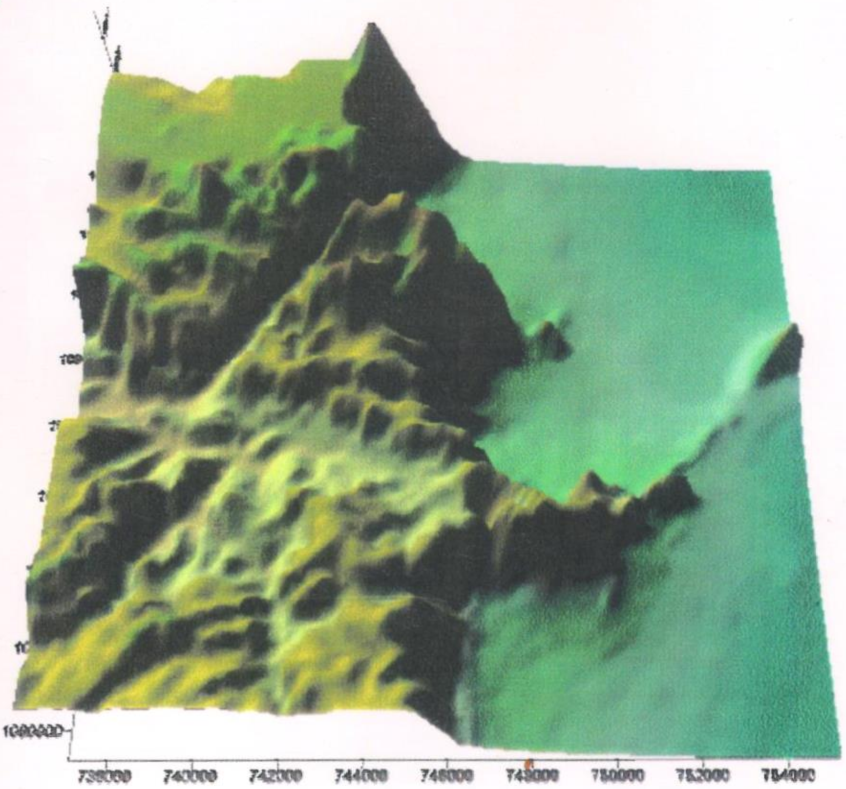
MICRO SURVEY OF WIND RESOURCES IN AND AROUND RAMAKKALMEDU WIND MONITORING STATION, KERALA

FINAL REPORT

Project funded by

Agency for Non Conventional Energy & Rural Technology, Thiruvananthapuram



C-WET

Wind Resource Assessment Unit
CENTRE FOR WIND ENERGY TECHNOLOGY (C-WET)
Chennai - 600 101

JULY 2003

C-WET/WRA/CP-10/2002-03

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Prepared by

E Sreevalsan, K C Dhimole & R Sasikumar

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Acknowledgments

We are thankful to Sri K .S. Vijayan, Director, Agency for Non Conventional Energy & Rural Technology, Thiruvananthapuram for entrusting the Micro Survey Analysis study at Ramakkalmedu , Kerala to the Centre for Wind Energy Technology.

Our sincere thanks are to Shri. M P Ramesh, Executive Director, Centre for Wind Energy Technology, Chennai for his valuable suggestions in executing this project.

We also would like to acknowledge the contribution of the staff of Wind Resource Assessment Unit , C-WET, Chennai for extending help in preparing the report.

Executive summary

The Agency for Non Conventional Energy & Rural Technology, has entrusted the Micro Survey Analysis study at Ramakkalmedu site in Kerala to Centre for Wind Energy Technology, Chennai. The C-WET has carried out the work and brief summary of the project is given below.

In this report, first chapter describes the status of wind power projects in India, wind-monitoring project in Kerala and background of this project.

In the second chapter, wind characteristics at Ramakkalmedu wind monitored site is explained in detail. The maximum and minimum monthly mean wind speeds observed at 20 M level were 46.96 kmph in June and 17.86 kmph in April. The annual average wind speed at the site is 30.29 kmph at 20 m level and one of the highest annual mean wind speed observed in the country. Out of 12 months except the month for April the months the wind speeds are found to be in the range 25 to 45 kmph. The annual mean wind power density is found to be 540 W/m^2 at 20 m level. The mean power law index is found to be either zero or negative which indicates the influence of speed up factor at lower levels especially during south west monsoon months and it cannot yield any conclusion on vertical wind profile. The data for a period of Jan 1992 to Dec 1995 were used for this study.

In the third chapter , the results of Micro Survey analysis in and around Ramakkalmedu wind monitoring station are described. Wind Atlas Analysis and Application Programme (WAsP) was used for analysis. Since the Region of interest is very complex, RIX analysis was also carried out to eliminate the error. With the applicability of WAsP verified under the limitations detailed computations of wind power density were carried out with a 250m x 250m grid for 50 sq.km and for finer results analysis were carried out with a grid 50m x 50 m at the windy areas. The details potential sites are given in this chapter. Since wind resource assessment of the Region of Interest is made with reference to a single point measurement, it is suggested to carry out wind monitoring at moresites for the better accurate results.

The fourth chapter devoted on master plan for wind farm projects in Ramakkalmedu areas is given. It includes the potential, details of wind farmable sites, which include the details of electrical infrastructure, approach & accessibility *in the region of Interest. This will help the promoters/developer to plan wind farm at the potential sites.*

The estimated installed capacity work out to be 80 MW considering the present available technology. With the advent of wind turbine technology the capacity may go up. The expected generation from 80 MW consisting of 500 kW machines at 40 .5 m hub height would be 188million Units /year with an average capacity factor of 27 % for the entire area. Higher capacity machines of MW range are appropriate for the better utilisation of wind resources available in this region.

Chapter 1
BACKGROUND OF THE PROJECT

1.1.Introduction

Wind energy technology is one of the most promising energy technologies for today and coming centuries. The technology of wind turbines has grown dramatically in size and power output in the last one decade. Although wind turbine design has become a high-tech industry, wind turbines can easily be installed within a short period, serviced and maintained locally compared to the conventional power technologies. In near future it may become the least expensive energy technology. Moreover it leaves no harmful emissions or residue in the environment. Wind power is becoming popular in Indian Energy sector also.

The total installed wind power capacity has crossed 31,000 MW (as on 31.12.2002) globally, India ranks 5th with an installed capacity of 1869.5 MW of wind power after Germany, USA, Denmark and Spain. Out of the total installed wind power capacity of 1870 MW, about 1804 MW has come from commercial projects taken up through private investments. This is the result of joint effort by Government and Industry.

While planning a wind energy farm it is very important to have adequate information about the wind characteristic for that regions in different seasons. In order to assess wind resources of the country, Ministry of Non-Conventional Energy Sources, Govt. of India launched a National Wind Resource Assessment Programme in 1986 with the technical assistance of the erstwhile Field Research Unit of the Indian institute of Tropical Meteorology (IITM) Bangalore and the State nodal agencies. The wind monitoring has so far covered 456 locations covering 17 States and three Union Territories. At present 64 stations are in operation spread over 11 States and one Union Territory of Lakshadweep. Comprehensive data for 198 stations have been published in the "Wind Energy Resource Survey Volume I to VI containing Wind power density, Power law index, Energy pattern factor, Mean monthly wind speed (year-wise), Weibull parameters, etc. To assess wind potential availability around selected wind monitoring stations for commercial exploitation, a micro-level study has been carried out around 87 wind monitoring stations and report prepared for each station. These reports present the result of Micro-Survey of wind resources around wind monitoring station covering an area of 20 x 20 sq.km including

Master plan for wind farm sites. There is an enough scope to further study the wind climatology of India from point of view of wind energy utilisation.

The main prerequisite for a successful wind farm is an adequate wind resource. Since wind resource shows, so much spatial variability the best way to assess a location is the in situ resource assessment. Several approaches are available for assessing wind resource within a given land area. These approaches can be categorised as three basic scales or stages of wind resource assessment; preliminary site identification, site wind resource evaluation and micro survey and micrositing.

a. Preliminary site identification: This process screens a relatively large regions for suitable wind resource areas based on information such as available meteorological data, topography, biological and other wind indicators.
b. Site Wind Resource Evaluation: This stage applies to wind measurement programs to characterise the wind resource in a defined area or set of areas where wind power development is being considered.
c. Micro survey and micrositing: The smallest scale or third stage of wind resource assessment is micro survey. Their main objective is to quantify the small-scale variability of the wind resource over the region of interest. Ultimately, micrositing is used to position one or more wind turbines on an identified site to maximize the overall energy output of the wind plant. Normally micrositing is beyond the scope of wind resource assessment projects

1.2 Wind monitoring project in Kerala

As a part of National Wind Energy Assessment Programme, the Agency for Non-conventional Energy & Rural Technology (ANERT) has established 21 wind monitoring stations in Kerala during the period 1990-1998 with the technical assistance of the then Field Research Unit of Indian Institute of Tropical Meteorology. Preliminary site selection was carried out by ANERT. About 40 sites were identified after study of topo sheets and ground relief features and all sites were inspected by the ANERT and report submitted to the then IITM, Bangalore. Finally 21 sites were selected for observations mainly in Palghat gap and Eastern mountainous region of the state. 20-metre high mast was used for the measurement. Out of 21 sites, 16 sites were found with mean annual wind power density more than $150 W/m^2$ at 30 m above ground level. The final data generated are wind speed, wind rose, velocity frequency distribution, peak wind speed, lull, Weibull parameters etc. All the data generated so far are published in either different volumes of "Wind Energy Resource Survey in India" Volume I to VI and in the various Interim Reports prepared by the IITM-FRU. These data are very much useful for the planning of wind farms.

1.3. Background of the project

Agency for Non Conventional Energy & Rural Technology (ANERT) established by Govt. of Kerala , vide their letter No.02/2001/WF/ANERT dt:09/01/2002had requested C-WET to submit the proposal for preparing Micro Survey and Master Plan for Ramakkalmedu site in Kerala. The C-WET had submitted offer for Rs.2.6 lakhs vide no.C-WET/WRA/26/2001-2002 dated 27.05.02. Subsequently a work order was issued by ANERT on 31.07.2002.

MILESTONES OF THE PROJECT

1. Survey of India Map of the Region of Interest was sent by ANERT on 12.08.2002.
2. Advance payment of Rs 1.30 lakhs has been received on 26-08-2002
3. First site visit was carried out by C-WET during 19th to 22nd September 2002.
4. Second field visit was carried out by C-WET during 8th to 12th October 2002
5. Report is submitted on 25th October 2002.
6. Approval from ANERT on 25-06-03
7. Final Report is submitted on 17 July 2003

Chapter 2
WIND CHARACTERISTICS AT RAMAKKALMEDU WIND MONITORING STATION

2.1. Site Description

The Region of Interest falls in the high ranges of Western Ghats in the Idukki district of Kerala. Western Ghats in general, presents a succession of cliffs, ridges and conical peaks and is of highly irregular and rugged in topography i.e. highly complex in nature. The elevation of the hills gradually decreases towards west. The extreme east of the mountainous region abruptly stops with steep slops, which overlooks the valleys in Tamilnadu. Small platforms occurring among these hills may be considered as saddles in original chains shaped into the present forms through age-old erosion. The Ramakkalmedu wind mast is located over a ridge at a height of 1020 m above mean sea level and at a distance of 1 km from Ramakkalmed village. The orientation of the ridge is North- South. The entire area is with an open appearance. Details of Ramakkalmedu wind monitoring Station is given in table 2.1.

Table 2.1.

Details of Ramakkalmedu wind monitoring Station

1. NAME OF THE SITE	Ramakkalmedu
Lattitude	9^0 48'
Longitude	77^0 14'
Elevation	1020 m
Toposheet NO.	58G/1
2. STATE/DISTRICT/.TALUK/ VILLAGE	Kerala/Idukki/Udumbachola/Parathode
3. APPROACH DETAILS/ ACCESSIBILITY	About 14 km from Nedumkandam town. An approach Road is available from Nedumkandam to Ramakkalmedu. Mast was located at top of a ridge.
4. NATURE OF TERRAIN	Hilly terrain/ Complex
5.EXPOSURE	Open appearance
6. TYPE OF SOIL	Forest loam
7. PERIOD OF DATA UESD:	1992 January-1995December
8. INSTRUMENTS USED	Second Wind
9.. MAST HEIGHT	20 m
10. LEVELS OF OBSERVATION	10m and 20 m level

Ramakkalmedu area is available in the 1:50,000 scale Survey of India map no.58G/1 grid C3. Map showing Kerala in India is given in figure 2.1.Map showing Ramakkalmedu area in Kerala State and Idukki District are shown in fig.2. 2 &2. 3 respectively . Map of the Region of Interest is given in fig 2.4.

2.2 Climate in Idukki District

Information on meteorology of region of interest is very important for wind power projects for various reasons. This section gives a general idea of climate in Idukki district. Idukki district is surrounded by Trichur district on the north, Pathanamthitta district on the South, Ernakulam and Kottayam district on the west and the Tamil Nadu state on the eastern side. The year may be divided into four seasons. March to May is the hot season followed by the southwest monsoon season from June to September. October and November form the post-monsoon season. December to February may be called northeast monsoon season although the rains cease from December onwards.

Rainfall:

Records of rainfall in the district are available for 10 stations for the period ranging from 42 to 79 years. The average annual rainfall in the district is 2794.9 mm. The rainfall increases from north to south. The average annual rainfall varies from 5164.8 mm at Peermade to 649.2 mm at Chinnar. The southwest monsoon is very much active over the district by about the last week of May generally and continues until the beginning of October. June and July are the monsoon months with the heaviest rainfall. The total rainfall in these two months accounts for 65% of the annual total. Thundershowers are received in the hot season from March to May and in the post monsoon months from October to November. The rainfall in the hot season and post-monsoon season constitutes about 13% and 18% percent of annual rainfall respectively. The yearly variation of rainfall is not large. In a fifty-year period from 1901 to 1950, the highest rainfall occurred in 1904 when it amounted to 179% of the normal. Lowest rainfall was amounted to 73% of the normal in the year 1934. Considering the district as a whole rainfall less then 80% of the normal has occurred once, in the fifty year period. The annual rainfall in the district was between 2200 and 3200 mm in 36 years out of 50.

On an average there are 127 rainy days (i.e. days with rainfall of 2.5 mm or more) in a year. This number varies from 45 at Chinnar to 167 at Peermade .

The heaviest rainfall recorded in 24 hours at any station in the district was 483.9 mm at Devikulam on July 17, 1924. Five stations in the district had the record highest 24 hours rainfall in one of the three days, July 15, 16 and 17, 1924.

Temperature:

There is no meteorological observatory in the district. The description, which follows, is mainly based on the records of the observatories in the neighbouring districts, where the climatic conditions are similar. Temperature begins increasing after February. March and April are generally hottest months. The mean daily maximum temperature in these months is about 31^0 C and the mean daily minimum is about 25^0 C. With the onset of the southwest monsoon by the end of May, day's temperatures decrease slightly and whole of the monsoon season is generally pleasant. After the withdrawal of the southwest monsoon by about the beginning of October, temperature increases gradually and heat in the post monsoon and northeast monsoon seasons is nearly as intense as in summer.

Relative Humidity:

The air is highly humid nearly round the year. The relative humidities are comparatively less in the afternoons.

Cloudiness:

Skies are heavily clouded to overcast in the southwest monsoon season. Generally skies are moderately to heavily clouded in the post and pre monsoon months. In the rest of the year skies are clear or lightly clouded.

Winds:

Winds are generally moderate with some increase in force in the summer and monsoon seasons in the lower levels. In the period January to May winds strengthen in the afternoons. In the southwest monsoon season the winds are mainly westerly or northwesterly. Winds from northeast and east direction are not uncommon during mornings. During the rest of the year winds are northeasterly to easterly in the mornings and blow from directions between southwest and northwest in the afternoons.

Fig.2.1 Map of Kerala in India Map

Fig.2.2 Map of Idukki district in Kerala Map

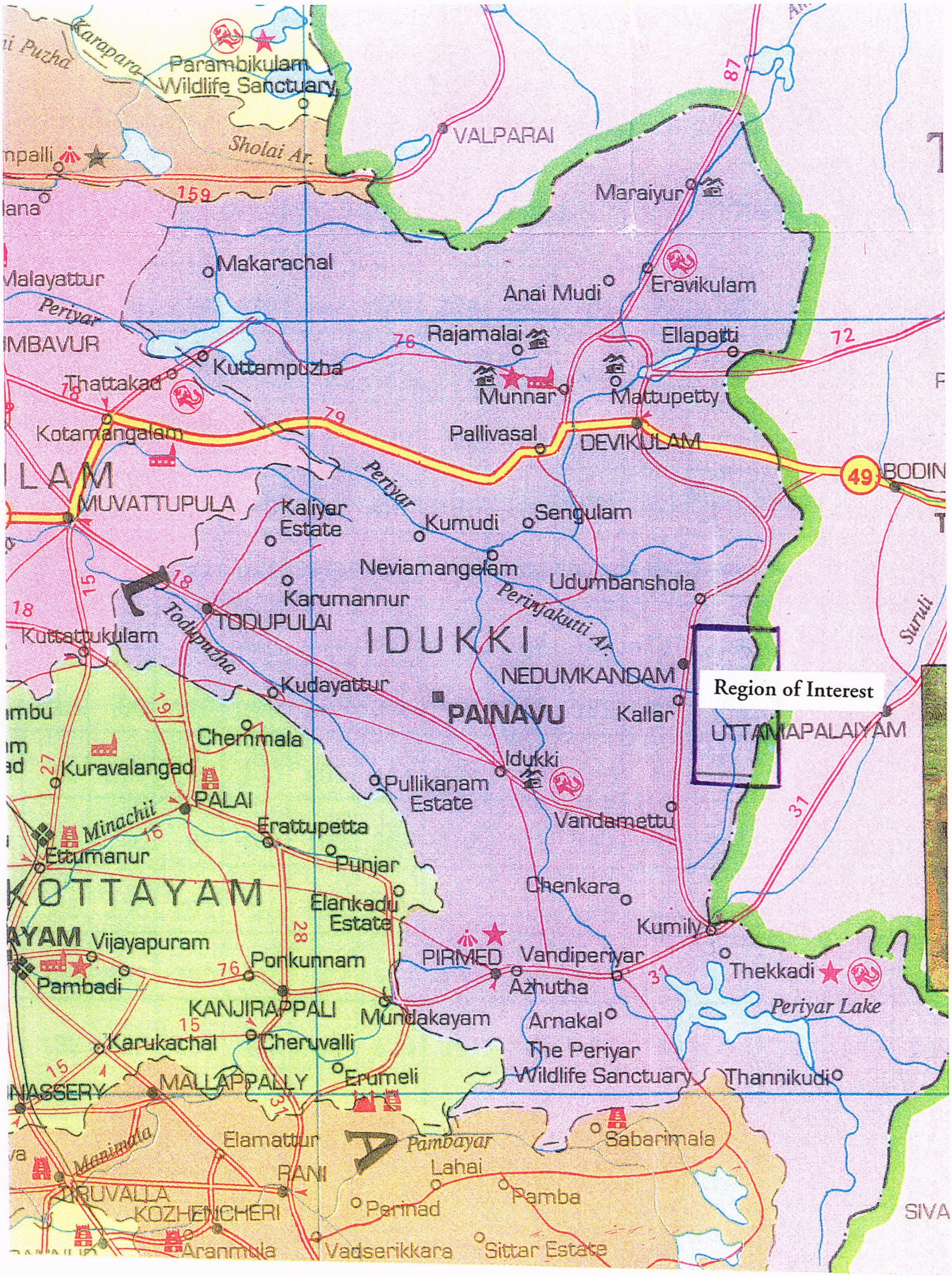


Fig.2.3 Map of Region of Interest in Idukki District

Fig.2.4 Map of Region of Interest

Special weather phenomena: Thunderstorms are frequent in the summer months and the post monsoon and early northeast monsoon seasons. Occasional squalls occur in association with thunderstorms in the latter summer.

2.3 Methodology

The following methodology was used for the wind measurement and analysis at Ramakkalmedu.

a.Data collection.

A wind monitoring station was established at a representative location of Ramakkalmedu area under National Wind Resource Assessment Programme and data collected for a period August 1991 to March 1998. A 20-m high mast was installed on a gently slopped north - south oriented ridge that is otherwise in a highly undulating terrain.

One pair of anemometer and wind vane was used at 10m and 20 m level to monitor the wind. The outputs from these sensors were connected to a microprocessor -based automatic data logger that was fixed at 1.5m above ground level. The entire sensors and data logger used for the project was of M/s Second Wind Inc., USA.. The data stored in EPROM chip for every two months were collected and processed.

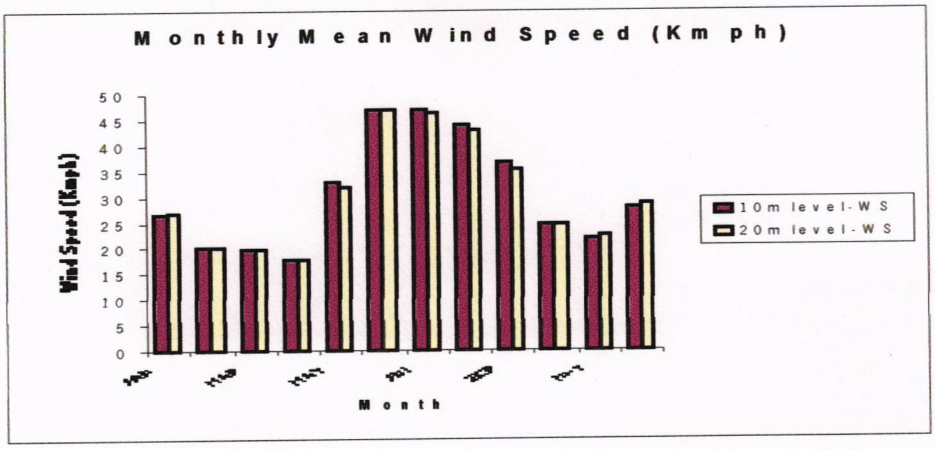
b. Analysis of data

Using basic equations of physical and mathematical sciences, wind data analysis of the site was carried out. The variation of wind speed with height above ground (often-called vertical profile) and the turbulence data analysis are of important.

2.4. Wind Characteristics at Ramakkalmedu Wind Monitoring Station

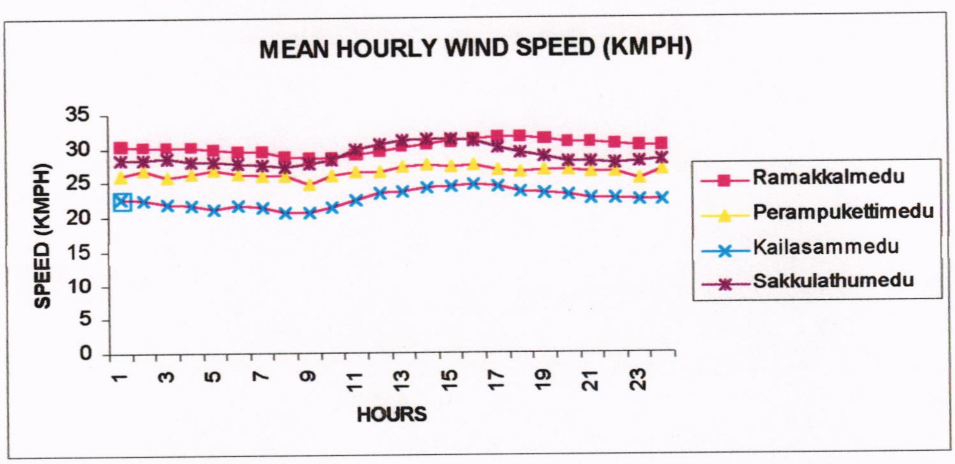
The maximum and minimum monthly mean wind speeds observed at 20 M level were 46.96 kmph in June and 17.86 kmph in April. The annual average wind speed at the site is 30.29 kmph at 20 m level and one of the highest annual mean wind speed observed in the country. The monthly variations of wind speed at two levels are shown in fig 2.4. The mean power law index is found to be either zero or negative which indicates the influence of terrain induced flow distortions at levels especially during south west monsoon months. In the winter months the winds are following the general trend of variations with height though is marginal. The relative changes in the upper and lower levels are found not significantly large. The area is found having very strong winds at least 10 months in an year and zero or negative power law index which cannot yield any conclusion on vertical wind profile.

Figure 2.5.The monthly average wind speed at Ramakkalmedu



The annual mean wind power density is found to be 540 W/m^2 at 20 m level. Out of 12 months except the month for April the months the wind speeds are found to be in the range 25 to 45 kmph. A few more wind monitoring stations such as Perampukettimedu , Sakkulathumedu, Kailasamedu and Kulathummedu were established in the vicinity of region of interst and all these stations have shown strong wind as shown by the Ramakkalmedu. One of the striking features noticed is that winds are generally decreasing as one goes towards west. The maximum wind pressure is felt close to the points, which abruptly ends with steep escarpment in the eastern side

Fig. 2.6. Diurnal pattern of the wind speed at Ramakkalmedu and adjacent area.



The diurnal pattern of the wind speed of Ramakkalmedu , Perampukettimedu, Kailasamedu and Sakkulathumedu at 20 m level is given in fig 2.6. It is evident from the figure the wind speed is almost constant throughout the year.

The graph (Fig.2.7) indicates, inter annual variations of wind power density for the years 1992,1993,1994 and 1995. There were slight variations in wind power density but within in the limit.

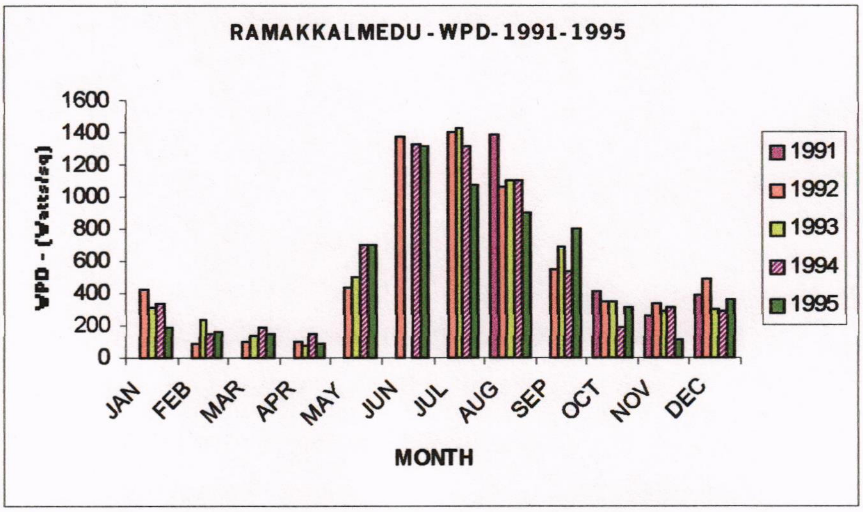
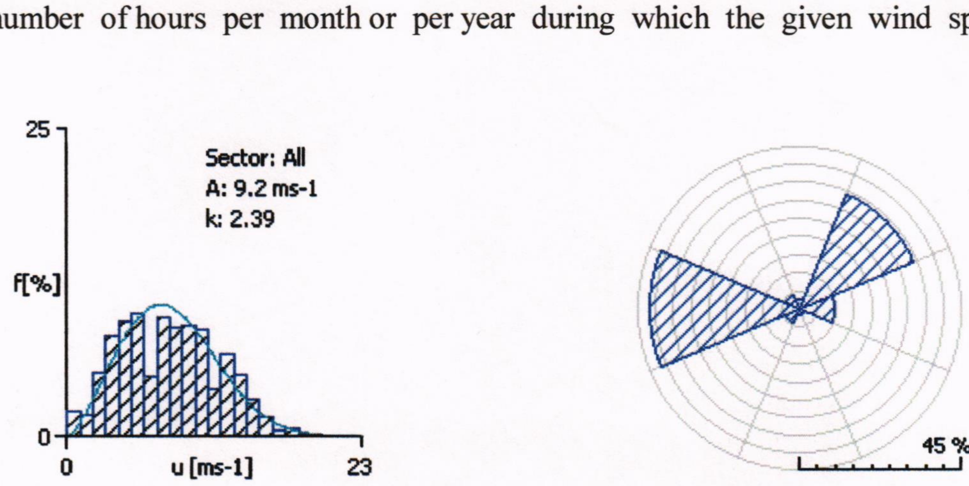


Fig.2.7 Inter annual variations of wind powerdensity

Frequency distribution

Apart from the distribution of the wind speed over a day or a year, it is important to know the number of hours per month or per year during which the given wind speed



'a 'b

. Fig 2.8 a .Histogram of annual wind speed and fitted Weibull distribution curve . b wind direction rose diagram is shown in figure b.

occurred i.e. frequency distribution of wind speed. Sector wise annual frequency distribution of the site is given in table 2.2. Histogram of annual wind speed and fitted Weibull distribution curve is given in the figure 2.8a and wind direction rose diagram is shown in figure 2.8b. Wind rose indicates that the predominant wind direction is west (41.8%) during south west monsoon and northeast (34.1%) during north east monsoon periods. Sector wise histogram with fitted Weibull curves are depicted in the figure 2.9. The values of Weibull parameters are also shown with graphs.

One of the main observations at this site is, 18% of annual hours get wind speed more than 12 m/sec which is very close to the rated wind speed of stall regulated wind electric generator.

m/s	N	NE	E	SE	S	SW	W	NW	Total
0	5	5	5	5	5	5	5	5	40
1	24	24	24	24	24	24	24	24	192
2	20	20	20	20	20	20	20	20	160
3	31	173	64	29	28	31	70	37	463
4	17	389	102	10	8	15	117	33	691
5	19	454	119	12	10	17	137	39	807
6	12	437	111	6	8	24	238	32	868
7	6	216	55	3	4	12	118	16	430
8	12	423	108	6	8	24	231	31	843
9	16	236	61	2	4	35	388	30	772
10	16	241	62	2	4	35	397	31	788
11	19	159	43	2	3	38	473	25	762
12	10	37	12	1	1	19	253	9	342
13	17	63	21	1	2	33	434	16	587
14	13	48	16	0	2	25	330	12	446
15	9	30	10	0	0	16	208	7	280
16	4	16	5	0	0	8	110	4	147
17	2	6	2	0	0	3	39	1	53
18	2	7	2	0	0	3	45	2	61
19	1	3	1	0	0	1	19	0	25
20	0	1	0	0	0	0	6	0	7
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0

Table 2.2 Annual frequency distribution of wind speed at Ramakkalmedu

The following details are given in the Annexure.

- The summary of wind data at both 10m and 20 m levels.(Annexure2. 1).

- Month wise Frequency Distribution of Wind Power Density for 20 m level.(Annexure 2.2)
- Numerical presentation of wind rose data for 20 m level(Annexure2. 3).
- Month wise percentage frequency distribution of wind speed (Annexure 2.4)
- Month wise mean hourly values of wind speed and 20 m level.(Annexure2. 5).
- Annual Monthly Wind speed and Monthly Wind Power Density.(Annexure2. 6).

Some photographs of the studied areas are also given (figure 2.10.)

Fig.2.9. Sector wise histogram with fitted Weibull curves

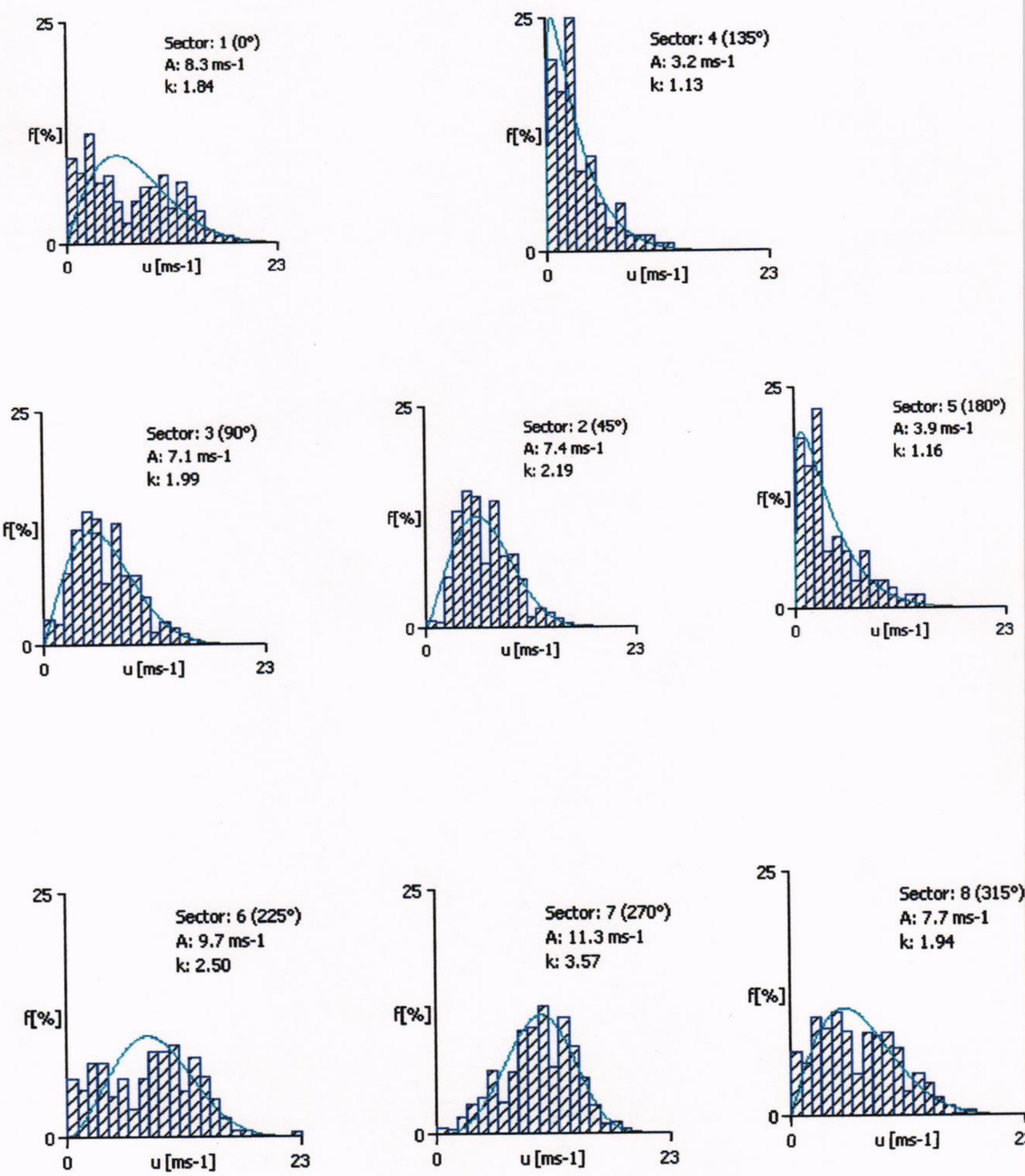


Fig2.10 a. A view of a typical ridge in Ramakkalmedu area

Fig2.10 b. A view of general nature of terrain in Ramakkalmedu area

Fig2.10 c. A view of Kambam valley from Ramakkalmedu Wind Monitoring Station

Fig2.10 d. A view of a typical peak in Ramakkalmedu area

STATIONS : RAMAKALMEDU **Annexure 2.1**

SUMMARY OF WIND DATA

Month	Monthly Mean Wind Speed (Kmph)		Monthly Standard Deviation (Kmph)		Hourly Maximum Wind Speed (Kmph)		Peak Wind Speed (Kmph) (Date/Year/Time of Occurrence)		Lull in Hours		Prevailing Wind Direction	
	(10m)	(20m)	(10m)	(20m)	(10m)	(20m)	(10m)	(20m)	(10m)	(20m)	(10m)	(20m)
JAN	26.66	26.97	1.31	1.30	60.74	65.97	83.67 (26/92/19:21)	81.25 (26/92/19:58)	29.00	25.00	NE	NE
FEB	19.99	20.28	1.13	1.25	65.97	64.36	100.56 (2/93/10:55)	96.54 (2/93/10:54)	79.00	69.00	NE/SE	NE
MAR	19.71	19.89	2.89	2.95	46.66	47.66	74.82 (19/95/12:51)	77.23 (13/93/16:25)	104.00	95.00	NE	NE
APR	17.80	17.86	1.54	1.64	45.45	42.64	75.62 (13/94/09:47)	86.89 (13/93/16:25)	129.00	118.00	W/NE/E	W/NE/S
MAY	32.86	31.90	2.46	2.42	84.07	84.87	109.41 (31/94/09:47)	111.02 (31/94/16.56)	53.00	49.00	W	W
JUN	47.10	46.96	0.72	0.53	81.25	85.68	120.68 (8/93/07:49)	132.74 (19/92/20:02)	1.00	0.00	W	W
JUL	46.84	46.26	0.85	0.76	82.86	S	123.89 (16/94/19.53)	127.92 (19/92/09:29)	1.00	1.00	W	W
AUG	43.88	42.88	1.00	0.93	78.44	71.60	111.83 (31/95/23:40)	107.80 (31/95/14:08)	4.00	4.00	W	W/N
SEP	36.44	35.31	2.03	1.92	76.83	74.82	102.17 (1/95/00:18)	101.37 (1/95/00:18)	16.00	14.00	W	W W
OCT	24.57	24.51	0.90	0.96	63.96	64.76	92.52 (17/95/15:49)	93.32 (17/95/15:49)	100.00	91.00	W	W
NOV	21.88	22.32	0.84	0.93	100.16	101.77	93.32 (7/93/04:12)	90.91 (7/93/15:42)	117.00	109.00	NE/W	NE
DEC	27.98	28.39	0.72	0.84	56.72	58.33	79.65 (20/92/02:02)	78.04 (20/92/13:04)	27	25	NE	NE
ANNUAL	30.48	30.29	10.33	9.98	100.16	101.77	123.89 (16/7/94/19:53)	132.74 (19/6/92/09:29)	659	599	-	-

(No data for June 1993)

Baed on data January 1992 - December 1995

STATION : RAMAKALMEDU

Annexure 2.2

DISTRIBUTION OF WIND POWER DENSITY

Class Interval (Kmph)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
0-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-8	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
8-10	0.1	0.4	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1
10-12	0.4	0.9	0.9	1.1	0.4	0.0	0.0	0.0	0.0	0.4	0.3	0.1	0.2
12-14	0.9	2.2	1.9	2.4	0.7			0.0	0.1	0.6	0.7	0.2	0.5
14-16	1.2	3.5	2.7	3.8	1.3		0.1	0.1	0.3	1.3	1.4	0.5	1.0
16-18	3.0	5.1	5.4	5.4	1.5	0.0	0.1	0.1	0.7	2.0	2.7	1.1	1.6
18-20	4.8	8.3	6.1	8.1	2.4			0.1	0.9	3.1	3.7	2.3	2.5
20-22	7.1	10.5	9.5	10.2	3.3		0.2	0.3	1.5	4.7	4.5	3.9	3.7
22-24	10.8	12.8	11.7	11.3	4.7	0.1	0.4	0.6	2.4	5.8	6.6	6.7	5.3
24-26	14.9	13.3	14.9	10.8	8.0	0.7	0.8	0.8	3.6	8.1	9.0	11.0	7.0
26-28	18.4	11.3	15.8	12.2	10.9	2.0	2.2	1.9	6.6	9.5	10.7	14.8	8.9
28-30	24.6	13.6	14.6	11.3	14.5	3.3	5.5	3.1	8.7	11.0	13.9	19.2	10.7
30-32	26.7	11.0	12.9	7.5	21.9	5.7	7.0	5.3	15.5	16.2	17.5	22.8	13.7
32-34	31.1	7.4	12.3	8.4	28.9	9.4	14.6	10.3	19.9	16.5	16.3	24.1	15.0
34-36	26.7	8.1	12.2	4.8	28.0	17.9	23.8	16.0	31.9	21.9	16.1	27.1	18.8
36-38	26.8	7.4	6.9	4.1	31.4	27.7	28.9	26.9	41.7	26.6	18.4	37.2	22.7
38-40	23.5	7.1	5.5	1.0	36.3	46.4	44.9	43.8	54.1	30.3	16.0	31.6	25.7
40-42	23.7	7.4	4.0	0.3	36.8	70.9	60.8	62.2	59.6	22.5	18.7	32.8	30.0
42-44	16.5	3.1	2.5	0.3	40.3	75.4	78.8	79.5	59.5	25.3	13.1	30.3	34.3
44-46	18.9	2.7	1.1		0.0	98.2	91.7	84.9	61.2	25.5	14.8	27.7	35.9
46-48	12.6	4.9	2.0		47.0	103.5	96.8	97.0	51.4	17.4	11.4	20.4	36.7
48-50	10.6	1.5			40.5	127.4	105.1	104.8	56.9	13.8	9.7	15.9	39.0
50-52	4.7	5.7			40.5	113.8	105.6	92.6	53.1	11.0	8.1	11.5	38.5
52-54	3.5	3.2			30.5	119.7	99.9	91.0	34.8	8.8	3.2	10.9	34.9
54-56	2.0	2.1			24.5	96.3	107.7	73.7	22.2	8.1	1.8	5.3	30.7
56-58	0.7	1.6			21.5	75.4	77.3	61.6	16.1	3.9	3.4	2.6	26.7
58-60		2.6			18.3	69.4	73.7	49.8	10.5	0.7	1.5	0.7	20.0
60-62		1.0			14.0	66.9	65.5	36.0	17.4	0.6		0.8	18.3
62-64	1.0	1.1			10.6	56.3	60.5	30.1	4.6		2.8		15.4
64-66	1.1	1.2			12.7	39.7	46.1	20.5	2.0	1.0	2.0		12.9
66-68					5.8	25.8	39.9	16.1	3.3	1.1	4.4		10.5
68-70					2.5	26.4	16.7	10.6					6.8
70-72					2.8	15.3	19.5	9.0			2.7		4.8
72-74					3.0	8.3	10.6	8.4	1.4		4.7		4.0
74-76					3.3	11.3	4.9				1.7		2.2
76-78						7.3	7.1		1.7				1.9
78-80						7.9	3.8						1.2
80-82													1.0
82-84											4.3		0.4
84-86					2.4	3.3					2.3		0.2
86-88													0.5
88-90											2.7		0.2
90-92													0.0
92-94													0.0
94-96											3.3		0.3
96-98													0.0
98-100													0.0
100-102											3.9		0.3
											4.2		0.3
SUM (MEAN FOR MONTH)	316.3	161.0	143.5	103.5	582.1	1332.0	1300.4	1037.0	643.7	298.7	262.5	361.4	545.2

Sensor Height : 20M

(No Data For June 1993)

Based on Data January 1992 - December 199_

Range 0 -2 Extends From 0.0 to 1.9 Kmph

2-4 Extemds Frp, 2.0 To 3.9 Kmph

And so on

STATION : RAMAKALMEDU **Annexure 2.3**

NUMERICAL PRESENTATION OF WIND ROSE DATA

PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEEDS FROM DIFFERENT DIRECTIONS

Range: (mph)	00-06	06-12	12-18	18-24	>>24	00-06	06-12	12-18	18-24	>>24	00-06	06-12	12-18	18-24	>>24
January (1992 - 1995)						February (1992 - 1995)					March (1992-1995)				
LULL	3.30					10.18					12.84				
North:		0.13	0.13	0.17	0.30		0.59	0.22	0.11	0.19		1.95	1.58	0.67	0.03
Noreast:		14.62	28.40	23.79	11.49		26.80	27.88	8.96	3.15		21.73	18.50	6.64	1.82
East:		3.77	6.74	4.72	2.26		5.78	5.07	2.44	1.18		4.55	5.36	2.59	0.98
Soueast:		0.10	0.03	0.00	0.00		0.30	0.07	0.00	0.00		1.04	0.81	0.30	0.03
South:		0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00		0.07	0.00	0.00	0.00
Souwest:		0.00	0.00	0.00	0.00		0.11	0.00	0.00	0.00		1.04	1.15	0.47	0.10
West:		0.07	0.00	0.00	0.00		2.92	2.11	0.22	0.00		3.77	5.46	3.13	0.20
Norwest:		0.20	0.03	0.00	0.00		1.18	0.44	0.07	0.00		1.15	1.01	0.91	0.10
April (1992 - 1995)						May (1992-1995)					June (1992-1995)				
LULL	16.40					6.66					0.05				
North:		1.04	0.45	0.10	0.00		0.61	0.24	0.03	0.03		0.00	0.00	0.00	0.00
Noreast:		16.78	9.94	1.91	0.17		4.06	0.81	0.10	0.07		0.00	0.00	0.00	0.00
East:		5.56	4.48	0.76	0.1		0.71	0.07	0	0		0.00	0.00	0.00	0.00
Soueast:		1.22	0.94	0.45	0.07		0.03	0.00	0.00	0.00		0.00	0.00	0.00	0.00
South:		2.36	2.33	0.69	0.03		0.10	0.00	0.00	0.00		0.00	0.00	0.00	0.05
Souwest:		1.53	2.61	1.70	0.14		0.51	0.91	1.25	1.59		0.00	0.42	1.34	3.76
West:		8.51	10.08	3.75	0.42		5.95	15.73	23.85	30.01		0.14	3.01	15.90	72.32
Norwest:		2.54	2.02	0.83	0.07		1.35	2.20	2.00	1.12		0.00	0.09	0.51	2.41
July (1992 - 1995)						August (1992-1995)					September (1992-1995)				
LULL	16.4					0.47					1.07				
North:		0.00	0.00	0.00	0.00		0.17	1.08	4.31	10.77		0.09	0.00	0.00	0.00
Noreast:		0.00	0.00	0.00	0.00		0.47	0.17	1.01	3.60		0.23	0.09	0.00	0.00
East:		0.00	0.00	0.00	0.00		0.07	0.03	0.27	1.28		0.09	0.00	0.00	0.00
Soueast:		0.00	0.00	0.00	0.07		0.00	0.00	0.10	0.44		0.00	0.00	0.00	0.05
South:		0.00	0.03	0.10	0.30		0.00	0.03	0.07	0.34		0.00	0.05	0.28	0.23
Souwest:		0.03	0.57	1.85	6.70		0.03	0.54	1.88	4.58		0.37	0.97	2.64	3.25
West:		0.40	4.04	16.97	65.35		0.47	4.34	15.71	45.19		3.52	12.80	30.00	37.88
Norwest:		0.03	0.24	0.88	2.29		0.13	0.40	0.81	1.24		0.65	1.25	2.41	2.09
October (1992 - 1995)						November (1992-1995)					December (1992-1995)				
LULL	9.85					19.76					3.57				
North:		0.22	0.00	0.00	0.00		0.17	0.06	0.00	0.00		0.04	0.00	0.00	0.00
Noreast:		10.07	8.68	2.07	0.27		15.09	19.70	12.62	5.59		9.64	25.13	23.24	13.07
East:		3.10	2.79	0.81	0.22		4.44	3.51	1.90	1.21		3.36	7.64	7.10	5.57
Soueast:		0.13	0.00	0.00	0.00		0.17	0.00	0.00	0.00		0.07	0.07	0.04	0.00
South:		0.04	0.00	0.00	0.00		0.06	0.00	0.00	0.00		0.00	0.00	0.00	0.00
Souwest:		0.49	0.36	0.54	0.22		0.40	0.23	0.06	0.00		0.07	0.04	0.00	0.00
West:		6.16	12.99	19.38	16.86		3.86	4.84	2.71	0.86		0.25	0.29	0.46	0.25
Norwest:		1.30	1.48	1.44	0.49		1.44	0.92	0.35	0.06		0.07	0.04	0.00	0.00

ANNUAL (1992-1995)	00-06	06-12	12-18	18-24	>>24
LULL	7.02				
North:		0.42	0.31	0.45	0.92
Noreast:		9.96	11.61	6.69	3.27
East:		2.62	2.97	1.72	1.07
Soueast:		0.26	0.16	0.07	0.05
South:		0.22	0.2	0.1	0.08
Souwest:		0.38	0.65	0.98	1.69
West:		3.00	6.31	11.01	22.45
Norwest:		0.84	0.84	0.85	0.82

Sensor Height : 20 M

PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEED

Class Interval (Kmph)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
0-2	0.4	0.3	1.0	1.0	0.4	0.0	0.0	0.1	0.1	1.0	2.0	0.3	0.5
2-4	0.4	1.1	1.5	1.9	0.7	0.0	0.0	0.0	0.2	1.9	2.3	0.4	0.9
4-6	0.5	1.4	2.3	3.0	1.0	0.0	0.0	0.0	0.3	2.2	3.9	0.6	1.3
6-8	0.6	2.2	3.3	4.7	1.7	0.0	0.1	0.1	0.7	3.7	3.7	1.0	1.8
8-10	1.0	4.6	4.5	4.4	2.9	0.0	0.0	0.2	0.6	4.1	4.0	1.2	2.3
10-12	2.7	5.8	6.1	7.1	2.8	0.0	0.1	0.2	0.9	4.2	4.5	1.3	3.0
12-14	3.5	8.6	7.3	9.3	2.7	0.0	0.0	0.3	1.2	5.1	5.5	2.0	3.8
14-16	3.2	8.7	7.0	9.9	3.5	0.0	0.1	0.3	1.7	5.2	6.8	2.9	4.1
16-18	5.2	9.0	9.5	9.5	2.7	0.0	0.1	0.1	1.5	5.3	6.4	4.0	4.5
18-20	6.0	10.5	7.7	10.2	3.1	0.0	0.0	0.3	1.9	5.8	5.7	4.9	4.7
20-22	6.6	9.8	8.9	9.6	3.1	0.0	0.2	0.6	2.2	5.4	6.1	6.2	4.9
22-24	7.6	9.0	8.3	8.1	3.4	0.1	0.3	0.5	2.5	5.7	6.3	7.7	5.0
24-26	8.2	7.3	8.2	6.0	4.5	0.4	0.4	1.1	3.6	5.2	5.9	8.1	4.9
26-28	8.0	4.9	6.9	5.3	4.8	0.9	0.9	1.3	3.8	4.8	3.1	8.4	4.7
28-30	8.7	4.8	5.2	4.0	5.2	1.2	1.9	1.9	5.5	5.7	3.2	8.0	4.9
30-32	7.7	3.2	3.7	2.2	6.4	1.7	2.0	3.0	5.8	4.8	4.7	6.9	4.3
32-34	7.4	1.8	3.0	2.0	7.0	2.3	3.5	3.8	7.6	5.2	3.9	6.5	4.5
34-36	5.3	1.6	2.5	1.0	5.7	3.6	4.8	5.4	8.4	5.3	3.7	7.4	4.6
36-38	4.5	1.3	1.2	0.7	5.4	4.7	4.9	7.5	9.2	5.1	2.7	5.3	4.4
38-40	3.4	1.0	0.8	0.1	5.3	6.8	6.5	9.0	8.6	3.3	2.7	4.7	4.4
40-42	3.0	0.9	0.5	0.0	4.6	8.9	7.6	9.9	7.4	3.2	1.6	3.8	4.3
42-44	1.8	0.3	0.3	0.0	4.4	8.2	8.5	9.2	6.6	2.8	1.6	3.0	3.9
44-46	1.8	0.3	0.1		2.9	9.3	8.7	9.2	4.9	1.6	1.1	1.9	3.5
46-48	1.0	0.4	0.2		3.9	8.6	8.0	8.7	4.7	1.1	0.8	1.3	3.2
48-50	0.8	0.1			3.0	9.4	7.7	6.8	3.9	0.8	0.6	0.8	2.8
50-52	0.3	0.4			2.7	7.4	6.9	5.9	2.3	0.6	0.2	0.7	2.3
52-54	0.2	0.2			1.8	6.9	5.8	4.3	1.3	0.5	0.1	0.3	1.8
54-56	0.1	0.1			1.3	5.0	5.6	3.2	0.8	0.2	0.2	0.1	1.4
56-58	0.0	0.1			1.0	3.5	3.6	2.3	0.5	0.0	0.1	0.0	0.9
58-60		0.1			0.8	2.9	3.1	1.5	0.7	0.1		0.0	0.8
60-62		0.0			0.5	2.5	2.5	1.1	0.2		0.1		0.6
62-64	0.0	0.0			0.4	1.9	2.1	0.7	0.1	0.0	0.1		0.4
64-66	0.0	0.0			0.4	1.3	1.4	0.5	0.1	0.0	0.1		0.3
66-68					0.2	0.7	1.1	0.3					0.2
68-70					0.1	0.7	0.4	0.2			0.1		0.1
70-72					0.1	0.4	0.5	0.2	0.0				0.1
72-74					0.1	0.2	0.2				0.1		0.0
74-76					0.1	0.2	0.1		0.0		0.0		0.0
76-78						0.1	0.1						0.0
78-80						0.1	0.1						0.0
80-82											0.1		0.0

Sensor Height : 20M

(No Data For June 1993)

Based on Data January 1992 - December 1995

Range 0 -2 Extends From 0.0 to 1.9 Kmph
2-4 Extemds Frp, 2.0 To 3.9 Kmph
And so on

STATION : RAMKALMEDU

Annexure 2.5

MEAN HOURLY WIND SPEED (KMPH)

Lat:09.82 N   Long: 77.23 E   Elevation: 1020 Masl

MONTH/	TIME	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVE
JAN	AVE	26.12	25.66	26.00	25.79	25.17	25.23	25.77	26.10	26.22	26.50	27.70	28.73	29.16	29.21	28.74	28.96	28.59	28.19	27.30	26.80	26.32	26.40	26.39	26.25	26.97
	S.D	8.63	8.84	9.62	10.13	9.99	10.03	10.06	9.96	9.86	10.62	11.40	11.16	10.66	10.02	9.15	8.57	7.61	7.32	7.72	8.96	9.15	8.72	8.56	8.71	1.30
FEB	AVE	20.62	19.77	18.75	18.81	18.82	19.21	19.27	18.78	17.91	18.36	20.12	21.11	21.74	21.64	21.18	21.38	21.55	22.65	21.37	20.54	20.32	20.62	20.96	21.18	20.28
	S.D	8.90	8.79	9.03	9.24	8.58	8.46	8.84	8.91	9.66	10.13	10.73	10.59	9.83	9.01	8.27	7.55	6.93	7.29	7.57	8.36	8.63	8.64	7.85	8.27	1.25
MAR	AVE	17.24	16.87	16.52	16.49	16.74	16.93	17.56	17.64	17.55	18.67	20.57	22.53	24.05	24.83	24.80	24.41	23.74	23.44	22.00	20.20	19.13	19.16	18.62	17.56	19.89
	S.D	7.74	7.71	7.88	8.17	8.75	8.81	8.78	9.08	8.88	8.80	8.60	9.06	9.49	9.34	8.07	6.47	5.81	5.80	6.26	7.55	7.99	7.56	7.10	7.27	2.95
APR	AVE	17.36	17.44	17.37	17.54	17.28	16.77	16.47	15.68	14.82	14.99	15.87	16.91	17.99	18.54	19.29	20.89	21.15	19.10	19.10	19.76	19.55	19.00	17.91	17.75	17.86
	S.D	7.97	7.98	8.33	8.52	8.51	8.79	8.21	8.13	8.13	7.06	6.00	5.33	5.37	5.65	5.32	5.35	6.07	7.21	8.09	8.22	8.44	8.27	7.93	7.68	1.64
MAY	AVE	32.78	32.84	32.88	33.88	33.64	33.36	33.54	31.53	30.10	29.02	27.89	27.33	27.44	28.20	29.56	31.19	32.45	33.57	34.87	35.24	35.09	33.52	32.63	33.09	31.90
	S.D	8.67	7.65	8.12	7.82	8.06	8.22	8.99	8.81	9.58	9.02	8.75	9.73	10.25	10.52	9.61	9.72	9.41	9.13	9.07	8.97	9.13	9.04	8.86	9.49	0.53
JUN	AVE	47.12	46.92	47.16	46.73	46.20	46.73	46.93	46.25	46.59	46.42	47.18	47.01	47.17	47.93	47.72	48.18	46.70	47.17	46.63	46.06	46.68	46.71	47.03	47.90	46.96
	S.D	8.67	7.65	8.12	7.82	8.06	8.22	8.99	8.81	9.59	9.02	8.75	9.73	10.25	10.52	9.61	9.72	9.41	9.13	9.07	8.97	9.13	9.04	8.86	9.49	0.53
JUL	AVE	46.64	46.13	46.04	46.30	46.34	45.23	45.07	45.62	45.73	45.26	44.93	45.67	46.81	47.22	47.35	47.18	47.52	47.00	46.46	46.83	47.30	46.00	45.69	45.90	46.26
	S.D	10.18	9.50	9.39	9.93	9.51	9.64	10.37	10.64	10.97	10.35	10.48	11.01	11.04	10.39	9.94	8.68	9.30	8.63	8.43	8.22	9.93	9.14	9.52	9.60	0.76
AUG	AVE	44.19	43.59	43.06	43.61	42.91	42.75	42.03	41.32	41.49	41.54	41.55	41.58	41.72	42.86	43.98	43.80	43.99	43.86	43.83	43.21	42.58	42.77	43.30	43.64	42.88
	S.D	7.72	7.83	8.02	8.27	8.72	8.48	8.98	9.55	10.13	10.55	10.89	10.62	10.61	10.85	10.56	9.73	9.44	8.81	9.23	8.58	8.95	8.99	8.96	8.24	0.93
SEP	AVE	37.25	36.88	37.08	36.94	36.84	35.99	35.08	34.13	32.37	32.31	31.87	31.31	32.14	34.19	35.97	36.51	37.28	37.32	36.88	36.59	36.23	35.92	35.13	35.29	35.31
	S.D	10.51	9.58	9.51	9.08	9.57	9.85	9.94	10.47	11.26	12.40	11.92	12.02	11.90	11.02	9.83	10.31	9.96	9.15	9.51	10.21	9.66	10.13	10.91	11.23	1.92
OCT	AVE	24.63	24.85	25.34	25.41	24.81	24.26	24.32	23.17	22.69	22.86	22.94	22.98	23.39	24.43	25.37	25.53	25.86	25.31	25.02	25.06	25.10	25.45	24.95	24.54	24.51
	S.D	11.69	12.69	12.96	12.71	12.11	11.94	11.94	11.69	11.89	11.45	11.52	12.28	12.32	11.74	11.42	11.57	11.79	11.69	12.30	12.51	12.59	11.81	12.17	11.52	0.96
NOV	AVE	22.50	22.86	22.40	22.40	22.61	22.32	21.87	21.27	20.20	20.68	21.09	21.44	21.82	22.07	21.88	22.22	23.67	24.18	23.75	23.09	22.73	22.74	22.88	22.96	22.32
	S.D	13.74	13.82	14.23	13.11	12.94	12.99	12.35	12.18	11.95	12.76	12.73	12.46	12.07	11.41	10.33	10.28	10.60	10.38	10.65	11.00	11.71	12.08	12.31	12.59	0.93
DEC	AVE	28.58	28.74	28.51	28.37	27.70	27.43	27.02	26.87	26.99	27.56	28.69	29.06	28.65	28.13	27.81	27.82	27.99	29.17	29.55	29.25	29.63	29.61	29.52	28.81	28.39
	S.D	9.52	10.08	9.26	8.75	9.33	9.81	10.78	11.02	10.90	11.25	11.79	11.39	11.06	9.89	9.45	8.62	7.49	7.02	7.59	8.75	9.24	9.66	9.36	9.21	0.84
ANNUAL	AVE	30.42	30.21	30.09	30.19	29.92	29.69	29.58	29.03	28.56	28.68	29.20	29.64	30.17	30.77	31.14	31.51	31.71	31.75	31.40	31.05	30.89	30.66	30.42	30.41	30.29
	S.D	10.58	10.48	10.59	10.63	10.52	10.42	10.30	10.33	10.57	10.27	9.89	9.61	9.52	6.67	9.77	9.61	9.39	9.49	9.64	9.78	10.01	9.80	9.96	10.30	9.98

Sensor Height : 20 M   (No Data For June 1993)   Based on Data January 1992 - December 1995

STATION : RAMAKALMEDU

20m

ANNEXURE 2'6

WIND POWER DENSITY

Unit : Watts / sq.

ANNEXURE 2'6

1992	420.14	91.41	97.80	98.71	439.15	1381.21	1405.45	1067.36	555.65	352.55	340.00	489.45	561.57
1993	311.79	234.41	133.73	76.01	498.84	(1334.00)	1429.78	1104.89	686.64	348.95	287.96	298.76	562.15
1994	343.34	150.45	191.79	147.97	693.85	1320.69	1311.29	1096.45	539.52	182.83	310.08	288.07	548.03
1995	185.53	166.08	147.08	86.87	699.46	1306.74	1077.79	899.89	795.15	309.09	109.80	365.10	512.38
	315.20	160.59	142.60	102.39	582.83	1336.21	1306.08	1042.15	644.24	298.36	261.96	360.35	546.03

WIND SPEED

m/sec

STATION / YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1992	30.4	17.9	17.14	17.56	28.41	46.51	47.03	42.66	32.65	25.44	23.09	32.37	30.10
1993	26.54	21.45	19.18	16.08	29.58	45.54	47.94	43.95	36.9	25.48	24.04	25.62	30.19
1994	27.35	21.05	22.94	20.04	35.76	46.81	46.1	43.25	31.88	19.93	24.04	26.81	30.50
1995	22.29	20.66	19.86	17.56	33.13	44.74	42.91	39.47	38.88	28.45	16.75	28.45	29.43

Chapter 3

MICRO SURVEY ANALYSIS IN AND AROUND RAMAKKALMEDU WIND MONITORING STATION

3.1 Introduction

The best method to assess the wind potential of a location is measuring the wind in situ for several years. However, as this takes a lot of time and is expensive, one would like to estimate the wind resources with atmospheric models. A few models have already been developed for generating the necessary wind parameters in identifying sites for wind electric generators in a given area. If reliable wind data is available from a nearby reference station, numerical modeling is one of the best suitable techniques. This model predicts the wind potential of a site by solving equations that describe the complex interaction between the atmosphere and earth surface. Accuracy on predictions depends upon the input data. This modeling technique is very commonly adopted these days for wind resource assessment.

Horizontal variation of the winds depends on orography, roughness and obstacle in that area. Surface roughness characteristics and obstacles are also responsible for the reduction of wind and the generation of turbulence or gustiness. Orographic elements such as hills, cliffs, escarpment and ridges exert an additional influence on wind. Near summit or crest of the features the wind will accelerate whereas near the foot and valleys it will decelerate.

The roughness of a terrain is determined by the size and distribution of the roughness element it contains: for land surfaces these are typically vegetation, built-up areas and soil surface. A length scale called the roughness length, z_o meter, commonly parameterizes the roughness of a terrain.

The obstacle provides shelter and shelter is defined as the relative decrease in wind speed caused by an obstacle in the terrain.

A mathematical function named Weibull density function is widely accepted for the prediction of wind characteristics since it is a good match with the experimental data. Weibull distribution shows its usefulness when the wind data of one reference station (along with terrain data) are being used to predict the wind regime in the surrounds of that station.

3.2 Methodology

Wind Atlas Analysis and Application Program (WAsP) is a software package developed by the Wind Energy and Atmospheric Physics Department, Riso National Laboratory, Denmark for the vertical and horizontal extrapolation of wind data and the estimation of wind climate and wind resources. It is a powerful tool for wind data analysis, wind atlas generation, wind climate estimation and estimation of wind power potential of a site. In this software Weibull distribution method is used for the horizontal extrapolation of the wind.

The WAsP model and wind atlas methodology was used for the analysis of wind resources in Ramakkalmedu area.

The operation of WAsP over complex terrain has some limitations. Wind flow over a complex terrain is also quite complex. There is no widely accepted measure of terrain complexity in wind flow modeling.

WA^{s}P- can predict characteristics of winds in flat and moderately complex terrain very well. For detailed wind turbine siting, WA^{s}P allows for modelling complications in the form of terrain inhomogeneities, sheltering obstacles and terrain height differences. Therefore identification of such complexities are very important before concluding WAsP results. In order to be able to apply the modelling technique and obtain reasonable results, it will be essential to carry out a *Ruggedness Index (RIX) analysis.*

One objective measure of steepness or ruggedness of terrain (complexity of the site) around a site is so-called ruggedness index or RIX. RIX is defined as the percentage of fraction of the terrain within a certain distance from a specific site, which is steeper than some critical slope, say 0.3. This index was proposed as a coarse measure of the extent of flow separation and thereby the extent to which the terrain isolates the requirements of linearized flow models.

A flat site will then have a RIX of 0%, a very complex (steep) site an index of, say 30% meaning that about 1/3 of the terrain is steeper than our critical slope.

The value of the index defined above will of course depend on the size of the area, the radius and the threshold slope. The study indicates that these should be chosen within fairly narrow limits. This analysis was carried out for making the assessment accurate.

For calculation of wind energy potential over an extended area, input information on several parameters is required i.e.:

a) Magnitude of the area considered in km^2
b) The mean WPD over the area.
c) Wind power that could be developed over one sq.km. by an array of WEG's arranged in lines and rows in some standard configuration.
d) The overall system efficiency of the particular WEG, which is governed by its rated power, swept area of the rotor and the capacity factor as applicable to the local wind regime.

The basic physical equations are given below:

Let the WEG's be arranged in lines and rows with spacing between them as 3D and 7D where D is the rotor diameter in metres.

The total number N of WEG's that would fill one sq.km. of land will become

$$N = (1/21D^2) \times 10^6 \qquad \text{-- (1)}$$

The wind power intercepted by one WEG in Watts in

$(\Pi D^2/4) \times P_d$ where P_d is the WPD in W/m^2.

Therefore the total power P_i intercepted by N turbines is given by

$$P_i = (\Pi D^2/4) \times (10^6/21D^2) \times P_d \qquad \text{-- (2)}$$

$$\text{or } P_i = (\Pi/4) \times (10^6/21) \times P_d \text{ per sq.km.} \qquad \text{-- (3)}$$

It can be seen from (2) that the total power intercepted by a given configuration of WEG's at a constant level is independent of the rotor diameter. The electrical power P_0 delivered by all the WEGs in the unit sq.km. area is dependent on the overall system efficiency E.

$$P_0 = P_i \times E \qquad \text{-- (4)}$$

The electric power output, P_o from all the WEG's installed within one sq.km. becomes.

$$P_o = (\Pi/4) \times (10^6/21) \times P_d \times 0.32 \text{ Watts.} \qquad \text{(E is assumed as 32\%.)} \qquad \text{-- (5)}$$

Multiplying (5) by the total effective area of land within which the mean WPD is P_d (W/m^2) we get the wind energy potential within that land area.

The installed capacity for the area available can be calculated by standard norm of $8MW/km^2$ where as 2.78 MW per kilometer on a ridge perpendicular to the prevailing wind direction (This is based on 50 m rotor diameter and 3D separation in the row)and 1.5 MW on east west oriented ridges (This is based on 50 m rotor diameter and 7D separation.)

3.3. Results

The general topography of the site is described under 2.1.

Ramakkalmedu area is available in the 1:50,000 scale Survey of India map no.58G/1 grid C3. This map was vectorized to obtain the contour lines (figure 3.1). Then Ramakkalmedu mast position was precisely marked on this map. In order to predict the wind characteristics at some points other than the point of measurement, the local terrain characteristics are to be taken into account. The drawing was then prepared to extract the orographic and roughness models for the area under interest. Actual details of the terrain characteristics were collected during the visit to the site and its surroundings. The roughness length (z_0) details of the site were assessed during the site visit and found in the range of 0.02 to 0.4 m. Since there is no significant obstacle offering shelter effect around the point of observation no obstacle file was created. Finally with the Wind data at the measured point, the WAsP software was run to predict the values for the region of interest at 30, 40 ,50 and 100 M levels where WAsP can give accurate results with reference to RIX values. The wind characteristics are defined in terms of direction wise Weibull factors. The calculations also integrate the possible power density for all sectors as well as define the direction wise contributions. The area is divided into 8 sectors and 0^0 sector is North.

The Wind atlas over the studied area as given by WAsP is shown in the table 3.1. Since the standard air density is taken as 1.225 kg/m^3 in the WAsP program , ai

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CHENNAI

Ramakkalmedu Area

State Boundary

Contour

Roads

Wind Farmable Area

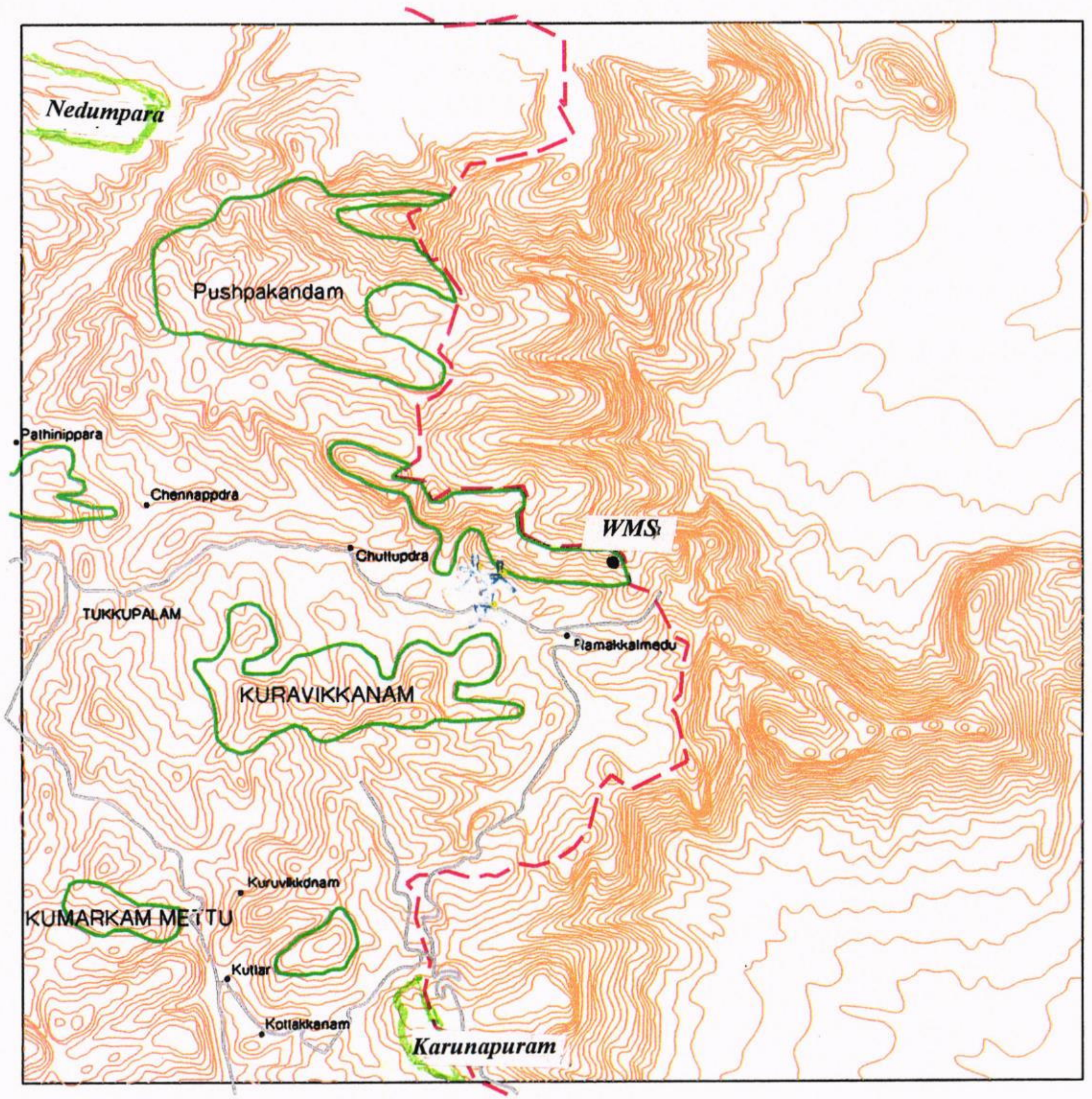

Fig.3.1 Vectorised Map of Ramakkalmedu area

results analysis were carried out with a grid 50m x 50 m at the windy areas . These results are given in the table 3.2. Since wind resource assessment of the Region of Interest is made with reference to a single point measurement, it is suggested to carry out wind monitoring at more sites for the better accurate results.

RIX values for 2226 points were worked out in the region of interest and 24 % are found to be under the operational envelope of WAsP. This was taken into account for the estimation of wind potential at the site.

The WAsP has its own limitations. The European Wind Atlas prepared with the help of WAsP indicates that the prediction may differ up to +/- 15% or more.

Table 3.2 Wind Potential sites around Ramakkalmedu Wind Monitoring Station

No	Site Name	Height a.g.l (m)	WPD W/m^2			
			Elevation 930m	**Elevation 980m**	**Elevation 1020 m**	**Elevation 1040m**
1	Ramakkalmedu	30	143	300	577	666
		40	182	347	604	702
		50	220	386	626	729
		100	434	592	795	896
			Elevation 1000m	**Elevation 1060**	**Elevation 1100 m**	**Elevation 1150 m**
2	Pushpakandam	30	264	378	581	586
		40	309	424	616	640
		50	347	463	645	682
		100	544	665	827	883
3	Kuruvikkanam		**Elevation 1000m**	**Elevation 1020m**	**Elevation 1040m**	**Elevation 1080m**
		30	361	487	544	786
		40	421	532	601	809
		50	469	570	646	825
		100	701	779	861	971
4	Karunapuram		**Elevation 960m**		**Elevation 1000m**	
		30	350		430	
		40	393		475	
		50	430		512	
		100	622		710	
5	Kumarakommettu/ Alliyarmala		**Elevation 980m**		**Elevation 1000m**	
		30	446		586	
		40	461		599	
		50	472		603	
		100	573		686	
6	Nedumpara/ Mattuttalamedu		**Elevation 1060 m**	**Elevation 1100 m**	**Elevation 1140 m**	**Elevation 1180 m**
		30	305	356	425	688
		40	350	390	471	710
		50	455	501	584	852
		100	581	591	657	864
7	Pathinippara		**Elevation 920 m**		**Elevation 940 m**	
		30	369		469	
		40	433		504	
		50	466		530	
		100	631		670	

3.4. Discussion and conclusion

A Digital Terrain Model map of elevated hills is also prepared and an isometric view of the region of interest is shown in the fig. 3.2

The Annual energy produced by a wind electric generator can be calculated by using the power curve of the machine and the frequency distribution of wind speed at hub height. Annual energy productions at wind monitoring station by different capacity machines are calculated and given in table 3.3 . The capacity factors worked out to be 25-35 % . In annual energy production 20% losses are taken into account considering 5% wake losses and 15% other losses.

Table 3.3 Annual energy productions at wind monitoring station by different capacity machines

Sl. No.	Site Name	Estimated Annual Energy Production				
		30m .Ht	40m .Ht	40m.Ht	40m.Ht	50m.Ht
		225kW	250kW	500kW	600kW	750kW
		kWhr	kWhr	kWhr	kWhr	kWhr
1	Perampukettimedu	6.7E+05	6.9E+05	1.38E+06	1.68E+06	2.1E+06
2	Ramakkalmedu	7.6E+05	7.4E+05	1.49E+06	1.8E+06	2.11E+06
3	Sakkulathumedu	6.9E+05	6.9E+05	1.39E+06	1.69E+06	2.05E+06
4	Kailasamedu	5.0E+05	5.9E+05	1.07E+06	1.4E+06	1.8E+06

Based on the above analysis of four year data it was observed that the wind potential at Ramakkalmedu is very much promising for the generation of grid quality power from wind .However, the wind farmable areas in these locations is rather limited.

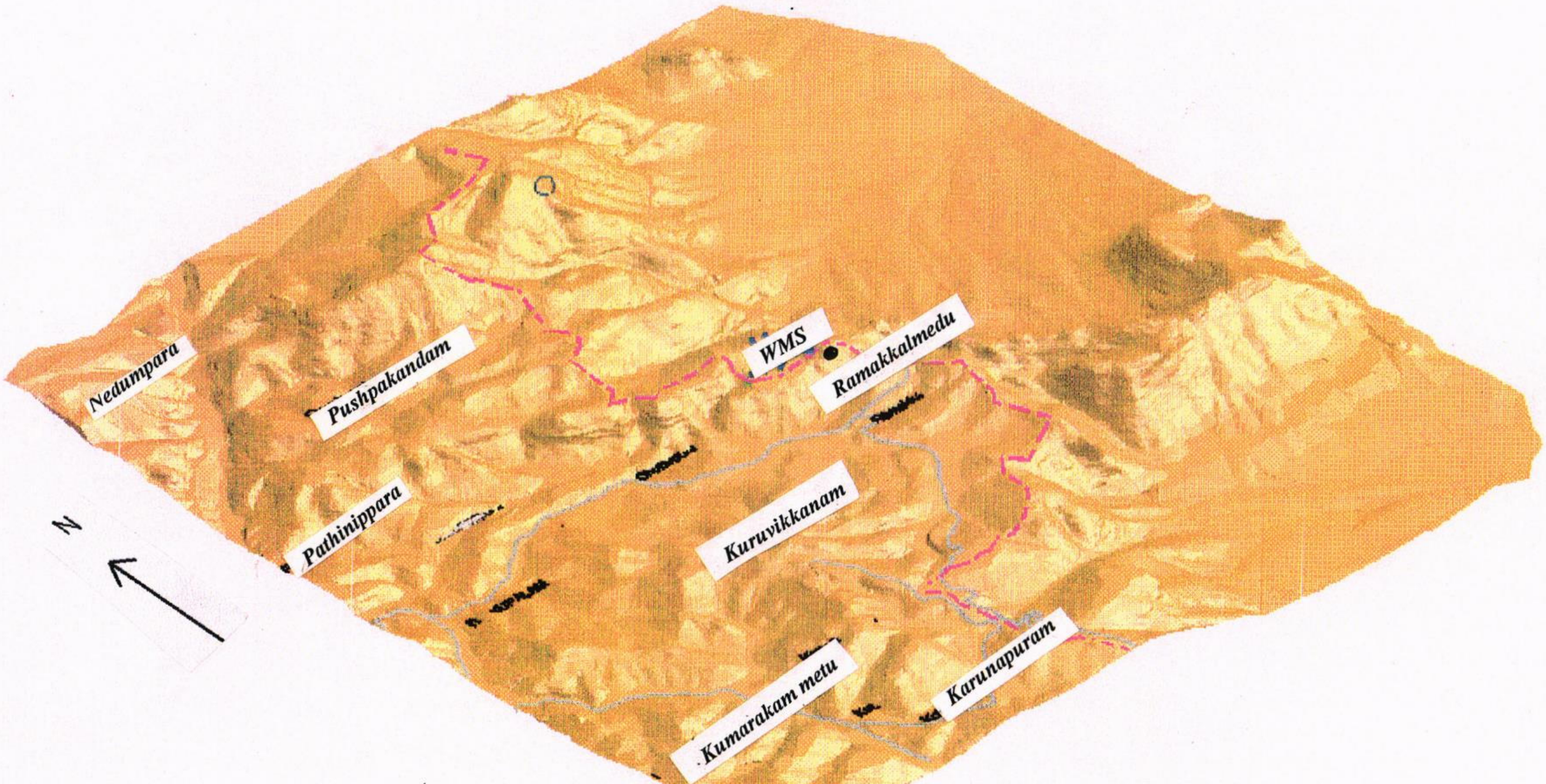

Fig.3.2 Digital Terrain Model of Ramakkalmedu site

Chapter 4

MASTER PLAN FOR RAMAKKALMEDU WINDFARM PROJECTS

4.1 Introduction

The master plan includes the potential and wind farmable sites in the region of Interest. This will help the promoters/developer to plan wind farm at the potential sites. In Ramakkalmedu area there are a few small hillocks which may not accommodate more than 1MW wind farm. Therefore these have not been considered in the master plan.

Once sites are identified, the other siting criteria for wind power projects are land availability and accessibility, terrain characteristics, grid availability, soil conditions, environmental considerations and public acceptance.

The wind potential sites with wind power density at different ground level at various elevations have been illustrated in table 3.3 under chapter 3. Total seven potential sites with installed capacity of 52 MW have been identified. Further there are 3 more adjacent sites also included with the estimated installed capacity of 28 MW. Hence the total installed capacity works out to be 80 MW. The potential on ridges oriented northwest - southeast is considered with 2.78 MW per kilometer length where as for east-west orientation it is 1.5 MW. The lands available in Ramakkalmedu for wind farms are either privately or government owned.

Details of electrical infrastructure, approach & accessibility for wind farmable sites are given below.

4.2 Electrical Infrastructure

66KV substation at Kattappana of Kerala State Electricity Board (KSEB) is the nearest substation and is about 26 km (length of line route) from Ramakkalmedu. A single line schematic diagram of the substation is given in Fig.4.1. Grid map of Idukki District is also given in fig 4.2. The interruption details observed at the substation indicate that the grid line is not presently stable. Stability has to be ensured for better grid availability

11 kV single circuit feeders, having mink ACSR conductors are coming upto all proposed wind farm sites. But all these lines are heavily loaded with rural connection, totally more than7000 KVA having 73 nos. of transformers of rating ranging from 63 KVA to 500 KVA. It is learnt that there are frequent tripping, voltage variations and power cuts

on these feeders. As such these feeders are not at all suitable for power evacuation from the proposed wind farm.

The transformer rating is estimated as 94 MVA (power factor is assumed as 0.85) for 80 MW wind farm and this can be accommodated with 3 x 32 MVA transformer at the substation.

In general, the grid system should fulfill the following criteria.

1. Frequency should be within 48 – 52 Hz
2. Voltage variations at the common coupling point 15%, when wind farm is connected or disconnected.
3. Voltage increase at each wind turbine should be below 13% of the rated voltage.
4. Asymmetry should be within 15%
5. The short circuit level at the common coupling point should not be below 5 to 10 times the maximum out put of the wind farm.
6. Wind turbines should be provided with the start current limiting devices: I(start)<1.3 I (rated).
7. Wind turbine should be provided with a capacitor bank for fall compensation of the idle running reactive power coneption (with Induction Generator Machines)

The evaluation of the grid should take into consideration the availability of the grid as well as the quality of the existing transmission and distribution lines. The quality of the lines is the main factor for possible break-downs of the system. Also, configuration of the existing grid and the power consumption at sub-stations near the wind farm and consumers, should be taken into account. Evacuation of power should preferably be through 33 KV lines or above, as these are more stable, and the sub-station should be less than 30 km from the project site.

The generated power from all wind turbines at 690 V shall be fed to 33 / 11kV and through 33 / 11 / 0.690 KV transformers. In this case, a dedicated 33 kV transmission line from Nedumkandam substation upto wind farm sites are suggested.

All these factors should be taken care of during the preparation of Detailed Project Report of a specific wind farm.

It is learnt that a new substation with voltage rating 110 / 33 / 11 kV is being setup at Nedumkandam. Once Nedumkandam substation is established, with associated transmission lines, power evacuation from Wind farms will be fulfilled. The MVA ratings required for each wind farm site is a suggested in site details table.

66 kV From Chenkulam hydro station to Vazhathopu-tapped at Kattapana

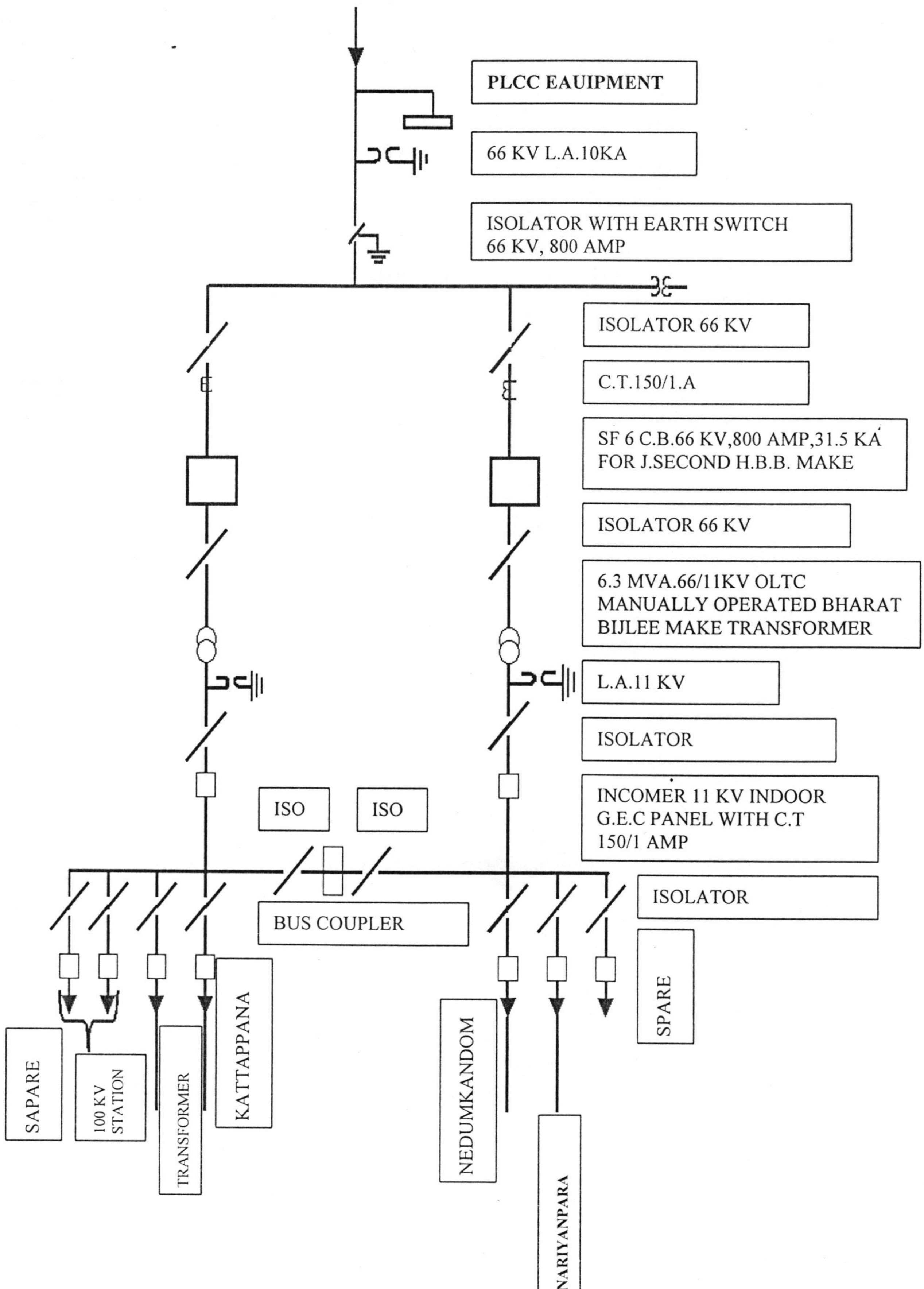

Fig.4.1 A single line schematic diagram of the substation

4.3 Approach and Accessibility

Developments of wind farms in this mountainous region are required construction of approach road to reach the top of ridges, which generally have no habitation, and therefore no roads. Though jeepable earthen or tarred roads are available to reach at a few sites , these roads are not at all sufficient for the transportation of wind electric generators and other heavy equipment required for the erection of machines. All sites need good approach road. The region under consideration being rather complex, infrastructure development required could be considerable and expensive.

The length of road from main road is given in site details. The geometry of existing WBM road are not upto the mark. All existing roads (jeep able / tarred) from the main road (State / District) will have to be improved, so as make it suitable for transportation of WEG components and cranes. This will involve, widening, improving gradient in portions of road having steeper gradients than 1:18 and providing extra width at bends. The ruling gradient of 1:18 is considered appropriate. The roads available at present are only upto the toe of the hills. A separate civil engineering study is suggested for constructing roads to the proposed wind farmable sites or this can be included as a part of Detailed Project Report of individual wind farms.

4.4 Wind farmable sites

Taking into various factors seven potential wind farmable sites with an aggregate of 52 MW have been found over an area of 10 km x 5 km around Ramakkalmedu Wind Monitoring Station. The potential at adjacent wind monitoring stations at Kailasamedu , Sakkulathumedu and Perampukettimedu is also estimated and included in this report. A total of 28 MW is estimated from these three locations. Details are given in Annexure 4.1 A map showing wind farmable site is given in the figure 4.1.

Since the scale of map used was 1:50000 for micro survey studies the physical boundary cannot be marked. The approximate wind farmable areas at Pushpakandam and Kuruvikkanam are worked out and given. For land acquisition, flat portion of the ridges (maximum 20m down from the flat portion of the hills) only may be considered. In Pusphakandam and Kuruvikkanam area the boundary for the wind farmable land is to be considered approximately for land acquisition purpose. The physical boundary for wind

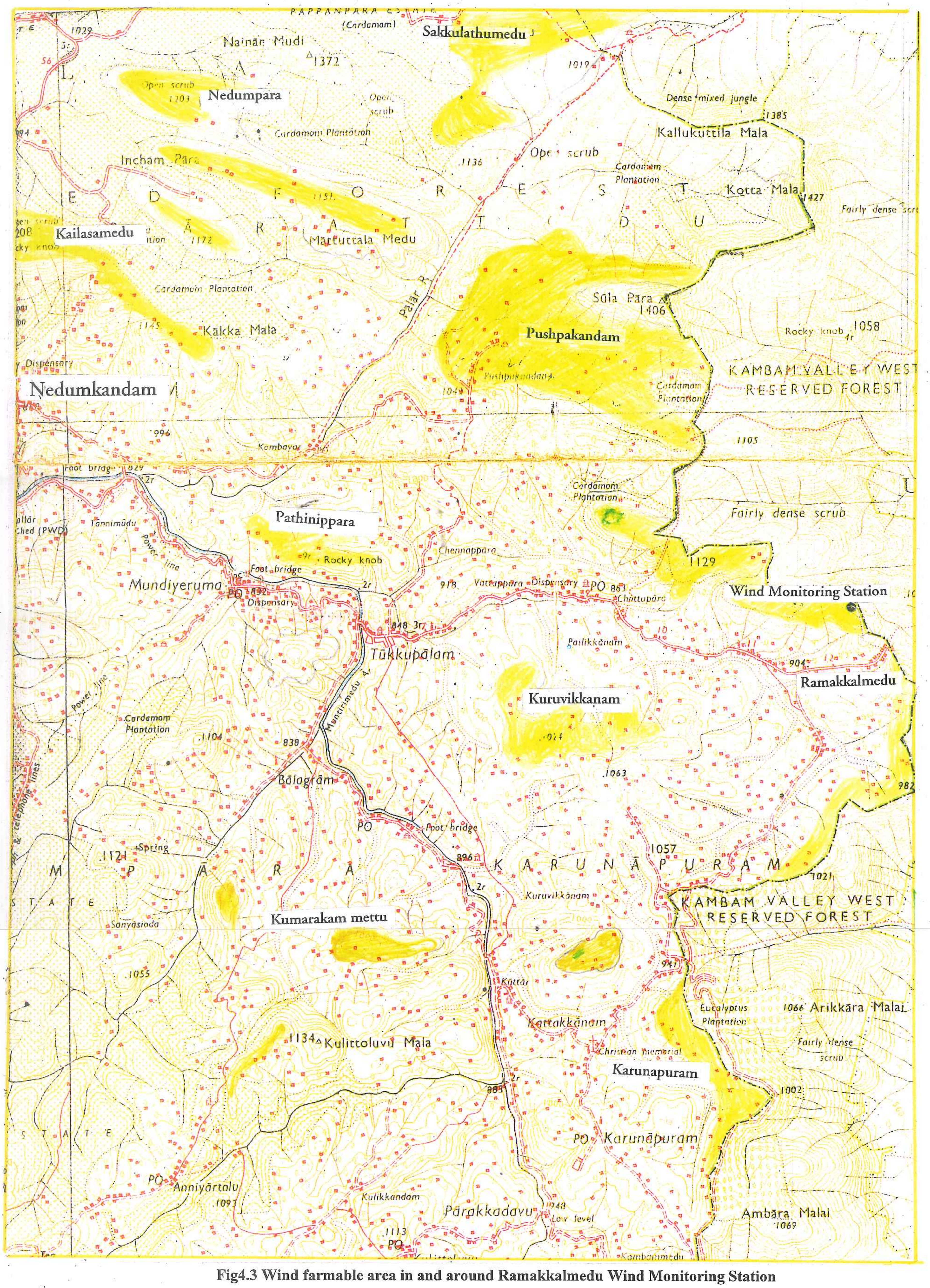

Fig4.3 Wind farmable area in and around Ramakkalmedu Wind Monitoring Station

Fig 4.2. Grid map of Idukki District

farmable area can be marked on the larger map viz. village survey map while micro-siting is done.

4.5 Conclusion:

The Ramakkalmedu though one of the best potential sites with wind power density 540 W/m^2 observed level at 20m have limitations due to its topography which is highly complex in nature. The estimated installed capacity work out to be 80 MW considering the present available technology .With the advent of wind turbine technology the capacity may go up. The expected generation from 80 MW consisting of 500 kW machines at 40 .5 m hub height would be 188000 MWh/year with an average capacity factor of 27 % for the entire area . Higher capacity machines of MW range is appropriate for the better utilisation of wind resources available in the region The wind farm, if develops will support the power generation capacity addition in the state of Kerala from the renewable source of energy.

SITE DETAILS – 1

1	Site Name	Nedumpara, Mattutala medu
2	Village	Kalkunthal
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	7 km
	Direction	North – West
7	Approach	Parathodu – Aduvilanthan Road (Jeepable) 3 km from Parathode
8	Nature of terrain	Hilly – Ridge East – West orientation
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam -Rocky
11	Altitude of the area	1060-1180 m
12	Estimated Capacity	10 MW Total length of 7 km ridge from three adjacent hills
13	Extractable Energy	21270 MWh/yr
14	Details of Nearest grid line	
	Name: -	Parathodu , 11 kV
	Distance: -	3 km
15	Nearest Substation	66/11kV. Kattappana , 26 km
16	Proposed Grid Connection/ Transformer rating for proposed wind farm.	110//33/11kV- 16 MVA

SITE DETAILS – 2

1	Site Name	Kuruvikkanam
2	Village	Karunapuram
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	3 km
	Direction	South-West
7	Approach	Thukkupalam – Kambammedu Road
8	Nature of terrain	Hilly – Small plateau
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	1000 m
12	Estimated Capacity	5 MW , (Elevated Scattered area of 50-60 Hectares of land)
13	Extractable Energy	13400 MWh/yr
14	Details of Nearest grid	
	Name: -	Kombumukku 11 kV
	Distance: -	1 km
15	Nearest Substation	Kattappana 66/11 kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	Nedumkandam 110/33 /11 kV 6 MVA

SITE DETAILS – 3

1	Site Name	Karunapuram
2	Village	Karunapuram
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	5 km
	Direction	South
7	Approach	Thukkupalam – Kambammedu Road ~ 10 km from Thukkupalam
8	Nature of terrain	Nearly flat
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	940 m
12	Estimated Capacity	3 MW (2 km long border ridge)
13	Extractable Energy	6500 MWh/yr
14	Details of Nearest grid	
	Name: -	Karunapuram 11 kV
	Distance: -	2 km
15	Nearest Substation	Kattappana 66/11kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	Nedumkandam110/33/11kV, 6 MVA

SITE DETAILS – 4

1	Site Name	Kumarakammedu & Alliyar mala
2	Village	Karunapuram
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
4	Location with reference to Wind Mast	
	Distance	7 km
	Direction	South West
5	Approach	Kulitholu – Kuttar Road . From Kuttar one km jeepable road
6	Nature of terrain	Hilly –
7	Type of Land (Private / Govt.)	Private / Govt.
8	Soil Condition	Forest loam
9	Altitude of the area	1000 -1100 m
12	Estimated Capacity Approximate area	4 MW , Two ridges of total length of 2.0km
13	Extractable Energy	8500 MWh/yr
14	Details of Nearest grid	
	Name: -	Third Camp
	Capacity: -	11kV
	Distance: -	2 km
15	Nearest substation	Kattappana 66/11 kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	Nedumkanndam 110/33/11kV, 6 MVA

SITE DETAILS – 5

1	Site Name	Ramakkalmedu
2	Village	Parathodu
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	Mast Site
	Direction	Mast Site
7	Approach	Thukkupalam – Ramakkalmedu Road
8	Nature of terrain	Hilly – Ridge
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	1000 -1100 m m
12	Estimated Capacity Approximate area	12 MW ,~ 6 km ridges (Zig zag) in E_W direction and ~1.5 km long N-S direction
13	Extractable Energy	32400MWh/yr
14	Details of Nearest grid	
	Name: -	Kombumukku 11 kV
	Distance: -	1 km
15	Nearest Substation	Kattappana 66/11kV
16	Proposed Grid Connection Transformer rating required	Nedumkandam 110/33/11kV 16 MVA

SITE DETAILS – 6

1	Site Name	Pattinippara
2	Village	Pampadumpara
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	5 km
	Direction	West
7	Approach	Pulianmala – Pampadumpara Road
8	Nature of terrain	Hilly –
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	900 m
12	Estimated Capacity Approximate area	3 MW (Two parallel ridges of length 1.5 km)
13	Extractable Energy	6500MWh/yr
14	Details of Nearest grid	Forest loam
	Name: -	Pampadumpara
	Capacity: -	11kV
	Distance: -	1 km
15	Nearest Substation	Kattappana 66 /11 kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	110/33/11kV, 6 MVA

SITE DETAILS – 7

1	Site Name	Pushpakandam
2	Village	Parathodu
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	3 km
	Direction	North
7	Approach	Thukkupalam – Pushpakandam Road
8	Nature of terrain	Hilly – Saddle between Sulappara andRamakkalmedu
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	900-1200m
12	Estimated Capacity Approximate area	15 MW , ~ 180 Ha.
13	Extractable Energy	32850 MWh/yr
14	Details of Nearest grid	
	Name: -	Chennappara 11kV
	Distance: -	2 km
15	Nearest Substation	Kattappana 11 kV
16	Proposed Grid Connection Required transformer rating	Nedumkandam110/33/11kV 18 MVA

SITE DETAILS – A

1	Site Name	Sakkulathumedu
2	Village	Chathurangappara
3	Nearest Town	Nedumkandam
4	Nearest Railway station	Ernakulam
5	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	6 km
	Direction	North
7	Approach	Udumbamchola – Sakkulathumedu Road 8 km
8	Nature of terrain	Hilly –saddle
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	1000- 1100 m
12	Estimated Capacity	10 MW
13	Extractable Energy	24500 MWh/yr
14	Details of Nearest grid	
	Name: -	Udumbamchola 11 kV
	Distance: -	8 km
15	Nearest Substation	Kattappana 66/11 kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	110/33/11 kV, 16 MVA

SITE DETAILS – B

1	Site Name	Kailasamedu
2	Village	Parathodu
3	Nearest Town	Nedumkandam
4.	Nearest Railway Station	Ernakulam
5.	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	10 km
	Direction	North -West
7	Approach	Nedumkandam – Udumbachola Road
8	Nature of terrain	Hilly – Ridge East -West orientation
9	Type of Land (Private / Govt.)	Private / Govt.
10	Soil Condition	Forest loam
11	Altitude of the area	900-1000m
12	Estimated capacity Approximate area	10 MW Long ridges
13	Extractable Energy	21000 MWh/yr
14	Details of Nearest grid	
	Name: -	Parathodu 11 kV
	Distance: -	3 km
15	Nearest Substation	Kattappana 66/11 kV
16	Proposed Grid Connection Required transformer rating	Nedumkandam 110/33/11kV 16 MVA

SITE DETAILS – C

1	Site Name	Perampukettimedu
2	Village	Chathurangampara
3	Nearest Town	Nedumkandam
4.	Nearest Railway Station	Ernakulam
5.	Nearest Airport	Kochi
6	Location with reference to Wind Mast	
	Distance	10 km
	Direction	North -West
7	Approach	Nedumkandam – Udumbachola Road
8	Nature of terrain	Hilly –Northt -south ridge
9	Type of Land (Private / Govt.)	Private/Government
10	Soil Condition	Forest loam
11	Altitude of the area	1160 m
12	Estimated capacity Approximate area	8 MW Long ridges
13	Extractable Energy	21000 MWh/yr
15	Nearest Substation	Kattappana 66 /11 kV
16	Proposed Grid Connection Transformer rating for proposed wind farm	110/33/11kV 16 MVA