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Wind Energy Cost and Feasibility of a 2 MW Wind Power Project

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Abstract – *The present research work has been carried out on 2 MW installed capacity Wind Power Project, at Motha District Amaravati, Maharashtra State, India. The main objectives were to evaluate various costs involved in the energy production. The cost of energy production per kWh (electrical energy) was calculated for the first year of operation. The economics of wind energy and thereby the feasibility of the power project were examined by estimating per unit cost of energy, net present value (NPV), benefit-cost ratio (B-C), internal rate of return (IRR), and pay back period of the power system. The discounted cash flow (DCF) method was used to find out the IRR. In wind energy conversion system, three cost; installed capital cost, specific capital cost, and life cycle cost of energy, were examined for the evaluation of the production cost of energy generated. Considering the discount rate on the investment for the project as 7.5 percent, the B-C ratio comes to 3.51 and IRR comes to 21.82%.*

Keywords – Benefit-cost ratio, discounted cash flow, net present value, wind power project.

1. INTRODUCTION

Electricity plays vital role in the socio-economic development of the nation. India, one of the fast developing countries in the world, thrives for the energy. The second development stage in the India is on the verge of completion. The commercial energy resources available in the country are limited. Several studies have established that wind energy produces more jobs per capital invested or per kilowatt-hour generated than most conventional resources. Out of the various renewable energy sources, wind is the only source that has reached commercial viability stage for large grid connected requirements.

The government of India, in 1952, has initiated an ambitious project to harvest energy from the wind. In December 1952, a wind power sub-committee was constituted under the Council of Scientific and Industrial Research, New Delhi. Wind technology in India was introduced in the late 1970's with Danish Development Co-operation.

The market-oriented approach of the government of India, since the inception of the wind power programme in 1983-84, has resulted in effective commercialization of wind power projects. Wind potential in the country has been assessed at 45,000 MW while in Maharashtra it is 3650 MW, as of today.

The potential sites were identified after studies were carried out at different wind monitoring stations. The government of India through the Ministry of Non-conventional Energy Sources established 34 demonstration projects in 11 states with the total installation capacity of 62.8 MW. These demonstration projects attracted large-scale private sector investment [1]. Wind power capacity of 615 MW was added during 2003-04 taking the cumulative capacity to 2483 MW, the fifth largest wind power installed capacity in the world [2].

The wind power project is installed at village Motha near the popular hill station, Chilkhaldara situated in the seven-hill ranges in Western Vidarbha of the state of Maharashtra, India. The project consists of two-wind turbines of 1 MW each. The financial breakdown of the system was studied for the appraisal of project. The working life of the wind turbine has been considered for 20 years. This power project is one of the demonstration projects installed by Government of India.

2. MATERIALS AND METHODS

Wind power generation data were collected from the station for first year of operation (2003-2004). The gathered wind energy generation data were analyzed for the energy pricing and system reliability. The costs involved in the project were collected from the manufacturing company and the installation company. The agreement between the installation company and the government was that for the operation of the wind power project, the company has to serve at least five years from the installation of the wind power project. The installation company has asked Rs 0.2 million per year for carrying out the operation and maintenance for the five year [3].

Theory for Analysis

The economics of the wind power project was calculated by evaluating various wind energy costs and by using the discounted cash flow technique for project feasibility.

Wind Energy Costs

The costs of these (wind, solar etc.) renewable energy systems have decreased significantly over the past 15 years. Three methods were customarily used to measure the costs and economic performance of wind turbine systems. The measures began with the installed capital cost, then continued with the specific capital cost (the

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installed capital cost to generate one unit of energy per year), and ended with the cost of energy [4], [5].

Installed capital cost: This measure includes all planning, equipment purchase, construction and installation costs for a turnkey wind system, that is ready to operate. As such this cost will include the wind turbine and tower delivered and installed at the site together with all electrical, maintenance and other supporting infrastructure like land [4], [5].

Specific capital cost: The second measure of cost combines the installed cost, the strength of the wind resource and the matching of the wind resource to the wind turbine power curve. The specific capital cost is the installed cost to obtain a Kilowatt-hour of energy per year. That is, the cost to procure, install and make ready generating capacity that will generate a kilowatt-hour per year.

$$C = \frac{\text{Installed Capital Cost}}{\text{Energy Production per year}}, \text{Rs}/(\text{kWh}/\text{yr}) \qquad (1)$$

The specific capital cost, does not include the cost of operation and maintenance over the lifetime of the facility, the costs of frequent major overhauls or the cost of capital.

Life-cycle cost of energy: The third and the most comprehensive measure of wind energy cost is the life-cycle cost of energy (CoE). This measure incorporates all elements of cost *i.e.*, installed capital cost, cost of capital, cost of operations and maintenance and cost of major overhauls and subsystem replacement.

$$CoE = \frac{ICC + FCC + O\&M + LRC}{\text{Energy Production per year}} \qquad (2)$$

where, ICC = Installed capital cost, FCR = Annual fixed charge rate, O&M= Annual operation and maintenance cost and LRC= Levelized replacement cost (considered 25 percent over O&M).

Economic Feasibility of Wind Farm

The project evaluation technique (discounted cash flow) was used to measure the economic feasibility of wind farm. This technique measure the productivity of capital invested and for which the flows of costs and returns over life period of the wind farm are required. These costs can be brought to refer to the particular point of time *i.e.*, present period by discount/ compounding them.

Comparative picture of different measures of capital productivity used in economic evaluation of investment in wind farm were used are: net present value, benefit cost ratio, internal rate of return and payback period [6]-[8].

Net present value: In this method, generally the discount rate/compound rate, which reflects the price of the investment funds, is used to arrive at costs and returns to a common point of time. These costs are subtracted from the return to get the net present values of the project. The positive net present values indicate that the investment is worthwhile and the size of the net present value (NPV) indicates how worthwhile the project is in utilizing the resources to maximize income [7], [9], and [10]. Following expression is used to work out the net present value:

$$NPV = \sum_{t=1}^{N} \frac{R_t - C_t}{(1+i)^t} \qquad (3)$$

Where R is the returns in year t, C is the costs in year t, N is the project life, i is the discount rate in per cent. The decision criteria are:

If NPV >0 Investment is worthwhile
NPV<0 Investment is not worthwhile
NPV=0 Neutral case.

Benefit cost ratio: The benefit cost ratio measures the returns or benefit per unit of cost of investment.

$$BCR = \frac{\sum_{t=1}^{N} \frac{R_t}{(1+i)^t}}{\sum_{t=1}^{N} \frac{C_t}{(1+i)^t}} \qquad (4)$$

The decision criteria are:

If B-C>1 Investment is worthwhile
B-C<1 Investment is not worthwhile
B-C=1 Neutral case.

Internal rate of return: The internal rate of return means the discount/ compound rate at which the present value of returns equals that of costs. Accordingly, the derived discount rate (IRR-r) is compared with the price of the investment funds to know the worthiness of the project.

$$IRR - r = \sum_{t=1}^{N} \frac{R_t - C_t}{(1+i)^t} \qquad (5)$$

The decision profitability criteria are:

If IRR-r >1 Investment is worthwhile
IRR-r <1 Investment is not worthwhile
IRR-r =1 Neutral case.

Payback period: This is the simplest of the techniques for evaluating an investment proposal. It is defined as the time period within which the initial investment of the project is recovered in the form of benefits. In other words, this is the length of time between the starting time of the project and the time when the initial investment is recoupled in the form of yearly benefits. Expressing it in notation:

$$P = \frac{I}{C} \qquad (6)$$

where, P is the payback period, I is the initial investment, and C is the yearly net cash flow.

3. RESULTS AND DISCUSSIONS

Economics of Wind Power Project

The economics of wind energy and feasibility of the project was examined by estimating per unit cost of energy and by estimating NPV, B-C ratio, IRR and payback period. The information gathered from station regarding the capital cost and energy production of 2 MW wind farm for one year are indicated in Table 1. The annual capacity factor was calculated from the energy data collected per month for the station.

Wind Energy Cost per Unit Electrical Energy Generation

Three costs; installed capital cost, specific capital cost, and life cycle cost of energy, were examined for the evaluation of the production cost of the wind energy conversion system.

Total installation cost for 2 MW capacity of wind power project comes to Rs 106.92 million. Installed capital cost per kilowatt was worked out to be Rs 53640 with 10 percent inclusive of the land cost. Canada *et al.* [11] reported that equipment and installation costs were found to be $1,200,000 per 1.5 MW general electrical wind turbine. The annual wind energy production of the site for this year was 3.73 MWh of electrical unit (Table 1). The installed capital cost (equipment and land) is value at Rs 106.92 million, the specific capital cost was calculated to be (106.92/3.73) *i.e.*, 28.897 ≈ 28.90 Rs/(kWh/yr) on the basis of first year operation.

Table 1. Capital statement and energy production of 2 MW wind farm

Sr. No.	Particular	Parameter
1	Wind farm capacity	2 MW
2	Installed capital cost	
	a. Equipment cost	Rs 97.2 million
	b. Land cost	10 % of Equipment cost
3	Total installation cost	Rs 106.92 million
4	Annual capacity factor	23 % (From initial year of operation)
5	Annual operation and maintenance cost	Rs 0.2 million
6	Sale price of electricity	3.50 Rs/kWh
7	Discount rate / Annual fixed charge rate (FCR)	7.5 %
8	Project life time	20 Year
9	The annual energy yield (kWh)	3.73 million kWh
10	The gross annual income for first year	Rs 13.05 million
11	Levelised replacement cost	25% on the annual operation and maintenance cost for the first year

Capital cost component was calculated using specific capital cost (28.90 Rs/kWh/yr) and fixed charge rate of 7.5 per cent, which comes to 2.17 Rs/kWh. Annual operation and maintenance cost was Rs 0.2 million for the wind power project and this was 0.05 Rs/kWh for one year. Kemmet [12], reported that annual operating costs were 2% to 3% of the initial system cost or approximately 1 to 2 cents per kWh of output. Cost of levelized replacement was examined by considering 25 percent of wind farm operation and maintenance cost, which comes to 0.0125 Rs/kWh [5].

The cost of energy is equal to the sum of the three components mentioned above *i.e.*, capital cost component (2.17 Rs per kWh), operation and maintenance cost (0.05 Rs per kWh) and cost of replacement (0.0125 Rs per kWh) which comes to 2.23 Rs per kWh. Joseph *et al.* [13] have recorded the cost of electricity from wind to the extent of 4 cents per kWh. The relative magnitudes of these estimated cost values (Table 2) provided insight into where the overall economics of this system may be impacted. From Table 2 it is seen that the leading component of cost of energy is the capital cost component followed by the cost of operation and maintenance. The capital cost represents 97.20 percent of the total cost of energy. This is true because all renewable energy systems require very high initial investment and operation maintenance and replacement cost are meager *i.e.*, 2.8 percent only.

Profit Statement of Wind Power Project at Motha

Information presented in Table 3 shows the profit statement for the 2MW wind power project. The profit per kWh of energy production was worked out to be Rs 1.27 in the first year of operation. Considering electrical energy production of 3.73 million kWh and selling price of Rs 3.5 per kWh, the gross annual income comes to Rs 13.05 million. The production cost comes to (Rs 2.23 X 3.73 million kWh) Rs 8.31 million and therefore profit for the first year of operation is Rs 4.73 million.

Economic Feasibility of Wind Power Project

For initial project appraisal, some form of discounted cash flow is normally required and the non-discounted indicators are not used. In economic term, the discount rate is an indication of the opportunity cost of capital to the organization. Opportunity cost is the return on the next best investment and so below it will not be worthwhile to invest in the project. In India at present, discount rate of 7.5 percent is common for commercial power projects reflecting the value placed on capital and the perceived level of risks [2], [8].

While working out the costs and returns from wind power project in the above analysis which was carried out for first year of installation, the time factor was not considered. To bring the past and future costs to present worth, compounding and discounting technique were used and were done at 7.5 per cent discount rate. The economic feasibility of wind power project was examined by working out the net present value (NPV), benefit-cost ratio (B-C ratio), internal rate of return (IRR), payback period, considering operation and maintenance cost for first five years as 0.2 million per year, from 6 to 10 years as 0.3 million per year, from 11 to 15 years as 0.35 million per year and 16 to 20 years as 0.4 million per year. For the income calculations, the sale price of wind energy generated per kWh is taken as Rs 3.5 in the first year of operation and small escalator from the next year as 15 paise (Rs 0.15) per kWh every year for a period of thirteen years [14]. The present worth of cost and present worth of benefits at 7.5 percent discount rate are Rs 109.80 million and Rs 386.03 million respectively (Table 4).

Net Present Value

The information presented in Table 4 reveals that the net present value (NPV) is positive and so the project is feasible and suitable for further consideration. The net present worth for wind power project was worked out to be Rs 276.23 million with 7.5 percent discount rate and discount factor in 20 years as 0.2354. This discount factor indicates that the present value of income stream in that year is only 23.54 percent of its cash value.

Benefit-Cost ratio

The project is insensitive to operation and maintenance costs at the level of each year (as only 0.2 million to 0.4 million per year range is considered for operation and maintenance cost). The B-C ratio of wind power project was found out by taking ratio of present worth of benefit and present worth of cost, which comes to 3.51. Since the ratio is greater than unity, the investment is financially justified. However, the capital investment of one rupee in wind power project shows a profit of Rs 2.51.

Internal Rate of Return

The internal rate of return of the wind power project for the 20 years life period was worked out from the trial and error method of calculation. The IRR in the present case was worked out to be 21.82 per cent.

Payback Period

Payback period discriminates whether the project is feasible or not for the threshold lifetime. The net cash flow is calculated by deducting yearly operation and maintenance cost from the gross annual income of the wind power project. Then cumulative net cash flow is calculated for different years (Table 5). Payback period of the wind power project was worked out to be six years five months and three days, where the cumulative net cash flow becomes equal to the initial investment. Canada *et al.* [11] reported that payback period of a wind farm with conservative estimate is around eight year [11].

It means that after nearly seven years of operation of the project, it will be giving net profit and since the life of the wind energy conversion system is nearly 20 years, the project is found economically feasible.

Table 2. Comparison of calculated cost of energy (CoE) component

CoE Component	Value (Rs/kWh)	Basic of Estimate	Percent of Total CoE
Capital cost	2.17	Used FCR = 7.5 % per year	97.20
Operation and maintenance cost	0.05	As planned by MEDA Rs 0.2 million per year	2.24
Levelized replacement cost	0.0125	25 % on the operation and maintenance cost	0.56
Total CoE	2.23	Total of all cost component	100

Table 3. Profit per unit of wind energy generation

Sr. No.	Particular	Per unit (Rs)
1	a) Capital cost component	2.17
	b) Annual O and M Cost	0.05
	c) Levelized replacement cost	0.0125
	Total cost of Energy (a+ b+ c)	2.23
2	Return per unit	3.5
3	Net profit (2-1)	1.27

Table 4. Financial outlays for wind power project, Motha

Sr. No.	Particular	Amount (Rs in million)/Percent
1	Present worth of cost	109.80
2	Present worth of benefit	386.03
3	Net present value (NPV)	276.23
4	Benefit-cost ratio (B-C)	3.51
5	Internal rate of return (IRR)	21.82

4. CONCLUSION

Wind energy cost was determined for the energy production in terms of Rs per kWh. A very simple technique was used for finding the cost of energy generation. The cost of energy of the wind generation includes three cost components. It was realized that installation cost is the leading factor in the wind energy cost.

Economic feasibility of the wind power project was determined over the life of the system. The result obtained from this method indicated that the project is feasible and acceptable based on the net present value (NPV). Payback period of the wind farm comes within the early few years. Internal rate of return of the wind farm was also more than the discount factor taken for the cash flow analysis.

Wind energy costs of the power project were worked for the installation capital cost, specific capital cost and the life-cycle cost of the energy. Installation cost per kW was found more, which affected the cost of energy of the wind energy conversion system.

The net present value of the wind power project was found positive for the lifetime of the project. In the year 20 the discount factor indicates that the present value of income stream is only 23.54 percent of its cash value.

The B-C ratio of wind power project was found out by taking ratio of present worth of benefit and present worth of cost, which comes to 3.51. Since the ratio is greater than unity, the investment is financially justified. The internal rate of return (IRR) in the present case is worked out to be 21.82 per cent. The payback period of the wind power project was worked out to be six years five months and three days, where the cumulative net cash flow becomes equal to the initial investment at the beginning.

Table 5: Computation of payback period of the wind farm of 2 MW capacity

Year	Initial Investment, Rs*	Income, Rs/year	Net Cash Flow, Rs/year	Cumulative Net Cash Flow, Rs/year
0	106.92	-	-	-
1	0.2	13.05	12.85	12.85
2	0.2	13.61	13.41	26.26
3	0.2	14.73	14.53	40.80
4	0.2	16.41	16.21	57.01
5	0.2	18.65	18.45	75.46
6	0.3	21.44	21.14	96.61
7**	0.3	24.80	24.50	121.11
8	0.3	28.72	28.42	149.53
9	0.3	33.19	32.89	182.43

* Shows rupees in million.
Payback period = Six years five months and 4 days
** Shows year in which the installed capital cost recoupled *i.e.*, Rs 106.92. million

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