Remote Village Electrification Plan through Renewable Energy in the Islands of Indian Sundarbans

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Abstract:

Sundarbans, world's largest inter-tidal delta region containing huge areas of mangrove forests, lies between India and Bangladesh. About 20 islands, inhabitated by more than 100,000 households in 131 villages in India, have no access to electricity. India's drive towards remote village electrification aims at development of the islands. The Energy and Resources Institute has prepared a Master Plan for Electrification by 2008 for West Bengal Renewable Energy Development Agency. Distributed generation through renewable energy route found out to be the suitable answer to the present situation. The basic emphasis was on the total electrification of the command areas by utilizing hybridization of different renewable energy resources. Biomass and Solar resources are adequate in the region with low wind potential in few locations. Priority was given to the possibility of setting up new power plants. Approximate simulations of plant performance were carried out through the software HOMER. Optimum configurations of appropriate power stations were suggested in the Plan depending on energy resources available in specific locations. Total 35 power stations have been proposed in the Plan. All of them are of hybrid types with SPV, Biomass, Wind and battery bank components depending on the suitability for individual locations. Total SPV capacity estimated is about 1.59 MWp while Biomass gasification and Wind are about 1.12 MWe and 20 kW respectively. The recommended steps would benefit more than11000 households from these power plants. In addition, 3200 commercial shops would also get electricity from the same stations. It was further inferred that about 39 thousand PV home lighting systems of 37 Wp capacity each would be required to deploy within scattered households. About half of the total households representing from each of the 131 villages would get benefit from the envisaged Plan.

Introduction: Indian Sundarbans region is located between 21°32' N – 22°40' N and 88°00' E - 89°00' E. It has the boundary of Hooghly river in the west; Ichhamati, Kalindi, Raymangal rivers in the east; Dampire-Hodges line in the north and Bay of Bengal in the south. The whole tract reaches inland for 100-130 km. It encloses marshy islands covered with dense forests. Many rare or endangered species live here, including tigers, aquatic mammals, birds and reptiles. The region has 102 islands out of which 54 are inhabited. The islands suffer from chronic shortage of electrical energy due to non-availability of grid quality power [1]. The rivers are tidal in nature and sometimes become even 1 km wide. It is extremely difficult to extend transmission lines from main land to these islands resulting in technical limitations and prohibitive cost. People depend on the expensive and often erratic supply of kerosene for their lighting needs. There are a few small diesel generator sets supplying electricity to the markets of some villages, but the diesel delivery mechanism is not reliable. As the region has the characteristics of sensitive ecosystem, remoteness, inadequate infrastructure for transport sector, distributed demand for electricity and dependency on petroleum products imported from main land, there is absence of diesel based grid systems. There exists little or no reliable access to communication systems, television, and health facilities, all of which requires electricity. West Bengal Renewable Energy Development Agency (WBREDA), in association with Ministry of Non-conventional Energy Sources, Government of India, has taken several initiatives since 1994 to meet the electrical energy needs for the people living in the islands [2]. There are several instances of positive impacts to the local society out of these interventions [3]. So far 40,950

households are benefited from WBREDA's initiatives [table1]. However, there are about 106150 households that do not have access to electricity at present. They are distributed in 131 villages in 20 islands covering South and North 24 Parganas Districts. For these villages WBREDA assigned a task to The Energy and Resources Institute (TERI) for developing a Master Plan for electrification. A combination of primary and secondary data was used for extensive analysis to arrive at optimum solutions. The Plan proposed 35 new power plants, all renewable energy based, that would cater to 11275 households and 3200 commercial shops. In addition about 39000 solar Home Lighting Systems (HLS) was suggested in the Plan.

This paper attempts to describe the highlights of this Plan.

Method: The approach was a combination of primary and secondary data collection through structured questionnaires and interactions with identified stakeholders. TERI engaged Indian Institute of Social Welfare and Business Management (IISW&BM) for the primary survey and organizing meetings with several stakeholders in local level. Primary survey was carried out in the shops of market places as well as in the households. Secondary information collected was related to land use, energy resources and technologies & equipments required for power generation and distribution. Surveys were also used to locate the sites of proposed power stations with respect to various load centres. The estimation of demand was based on the information of survey. Analysing these data, optimum configurations of appropriate power stations were suggested in the Plan depending on energy resources available in specific locations. Associated aspects like tariff calculations and probable plant management structure etc. were included in the Plan.

Renewable energy resources: Sundarbans region is blessed with good solar resource. Average annual solar radiation is about 1600 kWh/m^2 on horizontal surface. In a year there are 250 sunny days and 55 totally overcast days. The annual average solar radiation on horizontal surface is about 4.91 kWh/m^2 per day [1].

In general, Sundarbans has rich forest cover and well known for biomass resources. Availability of woody biomass for power generation and land availability for energy plantation were the two options that were explored through secondary data collection. About 26400 hectares of vested land might be available in the region [4]. However, energy plantation is normally done in the charlands (sandy embankments) and canal side spaces. The total area of charland in South 24 Parganas District is 12621 hectares in 11 Blocks and 7541 hectares in 6 Blocks of North 24 Parganas District respectively [1]. As the energy plantation in Sundarbans areas gives sustainable yield of around 3 metric tones per hectare per annum, it is expected that most of the requirements could easily be met by plantation in Charlands / vested lands / canal side space etc. Another source of biomass supply is by way of purchasing from social forestry wood stock. WBREDA is already utilizing this resource for its existing biomass plants.

In entire Sundarbans region there are two locations, namely Ganga Sagar and Fraserganj, where CWET (Centre for Wind Energy Technology, Government of India) has established wind-monitoring stations and published wind data. Both Ganga Sagar and Fraserganj monitoring stations were near to seashore. For this reason locations near these two places with closeness to seashore would have less variation in wind profile compared to that of the measured one. For entire Sundarbans islands orography remains similar, as the region is flat with mean altitude equal to mean sea level. However, the surface roughness varies from location to location and obstacles in the form of high trees and buildings might be present. For this reason special care was taken to consider obstacles in the prevalent wind directions for all locations.

Demand assessment: It was found that in almost all locations, people use kerosene for lighting purposes and the kerosene consumption varies from 4 litres to 7 litres/month per household. The access to electricity is one of their priorities and most of the households are interested to take the service connections. It was estimated that demand per household would be approaching 30 units per month with duration of supply for at least 8 hours. It was found that people need electricity for two hours (4am-6 am) in early morning for different domestic purposes and 6 hours (6pm-12pm) in the evening. This implies a low consumption pattern which can be managed by renewable energy sources. From the experience of existing plants run by WBREDA

in the region a diversity factor of 1.25 was considered in the demand calculation for domestic clusters. A load growth of 15% was assumed along with 2% distribution line loss. Surveys were also conducted in the markets. There are small capacity diesel gensets in many of the markets run by private operators. It was estimated that requirement per shop at the present rate of consumption would be 20 units per month for 5 hours in the evening. The community loads like student dormitories, video halls, street lights and hospitals etc. were also included in the survey. In all locations, domestic household cluster is concentrated around the main market of a village. From the survey, it was felt that the ideal location for establishing new power plants will be near market places where the gradual load growth is expected, in addition to the advantage that it would be relatively concentrated form of load demand. Accordingly the local Government (Pahchayat) officials cooperated to identify sites, which might be available for new power plants. In this manner the focus was narrowed down to 35 locations ultimately for establishment of new power plants.

Selection of technology: Instead of establishing power supply systems based on single renewable energy sources, exploiting energy from different sources enhances the reliability and capacity factor and improves the plant economics [5]. Therefore, technological options explored for different locations were based on hybridisation of RE technologies depending upon resources available locally. With this philosophy, efforts were made to simulate and analyze a large number of alternative configurations, depending on the availability of resources in specific locations. Thereafter optimization analyses were carried out to arrive at the best possible sizing configurations. For optimization, a software called HOMER has been used, which is a computer based simulation-optimization model developed by National Renewable Energy Laboratory, USA for evaluating design options for both off-grid and grid-connected power systems. The optimization and sensitivity analysis algorithms of the software allows to evaluate the economic and technical feasibility of a number of technology options taking into account the variation in technology costs and availability of energy resources [6]. Product details of different renewable energy technologies, along with cost estimates, from different manufactures were collected for carrying out techno-economic feasibility of different options [table2]. While narrowing down focus on a final solution of plant configuration, special attention was given to several important technical parameters including battery days of autonomy, unmet load probability, excess electricity generation possibilities etc. In the economic analysis, 'Real Interest Rate' has been used as the effective rate of interest to nullify the influence of inflation. This rate is based on interest rates on Central Government Securities published by Reserve Bank of India. Weighted averaged value of 5.71% corresponding to the year 2003-2004 was taken as the effective real rate of interest. The calculations are based on the assumption that 1 US Dollar=45 Indian Rupees (Rs). The suitable combinations of plant elements were chosen on the basis of technical as well as economic performance among all possible combinations.

Final Results: Total 35 power stations have been proposed in the Plan [table 3 and 4]. All of them are of hybrid types with SPV, Biomass, Wind and battery bank components depending on the suitability for individual locations. Total SPV capacity proposed is about 1.59 MWp while Biomass gasification and Wind are about 1.12 MWe and 20 kW respectively. Total 11275 households would get electricity for at least 8 hours per day from these power plants. In addition, 3200 commercial shops would also get electricity from the same plants. The estimated capital cost requirement is to the tune of Rs. 810 million.

The scattered households within the coverage area, which cannot be connected with the mini-grid lines because of the remoteness, will be provided with solar HLS. About 38934 HLS of 37 Wp would be required to deploy within scattered households involving a total capital expenditure of about Rs . 506 million.

It is proposed to deploy such new power systems in two phases. First phase will be completed within 2007 while second phase will be over by 2008. In the first phase 98 villages will be covered with 78158 households involving 419911 people. Total 25 power plants and 30686 HLS will be deployed involving total capital expenditure of about Rs. 954 million. In the second phase, 27992 households with a population of 152967 will be supplied with access to electricity covering 33 villages. Total 10 power plants along with 8248 HLS would

incur capital expenditure of about Rs. 362 million.

Discussion: In total, 131 villages were proposed to be covered with 47.3 % of total households with the total estimated capital expenditure of about Rs. 1316 million. It is to be noted that the average cost of village electrification is high in this region because of the high population density. There are, on average, 810 households per village in the region.

It is expected that initial capital costs of the projects would come from different grants. Essentially the plants should generate adequate revenue to take care of operational costs like O&M and replacement needs. The tariff values for each plant were proposed accordingly and verified with the willingness of the proposed consumers to pay for the service. The role of pre-paid energy meter would be significant for revenue collection. WBREDA would facilitate the electrification process by owning all of the assets associated with the power plants and guaranteeing a reliable supply of electricity to the consumer. A Village Electricity Cooperative (VEC) will be constituted in each location in consultation with WBREDA. It will consist of all consumers as its members. VEC would look after administration and monitoring of the plants including billing, metering and revenue collection and grievance redress. In this manner, involvement of the local people would ensure the sustainability of the projects through revenue generation.

This is the Master Plan for biggest single initiative of island electrification through renewables in India as far as the number of proposed consumers is concerned. We hope that in the near future Sundarbans will be lit up with renewable based electrical energy.

References:

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Renewable Energy Project	Number	Aggregate Capacity	Benefited Households	Population Covered
Solar Power Plant	13	707 kW	3,450	18,400
Solar Home Lighting System	-	74 W to 35 W per system	35,000	2,00,000
Biomass Gasifier Power Plant	2	1000 kW	1,500	9,000
Wind Diesel Hybrid System	1	510 kW	1,000	5,000
Total			40,950	2,32,400

Table 1: existing initiatives from WBREDA

Item	Capacity	Cost (Rs.)
PV module & accessories	30 kWp	6068700
Inverter & accessories	30 kVA	2183310
Battery bank & accessories	800 Ah, 2VDC, 120 nos.	1008000
Gasifier system	40 kWe	2000000
Gasifier system	20 kWe	1000000
Gasifier system	10 kWe	800000
Overhead Distribution system	LT 3 phase, 4 wire with 25 sq. mm AAC conductor per km	200000
Woody biomass	1 kg	1
Aero generator & accessories	5 kW	750000
Aero generator & accessories	1.5 kW	400000
Service connection per household	Including prepaid energy meter	6000

Table 2: Basic cost assumptions

Sl No.	Name of the village of proposed power plant	No. of estimated consumers	Estimated Annual average electricity demand (kWh/day)	Proposed Power generating components	Initial capital cost requirements (Rs.)	Estimated tariff (Rs./ kWh)	Prevailing tariff with small DG set (Rs/kWh) in markets
1	Jeliakhali Paschim	215	192	60 kWp PV + 10 kWe biomass	25774040	9.64	21
2	Durgamandap	385	318	60 kWp PV + 20 kWe biomass	25768715	6.70	28
3	Purba Radhanagar	580	505	25 kWp PV + 60 kWe biomass	19004236	5.49	Nil
4	Battali	580	490	30 kWp PV + 60 kWe biomass	19626015	5.38	Nil
5	Kachukhali	250	215	50 kWp PV + 10 kWe biomass	22949120	9.43	Nil
6	Kamakshyapur	620	534	40 kWp PV + (40+20) kWe biomass	25345971	6.36	34
7	Amlamethi	650	567	30 kWp PV + 60 kWe biomass	23034005	5.89	34
8	Kumirmari	600	520	30 kWp PV + 60 kWe biomass	25924005	6.12	28
9	Amtali	445	375	45 kWp PV + 40 kWe biomass	24529675	7.13	29

10	Chandipur	280	242	30 kWp PV + 20 kWe biomass	16257995	6.92	33
11	Dayapur	295	283	30 kWp PV + 20 kWe biomass	16281995	6.72	Nil
12	Pakhiralay	215	247	50 kWp PV + 20 kWe biomass	22578866	8.26	Nil
13	Uttar Surendraganj	532	442	50 kWp PV + 40 kWe biomass	27109349	6.33	23
14	Lakshmijanardanpur	155	138	40 kWp PV + 10 kWe biomass	17900686	11.10	29
15	Upendranagar	273	232	50 kWp PV + 20 kWe biomass	22835334	8.45	29
16	Kshetramohanpur	262	224	40 kWp PV + 20 kWe biomass	21672195	9.11	20
17	Shibnagar	180	155	45 kWp PV + 10 kWe biomass	18828380	10.12	25
18	Laxmipur	180	207	50 kWp PV + 10 kWe biomass	22383120	9.54	25
19	Purba Sripatinagar	652	559	30 kWp PV + 60 kWe biomass	20520005	5.29	25
20	Ghoramara	455	385	40 kWp PV + 40 kWe biomass	23952747	6.93	Nil
21	Mahishamari	390	339	90 kWp PV + 20 kW wind	35883557	8.75	25
22	Muriganga	270	235	20 kWp PV + 20 kWe biomass	13403324	7.43	27
23	Gobindapur	370	341	60 kWp PV + 20 kWe biomass	22642695	7.33	37
24	Krishnanagar	450	461	60 kWp PV + 20 kWe biomass	24112695	6.41	21
25	Shibpur	385	348	15 kWp PV + 40 kWe biomass	16881187	6.50	25
Total					555199912		

Table 3: Proposed power plants in Phase I

Sl No.	Name of the village of proposed power plant	No. of estimated consumers	Estimated Annual average electricity demand (kWh/day)	Proposed Power generating components	Initial capital cost requirements (Rs.)	Estimated tariff (Rs./ kWh)	Prevailing tariff with small DG set (Rs/kWh)
1	Satjelia	750	648	25 kWp PV + 80 kWe biomass	24025977	5.79	21
2	Bally	480	417	45 kWp PV + 40 kWe biomass	24849675	6.67	29
3	Brojaballabpur	500	418	50 kWp PV + 40 kWe biomass	28261120	7.25	17
4	Dakshin Kashinagar	503	538	30 kWp PV + 50 kWe biomass	20316005	5.67	28
5	Maheshpur	380	322	25 kWp PV + 30 kWe biomass	15840316	6.76	Nil
6	Chhoto Banashyamnagar	240	207	50 kWp PV + 10 kWe biomass	20083357	8.52	21
7	Achintanagar	312	257	60 kWp PV + 20 kWe biomass	25688005	7.85	21
8	Sumatinagar	420	370	80 kWp PV + 20 kWe biomass	31146034	7.36	23
9	Bishnupur	250	207	45 kWp PV + 20 kWe biomass	21071655	9.30	21
10	Phuldubi	900	720	110 kWp PV + (20+40) kWe biomass	44480042	6.41	22
Total					255762190		

Table 4: Proposed Power Plants in Phase II