Mausam, (1982), 33, 4, 489-494

551.556.3 : 631.67 (540)

Utilization of wind energy for irrigation in India

A. JAGADEESH, N. C. VARSHNEYA and A. VARADARAJULU*

Department of Physics, University of Roorkee, Roorkee

(*Received 13 March 1981*)

सार – इस शोध पत्र में भारत मौसम विभाग द्वारा एकत्रित किए गए दीर्घकालीन पवन के आंकड़ों से विभिन्न राज्यों में पवन चक्कियों से उपलब्ध ऊर्जा विभव का आकलन प्रस्तुत किया गया है। विभिन्न राज्यों में फसल को उगाने के लिए जल की आवश्यकताओं और इन मांगों की पूर्ति के लिए ऊर्जा की आवश्यकता की गणना की गई है। यह दर्शाया गया है कि विभिन्न राज्यों में फसलों को उगाने के लिए उत्पन्न पवन ऊर्जा सिंचाई की आवश्यकताओं को काफी हद तक पूरा कर सकेगी। पवन की चाल को बढ़ाने के लिए उपयुक्त कगारों का वर्णन किया गया है जिससे शक्ति में भी वृद्धि होती है। इस शोध पत्र में कम कीमत में ज्यादा दक्षता वाली पवन चक्कियों के बड़े पैमाने पर उत्पादन का सुझाव दिया गया है, ये कम पवन चालों में भी चलने योग्य होती है।

ABSTRACT. The energy potential available from windmills in different States based on long term India Met. Dep. wind data has been estimated and presented in this paper. The water requirements for crops grown in the different States and the energy needed to meet these demands are calculated. It is shown that wind energy generated will meet the irrigation needs of crops grown in the different States, quite adequately. Suitable escarpments to increase wind speeds which in turn increase power is discussed. Large scale manufacture of low-cost high efficiency windmills which are capable of operating even in low wind speeds is also suggested in the paper.

1. Introduction

The energy crisis and the realisation that fossil fuels are fast depleting have drawn the attention of scientists and engineers recently in many countries on tapping of non-conventional and renewable energy sources. The interest in these areas such as harnessing the wind energy is not new and although attempts have been made at various times, it could not become popular due to economic considerations, the main drawbacks being its dilute distribution and uncertain availability. However, due to continuous increase in energy costs from conventional sources, better understanding of aerodynamics of rotating aerofoils and development of cheaper and stronger materials etc, it is considered that the time is now ripe to have a fresh look at the non-conventional sources of energy, not for replacing the conventional sources but to supplement them.

In India, one of the major fields of application, where wind energy may be effectively used, is the pumping of water for irrigation and drinking purposes. In remote villages the pumping of water by windmills can compete on the economics of the system with conventional systems such as diesel pumpsets or electric pumpsets as is evident from our analysis in this paper. The requirements of water for crops on small holdings envisage the development of windpumps which can be run without skilled assistance.

In this paper an attempt is made to know the economic viability of windpumps for irrigation in rural areas, which is a pressing problem facing the country.

2. Wind data

The only source of data on winds available in the country is the India Meteorological Department (IMD 1966). The data available are from :

(*i*) Continuous wind speed records at some observatories and

(*ii*) Daily mean speeds, hourly means at 0830 and 1730 IST and the mean between these two hours at more than 200 stations spread over the country.

Monthly average wind speeds in km/hr at some stations region-wise taken from IMD are presented in Table 1 which gives a broad picture of the seasonal variation of wind pattern.

*Department of Physics, Srikrishnadevaraya University, Ananthapur (A.P.)

TABLE 1

Monthly average wind speeds in km/hr at some stations

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual average
Coastal areas													
Southern tip (Cape Comorin)	21.8	19.4	15.1	12.7	19.0	18.7	18.6	19.7	18.3	13.9	16.1	19.5	17.7
West coast (Okha)	17.4	17.1	18.0	19.8	22.8	22.8	24.3	22.1	15.9	11.7	15.4	17.5	18.7
East coast (Puri)	11.9	15.9	20.5	24.0	26.2	23.3	23.3	19.7	15.9	12.3	10.2	10.5	17.8
Inland locations													
Eastern region (Calcutta)	4.1	5.1	8.4	13.0	16.2	12.4	11.5	10.0	8.4	5.0	3.9	3.5	8.5
Northern region (Mukteshwar)	11.0	12.3	12.9	14.9	16.7	15.4	12.1	10.1	10.0	10.2	10.3	10.5	12.2
Central region (Indore)	9.5	10.8	13.0	15.5	24.4	27.0	26.2	21.7	18.5	9.8	7.5	7.1	15.9
Western region (Phalodi)	10.0	8.8	12.9	14.1	20.7	25.6	23.6	19.4	16.6	11.6	11.8	8.3	15.3
Southern region (Coimbatore)	10.3	10.7	12.0	14.7	23.0	32.6	31.0	30.8	20.2	16.3	9.5	10.1	18.9

Source : India Met. Dep. (1966)

2.1. *Energy extractable from the wind*

A wind stream of speed V has an energy flux $\frac{1}{2}d\ V^3$ which at normal temperature (30°C) amounts to about $0.013V^3$ W/m^2 if V is in km/hr (and $0.6\ V^3$W/m^2 if V is in m/s). Here V is velocity of wind and 'd' is density of air and W is expressed in watts. However, the total energy in a fluctuating wind is often considerably higher than the energy estimated by this formula if V is taken as the mean wind speed; the reason is that the energy content at higher wind speeds is disproportionately more than at lower speeds. The energy in the mean wind has, therefore, to be multiplied by a so called Energy Pattern Factor (EPF) to obtain the total energy content (Shrinivasa *et al.* 1979). The value of this factor at some stations is available (Tewari *et al.* 1980). In estimating the energy, the above values have been taken.

2.2. *Area and efficiency of the windmill*

From the studies of Musgrove (1976), Coty and Dubey (1976), Ljungstrom (1977) and Railly (1977), Ryle (1977) concludes that 'the vertical mixing of air allows one to site wind turbines so that their swept area corresponds to between 0.15 & 1.5 per cent of the ground area'. He uses a value of 0.4 per cent for the United Kingdom. We also use the same value in estimating the wind energy potential in different States.

According to Golding (1962) the overall efficiency of a simple windmill when the winds are not steady is about 6-7 per cent. I.I.Sc. windmill has 11 per cent efficiency at the design wind speed but averages to less than 4 per cent in varying wind speeds (Govindaraju & Narasimha 1979). Therefore, it is believed that even simple windmills in principle achieve overall operating efficiencies of about 15 per cent when provided with suitable matching devices (Shrinivasa *et al.* 1979). But inexpensive load matching devices are yet to be built. Hence, in estimating wind energy potential in different States, we use a value of 10 per cent as the efficiency of extraction from the wind.

2.3. *Total extractable energy*

We estimate the total available wind energy in different States taking into account the annual mean wind speeds at 103 meteorological stations in these States and on the following assumptions :

(a) The value of energy pattern factor available at a station is valid for all the stations in the State.

(b) The efficiency of extraction of energy from the wind = 10 per cent.

(c) The wind-speeds measured at the meteorological stations are valid in the entire district in which each station is situated. Where a district has no station, the mean wind speed is the same as in a neighbouring district in the same geographical region and

(d) The windmill area that can be used for extraction of energy from the wind is 0.4 per cent of the total unforested area.

The estimated wind energy potential in different States derived on the above assumptions is shown in Table 2 which is compared with electricity consumption.

2.4. *Water requirements of crops*

Water requirements (in millimetres) for field crops have been calculated by Dakshinamurthi

TABLE 2

Estimates of wind energy potential

State	Estimated wind energy (x 10^9 kwh)	Electricity consumption during 1978-79* (x 10^9 kwh)
Andhra Pradesh	30.93	4.201
Gujarat	27.02	6.851
Kerala	3.237	2.422
Maharashtra	21.25	12.851
Madhya Pradesh	21.04	4.281
Orissa	8.49	2.424
Rajasthan	23.97	2.6
Tamilnadu	15.23	8.178

*Source : Central Electricity Authority, Commercial Directorate, 1980.

TABLE 3

Water requirements (in mm) for field crops (other than rice) at 70 per cent field irrigation efficiency

Zone and climate	Season		
	Kharif (Jul-Oct)	Rabi (Nov-Feb)	Hot season (Mar-Jun)
North zone (sub-tropical) : Cool temperature and semi-arid	150-350	125-250	300-400
Eastern zone (Sub-tropical) :			
Hot and humid	500-600	400-500	800-900
Hot, sub-humid, & humid	450-550	400-500	600-700
South zone (tropical) :			
Hot, sub-humid, & humid areas	450-500	500-600	650-710
Central & Western zone (tropical) :			
Hot and semi-arid areas	660-700	600-700	900-1000
Hot and arid areas	900-1000	800-900	1200-1400

Source : Dakshinamurthi *et al.* (1973)

et al. (1973). It has been estimated that water requirement of rice is 12 mm/day on clayed soils and 18 mm/day on loamy soils. The water requirement of field crops (other than rice) are given in Table 3.

Pumping water for irrigation is from two sources :

(1) Open wells and

(2) Ground water (through bore wells).

In central, southern and western parts of the country, pumping from open wells is a commonsight. It is evident from Table 3 that in hot season the water requirement for crops grown in these areas is about 50 per cent more than those cultivated during the Rabi and Kharif seasons. Moreover during the hot season, the water-table goes down. A variation in depth by a factor of 2 is quite common in shallow wells in which the watertable averages about 7 to 10 m (Rajput and Yadav 1974). A change in depth by a factor of 2 amounts to a corresponding change in energy requirements by a factor of 2, on the assumption that same quantity of water is drawn. But this necessitates an increase by 50 per cent in water requirement during hot season. For a particular area the total energy requirement could increase by a factor of 3 during the hot season.

According to Rajput and Yadav (1974) the water requirement for rice during Rabi season is around 1500 mm and for other crops in the tropical zone, about 600 to 700 mm (Table 3). During hot season, the water requirement for rice increases to 2000-2500 mm and for other crops to 900-1000 mm. On a rough estimate one can assume water requirements for rice and other crops in the ratio 2.2 : 1. If the water availability from open wells is taken as 20,000 m^3 per year, it would be possible to irrigate a maximum area of 0.44 ha under rice and about 1 ha under other crops.

The average daily water requirement for rice in 0.44 ha during Rabi season amounts to 55 m^3 per day. If this is pumped over a total head of 6.67 m, the useful daily energy output is equivalent to 1 kwh. The energy requirement for a crop grown during the hot season would amount to 3 kwh per day and for a crop grown during Kharif season, another 1 kwh per day on the average . Thus the total requirement would be about 600 kwh annually (Tewari 1978).

Irrigation throughout the year, especially during summer may not be possible in most parts of the country. If irrigation is carried out during Rabi and Kharif seasons only, the energy needs will be much less.

For our discussion we assume the energy reguirement per year per 0.44 ha for rice crop as 600 kwh. In estimating the energy requirement it is assumed that rice per hectare needs 1360 kwh annually and other crops 620 kwh.

The area in which rice and other crops (including food grains other than rice, oilseeds etc) grown is given Statewise in Table 4.

TABLE 4

Area and type of crops grown in different States

State	Rice/Area in 1000 hectares 1974-75	Other crops/ Area in 1000 hectares 1974-75
Andhra Pradesh	3,565	7,708
Gujarat	367	6,814.31
Kerala	881.5	279.46
Maharashtra	1,324	16,064.4
Madhya Pradesh	4,526	14,799.88
Orissa	4,432	2,076.06
Rajasthan	129.5	13,151.19
Tamilnadu	2,246	2,540.82

Source : *The Times of India Directory and Year Book*, 1977.

TABLE 5

Energy requirements of crops and wind energy potential (in 10^9 kwh)

State	Energy required for a irrigating			Estimated wind energy potential	Electricity consumption for agriculture (1978-79*)
	Rice	Other crops	Total		
Andhra Pradesh	4.8	4.778	9.578	30.93	0.8398
Gujarat	0.499	4.22	4.719	27.02	1.114
Kerala	1.19	0.173	1.363	3.237	0.077
Maharashtra	1.8	9.959	11.759	21.25	1.379
Madhya Pradesh	6.1	9.175	15.275	21.04	0.281
Orissa	6.027	1.28	7.307	8.49	0.049
Rajasthan	0.176	8.15	8.326	23.97	0.511
Tamilnadu	3.05	1.57	4.62	15.23	2.157

*Central Electricity Authority, Commercial Directorate, New Delhi, 1980

The energy required to irrigate this area alongwith wind energy potential and electricity consumption for agriculture is given in Table 5.

It can be seen from Table 5 that even if 10 per cent of the available wind energy is tapped, it can save the present electricity consumption for agriculture, to some extent which can be used in other sectors, like industry.

Though the entire area in different States cannot be covered by windmills for extracting energy for irrigation (for lack of adequately strong winds, lack of groundwater etc) we can find many windy sites along open areas, coasts, hill tops, valleys etc. The windmills will be particularly useful in providing energy for irrigation in non-electrified areas.

2.5. *Windmills available in the country*

Many windmill designs have been tried in India for possible commercial exploitation.

Sherman's Madurai windmill which was adopted from the well known Cretan sail windmills, was designed to operate in low wind velocities. It has a 10 m diameter sail rotor coupled with a variable stroke reciprocating pump. Its efficiency was 8.6 per cent at the rated wind speed of 8 km/hr (ESCAP 1977). The cost of the windmill was Rs. 5,480.

The 10 m NAL windmill which has a six-sail rotor has to be coupled with a swinging vane rotary vane pump in order to obtain high performance in low wind speeds. The windmill can operate in low wind velocities (6 km/hr) and costs around Rs. 10,000 (Tewari 1978).

Indian Institute of Science, Bangalore designed and installed a sail type Savonius Rotor at Ungra village in 1977. This delivers on an average 2,500 litres of water a day excluding the monsoon months and is estimated to cost Rs. 3,000 (Govindaraju & Narasimha 1979).

Central Salt and Marine Chemicals Research Institute, Bhavnagar, has designed and fabricated a Savonius type rotor windmill with a projected area of 2 sq. m and a height of 2 m. It has also designed a proto type of Savonius rotor with projected sail area of 7.5 sq. m and a height of 3 m. The efficiency obtained with this windmill varied between 2.1 per cent and 8 per cent (Rao 1979).

A sail type windmill of 8 m diameter was designed and installed near the observatory of Central Arid Zone Research Institute, Jodhpur on a wooden tower of 6 m height. The windmill was able to pump water from a level of 3.5 m below the ground at an average rate of 1,050 litres/hr at a mean daily wind speed of 15-20 km/hr and 1,250 litres/hr at a wind speed of 26 km/hr and costs around Rs. 3,000 (Krishnan 1979).

At Auroville, Tamilnadu, three types of windmills were designed and installed. 'Banyans' windmill pumps on daily average 10 cu. m of water from a depth of 27 m in average wind speeds of 6 to 8 km/hr while 'The Centre Fields windmill' 20 cu. m of water per day and the latter costs around Rs. 15,000 (Jaap *et al.* 1979).

AMM Chettiar Research Centre, Madras has developed 'Anila-1' mainly for water pumping in coastal areas. Palm trees, casurina poles, jute sails and wooden planks being the materials required, these are easily procured from the vicinity. This windmill pump discharges 2,000 litres/hr of water at a total lift of 8 metres in wind speeds of 25 km/hr and costs around Rs. 2,000 (Geethaguru 1979).

A Dutch team from TOOL Foundation in co-operation with the Organisation of the Rural Poor (ORP), Ghazipur (U.P.) has started commercial production of windmills. In velocities between 2&3 m/s the discharge of water will be about 3.6 m^3/hr. The windmill starts pumping water in wind speeds from 2.5 m/s onwards. The windmill pumps the water into a storage tank (size $10 \times 10 \times 1.5$ m). Out of the storage tank the farmer can irrigate his crops with the help of a syphon at any moment he likes. The syphon gives a flow of approximately 4 litres/sec, which facilitates high efficiency. The storage tank can also be used for fish rearing and for the cultivation of blue green algae which can be used as manure. A single windmill will serve the water requirement of 1.2-1.4 hectares. This windmill costs Rs. 5,100 and its life will be about 15 years. From the cost of windmill, its duration of life and its output, it was found that the cost of 1 m^3 of water pumped by this windmill will be around Re. 0.10 as compared with the price of 1 m^3 of water pumped by a 5 HP diesel pump set with an expected duration of life of 15 years and 600 running hours per year being Re 0.22 (Jaap Wilting 1979).

2.6. *Better utilization of wind through escarpments*

The reason for the slow progress of windmills for extracting energy in India is often attributed to generally low wind speeds prevailing in most parts of the country.

We know that wind speed gets accelerated if it is allowed to escalate over an artificially constructed dam. The speed inturn increases the power as its cube. Installing windmills over such a dam would thus be a more economical way to harness windpower especially in plains and in rural areas.

The laboratory experimental results on models simulating dams (Varshneya and Iswarchand) have shown that the wind speed gets accelerated on top of the dam by a factor of 1.5 as it escalates over a 30° slope of 10 m high dam, which could be a simple earth dam. The power gain will be 3.38.

The construction of a 10 m high and 30° slope earthern dam is economically feasible in rural areas. To meet the energy needs of a village such as irrigation, drinking water etc, 15 windmills of 10 m diameter rotor can be installed on a 160 m span, 10 m high and 30° slope earthern dam. This drastically reduces the construction and maintenance costs (such as in the case of steel structures).

These results indicate that even areas of average or even low winds can be utilized for harnessing wind energy through escarpments, quite economically.

3. Conclusions

It has been shown that the energy generated by windmills can be effectively and economically utilized for irrigation in India. For optimum utilization of wind energy to lift water, what is needed is a low cost, high efficiency windpump which can operate even at low wind speeds. TOOL-ORP and Anila-1 windmills offer promise in this direction. The Government should encourage the manufacturer of windmills of the above types on a large scale either in public or private sectors. As many farmers in rural areas hold small farms (less than 1 hectare), a "Community Windmill Programme" can be launched by the Government. In areas of moderate winds it is profitable to construct earthern dams to increase the wind speeds which in turn increases the power. More detailed wind and groundwater surveys should also be undertaken.

References

Coty, U. and Dubey, M., 1976, 2nd Annual Energy Symposium, Los Angeles Council for Engineers and Scientists, Los Angeles.

Dakshinamurthi, C., Michael, A. M. and Mohan, S., 1973, Water Resources of India and their Utilisation in Agriculture, IARI monograph No. 3, Indian Agric. Res. Inst., New Delhi.

Economic and Social Commission for Asia and the Pacific, 1977, Workshop on Biogas and other Rural Energy Sources, Report on the Practical Application of Wind-Powered Water Pumps, Report NR/BG RER/S, Bangkok.

Geethaguru, M., 1979, Developments at AMM Murugappa Chettiar Research Centre, Proc. of the Wind Energy Workshop, Bangalore, 12-15.

Golding, E. W., 1962, Technical Note TN-WP7-62, National Aeronautical Lab., Bangalore.

Govindaraju, S. P. and Narasimha, R., 1979, A low-cost water pumping windmill using a sail type Savonius rotor, Rep. 79 FM2, Dep. of Aero. Eng., Indian Institute of Science, Bangalore.

Govindaraju, S. P. and Narasimha, R., 1979, Windmill for rural use, Proc. of the Wind energy workshop, Bangalore, 20-21.

IMD, 1966, *Climatological Tables of Observatories in India* (1931-1960), India Met. Dep.

Jaap, Ed., Vijay, Jean, Robbie and Joel, 1979, Wind energy developments at Auroville, Tamilnadu, Proc. of the wind energy workshop, Bangalore, 34-42.

Jaap Wilting, 1979, ORP-TOOL Windmill Project at Ghazipur, Proc. of the wind energy workshop, Bangalore, 82-84.

Krishnan, A., 1979, Utilisation of Windpower for pumping water and power generation in India, Proc. of the wind energy workshop, Bangalore, 45.

Ljungstrom. O., 1977, Proc. of the International Symposium on Wind Energy Systems, Cambridge, UK (BHRA Fluid Engineering, Cranfield).

Musgrove, P., 1976, *New Sci.*, **72**, 596.

Railly, J. W., 1977, *New Sci.*, **73**, 231.

Rajput, R. K. and Yadav, T. S. P., 1974, *Indian Farming*, **24** (No. 7), 20.

Rao, K. S., Majethia, K. M., Thaker, B. G. and Gohel, H. M., 1979, Developments at Central Salt and Marine Chemicals Research Institute, Bhavnagar, Proc. of the wind energy workshop, Bangalore, 57-59.

Ryle, M., 1977, *Nature* (London), **267**, 111.

Shrinivasa, U., Narasimha, R. and Govindaraju, S. P., 1979, Performance of windmills, Report 79 FM4, Dept. of Aero. Eng., Indian Institute of Science, Bangalore.

Shrinivasa, U., Narasimha, R. and Govindaraju, S. P., 1979, Prospects for wind energy utilisation in Karnataka State, *Proc. Indian Acad. Sci.*, C_2, Part 4, 528.

Tewari, S. K., 1978, Economics of Wind energy use for irrigation in India, *Science*, **202**, 484.

Tewari, S. K., Narasimhaiah and Samraj, A. C., 1980, Wind energy availability at some locations in India, Symp. on "Renewable sources of energy" organised by National Academy of Sciences, Allahabad.

Varshneya, N. C. and Iswarchand, Better Utilisation of wind through its escalation over dam, *The Journal of the Institution of Engineers* (India), (In Press).