANU and DMS will provide expert advice from other staff to assist with any difficult methodological points which may arise in the data analysis and mathematical modelling.

DLUR will provide workshop facilities, motor vehicles and technical assistance, as well as one propeller vane and one data logger which are suitable for measurements on a time scale of several seconds.

(g) ADDITIONAL JUSTIFICATION FOR EXPENDITURE

(i) Travel. Two visits to north-west Tasmania with a land cruiser will be required to sample different wind conditions: 2 x $1500 = $3000. Local travel for site selection and wind monitoring in the ACT region: $1000. Visits to Sydney for discussions with Dr H. Outhred (two per year for two years): $500. Total travel cost: $4500.
(ii) Equipment. The Gill propeller vane is one of the few moderately priced instruments currently available for very sensitive measurements of horizontal wind speed and direction. The vane achieves a delay distance (50% recovery) of 1.2 metres. Damping ratio is 0.49. The wind speed sensor is a molded polystyrene propeller which provides a distance constant (60% recovery) of 1.0 metres or less. A close match has been achieved between vane and propeller.

Analog output signals for speed (and direction) are to be recorded on EDAS 2 microprocessor programmable data loggers with sampling time/ sampling intervals down to seconds. The data loggers are battery powered and solar panels will be used for recharging the battery arrays.

Scientific papers concerning wind energy, 1978-1981, by Brian Martin, Mark Diesendorf, Jetse Kalma and colleagues

J. Carlin and J. Haslett, "The probability distribution of wind power from a dispersed array of wind turbine generators", submitted to Journal of Applied Meteorology.

D. J. Daley and J. Haslett, "A thermal energy process with controlled input", submitted.

M. Diesendorf, "Recent Scandinavian R&D in wind electric power: implications for Australia", Search, 10, 165-173 (1979).

M. Diesendorf, "Environmental impact of wind power", Proc. Ann. Conf. Institute of Draftsmen Australia, ISBN 0 9596351 X, 1-9 (1980).

M. Diesendorf and G. Fulford, "Optimal rated speed of a wind generator", Wind Engineering, 3, 62-68 (1979).

M. Diesendorf and B. Martin, "Large-scale wind power for Western Australia", Proc. Solar Realities in Western Australia in the 1980s, International Solar Energy Society, ANZ Section, ISBN 0 909704 25 2, 47-52 (1979).

M. Diesendorf and B. Martin, "Integration of wind power into Australian electricity grids without storage: a computer simulation", Wind Engineering, 4, 221-226 (1980).

M. Diesendorf, B. Martin and J. Carlin, "The economic value of wind power in an electricity grid", submitted to BWEA Int. Colloq. on Wind Energy, Proc., August 1981.

M. Diesendorf and M. Westcott, "Renewable energy sources and storage", Nature, 275, 254 (1978).

J. Haslett, "The effect of dispersal on the capacity value of wind power", submitted to Wind Engineering.

J. Haslett, "On a general theory for modelling the interaction between wind energy conversion systems and the electricity grid", submitted to Journal of Operations Research.

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J. Haslett and M. Diesendorf, "On the capacity credit of wind power: a theoretical analysis", Solar Energy (in press).

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Wind Power Generation Dynamic Impacts on Electric Utility Systems

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SUMMARY

This report summarizes the work performed by Zaininger Engineering Company (ZECO) for the Electric Power Research Institute (EPRI) under Contract TPS 79-775.

The purpose of the study was to perform an initial assessment of potential wind power generation dynamic impacts on electric utility systems. A range of "worst case" wind fluctuations was examined using the Hawaiian Electric Company (HECO) system for case studies. Minute-to-minute system generation ramping, frequency variations, and short-term stability were assessed. A global approach to identifying potential dynamics problems was taken with several primary objectives: 1) to develop appropriate study methods for assessing dynamic impacts of large penetrations of wind power generation; 2) to apply these methods to an illustrative example utility system; and 3) to analyze results and draw general conclusions regarding potential wind turbine (WT) penetration limits attributable to dynamic problems.

The project approach consisted of several tasks. The appropriate HECO generation, transmission, and load representation were determined based upon 1985 HECO projections. A two-mass wind turbine dynamic model was developed from the best available information. HECO frequency excursion and ramping criteria and operating experience were examined and compared with operating criteria of the North American Power Systems Interconnection Committee (NAPSIC). Appropriate "worst case" wind fluctuations representative of the total WT cluster were then examined using the limited available minute-to-minute wind data.

Frequency excursion and minute-to-minute ramping calculations were performed for a range of wind turbine cluster sizes, initial operating conditions, and different frequency excursion and ramping criteria. These cases were associated with day-to-day normal operation "worst case" assumptions. The calculations were performed on a parametric basis because of the lack of existing minute-to-minute wind fluctuation data and coincident wind power plant performance model. For example, Figure S-1 presents the maximum allowable combined wind power plant

output/load change to limit system frequency excursions to 0.1 Hz. This figure presents data for a range of initial system load levels, spinning reserve criteria, and initial WT cluster output levels.

Figure S-2 presents the maximum allowable combined WT cluster/load change in a three minute period as a function of initial system demand. These data are plotted using allowable HECO three minute ramping criteria and operating reserve criteria.

Short-term transient stability calculations were performed assuming several "worst case" HECO system disturbances. In all cases studied, the HECO system was stable with and without up to 80 MW of wind turbines installed. For example, Figure S-3 presents one of the transient stability cases. In this case, under peak load conditions, the total 80 MW wind plant was tripped, and the HECO system remained stable.

Some general conclusions and observations resulting from this study are as follows:

- Utility system dynamic impacts may limit the potential penetration of wind turbines.
- Operating restrictions on large wind power plants due to dynamic impacts will tend to reduce their annual energy output. Hence, annual energy projections for large wind power plants should account for these restrictions.
- ✳ There is little representative minute-to-minute wind data presently available for assessing dynamic impacts of large clusters of wind turbines.
- An important potential dynamic constraint to WT penetration is minute-to-minute ramping requirements imposed on the rest of the system generation on a daily basis. This statement applies to both isolated and some interconnected utility systems.
- System frequency excursion limitations are an important dynamic consideration for isolated utility systems.
- Dynamic impacts of wind turbine clusters will be site specific.
- Consideration of wind plant output fluctuations under utility light loading conditions, as well as peak loads, is important.
- ✳ The conclusions of this study are considered as preliminary, due to the present lack of suitable site specific wind data and field experience with large clusters of wind turbines.