Problems in Extending Grid Connection to Remote Islands and Solution through Decentralized Mini Grid

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***Abstract*— Bangladesh is a country who is hardly able to provide sustainable electricity to its inhabitants as its demand for electricity far exceeds the paltry generation capacity. Many of its inhabitants are without any access to electricity. The situation is far worse in remote islands that are not connected to the national grids. The power demand in these islands is usually met up through small diesel generators which are very costly in terms of per unit (KWh) cost. These are also very harmful to the environment as the burning of fuels contributes many harmful gases to the environment. Powering these islands though diesel generators is not at all economically & environmentally feasible. Then there are only two other options available to electrify these islands. One is to extend the national grid to these islands while the other is to install renewable energy based hybrid mini-grid system. The aim of this paper is to investigate both the possibility of supplying electric energy to the Sandwip island. The final optimization of the hybrid system is carried out through Hybrid Optimization Model for Electric Renewables (HOMER) software to find out that whether the system is feasible for proper electrification in the island.**

***Keywords* — Grid extension, Decentralised power, Hybrid System, Renewable energy, HOMER.**

I. Introduction

Electricity is one of the most important factors for a developing country like Bangladesh. Like the rest of the countries of the world, the demand for power is increasing day by day in our country. There are about 30 islands in Bangladesh and these islands are scattered along the Bay of Bengal and the river mouth of Padma. It is extremely difficult and not feasible to extend transmission lines from the main land to these islands due to technical limitations and prohibitive cost. The power demand in these islands is usually met up through small diesel generators which are very costly in terms of per unit (KWh) cost. These are also very harmful to the environment as the burning of fuels contributes many harmful gases to the environment. Besides, the government needs to import the fuel from foreign countries and sell them at subsidised cost. So, the increased fuel consumption is detrimental to our economy as it will be more import dependent. In summary, powering these islands though diesel generators is not at all economically & environmentally feasible. Then there are only two other options available to electrify these islands. One is to extend the national grid to these islands; the other is to install renewable energy dominated mini-grid system that caters to both economical & environmental aspects. Renewable energy based hybrid power systems to the existing diesel based plants will significantly minimize delivery and transport problems and will drastically reduce maintenance and emissions, representing an advantageous and more suitable solution for rural areas. This will help us ensure meeting the needs of the present generation without compromising the ability of future generations to meet their needs.

II. Problems of Grid Extension to Remote Island

The main key variables in determining the cost of grid extension comprising installation of high or medium-voltage lines, substation(s) and a low-voltage distribution- are the size of the load to be electrified, the distance of the load from an existing transmission line, and the type of terrain to be crossed. The extension of national grid generally requires overhead transmission lines or Submarine power cable. But overhead transmission line needs supporting towers and it is very difficult to build tower amid sea or river. Then the other option to connect these islands to centralized grid by submarine power cable has the following problems.

A. Difficulties in laying the cables:

Purpose built ships and barges are required to accurately place cables on or beneath the seabed, guided by the route survey also power cables are much larger than fibre-optic telecom cables; therefore a differently equipped cable ship is required for their installation. Sometimes divers are used to assist installation in shallow water. Figure 1& 2 shows sophisticated mechanism needed to lay submarine power cables.

Fig.1 Bundling power cable for laying [1]

Fig.2 Power cable installation using Hydroplow [2]

B. Difficulties in repairing the cables:

Repair of damaged power cables require specialist ships and cable jointing experts to replace the damaged section with new cable. Completion of a repair can take anything from a few days to a few weeks, depending on the extent of the damage, location of the fault and time it takes to mobilise a suitably equipped ship. A damaged submarine power cable can impact the supply of essential services over a wide area.

C. Electromagnetic fields:

Electromagnetic fields are generated by operational transmission cables. Electric fields increase in strength as voltage increases and may be as strong as 1000 μV per m [3]. Magnetic fields are generated by the flow of current and increase in strength as current increases. Magnetic fields generated by cables may impair the orientation of fish and marine mammals and affect migratory behaviour. Field studies on fish provided first evidence that operating cables change migration and behaviour of marine animals [4]. Marine fish use the earth‘s magnetic field and field anomalies for orientation especially when migrating [5]. Elasmobranch fish can detect magnetic fields which are weak compared to the earth‘s magnetic field [6].

D. Effects of Natural Hazards:

Submarine cables are exposed to a range of natural hazards in all water depths and these include: Submarine earthquakes, Turbidity currents, Tsunami, storm surge and sea level rise, extreme weather (e.g. hurricanes). These hazards can damage the submarine cable and interrupt the power supply.

E. Thermal radiation:

When electric energy is transported, a certain amount gets lost as heat, leading to an increased temperature of the cable surface and subsequent warming of the surrounding environment. There is evidence that various marine organisms react sensitively to an even minor increase in the ambient temperature. For example, the recruitment of eastern populations of Atlantic cod decreases with increasing water temperature [7] and the mortality rates of some intertidal gastropods increases due to rising temperatures [8].

These are the problems inherent in submarine cable power transmission. But many other countries are using submarine cable power transmission to power their remote islands despite this huge environmental impact. Then what‘s wrong with us not considering this as a viable option?

The problem with developing countries like Bangladesh is that we don’t have surplus power like many developed countries who have installed submarine cable power transmission. Moreover, the installation of submarine power cable requires sophisticated mechanism, very good technical expertise & huge capital investment that is simply not possible for a developing country like Bangladesh. Also the experience of Bangladesh is not so good in this case which was seen in Bhola[9]. As we have enough solar radiation & good wind velocity that can be exploited for the installation of Renewable energy based decentralized mini-grids that cater to both environmental & economic aspect, it is certainly the wisest option to invest for new generation capacity from renewable sources.

III. Benefits of Decentralized Power Generation

Though at present most of the countries in the world are following the centralized power generation system, but it causes huge amount of energy loss. Figure 3 shows how centralized infrastructures waste huge amount of energy.

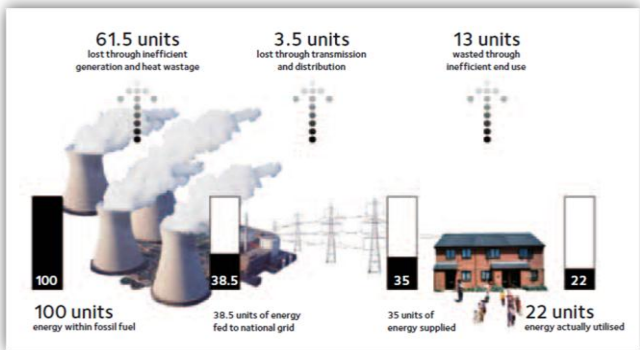


Fig.3 Centralized energy infrastructures waste more than two thirds of the energy available from fossil fuels [9].

So only 22% of primary energy input is eventually used in the home & the rest is lost in the centralized system and wasted through domestic energy inefficiency. It is found that 93% of electricity worldwide is supplied through centralized generation and distribution, resulting in wastage of 67% of primary energy inputs into electricity systems around the globe; energy which, if deployed efficiently, could supply existing world electricity demand nearly twice over [10]. The World Alliance for Decentralized Energy (WADE) has calculated that if the world were, henceforth, to pursue a decentralized approach to the replacement of ageing infrastructure and growth in demand, the projected increase in associated emissions could be almost halved by 2020 [11]. A calculation of associated emission reductions done for Greenpeace by Cambridge applied economist Jonathan Kohler, one of the authors of the Tyndall Centre‘s report, suggests that emissions associated with household energy demand would be cut by two-thirds[12]. Cost associated with power system will also decrease as major costs within the centralized electricity system is that represented by the high-voltage transmission and distribution networks.

IV. Hybrid Power System

Hybrid system is one kind of decentralized power generation system. It is a combination of two or more energy conversion devices (e.g. electricity generators or storage devices). The advantage of hybrid system is that it can capture the best features of each energy resource and can provide grid-quality electricity, with a power range between 1 kilowatt (kW) to several hundred kilowatts.

V. Renewable Energy Scenario of Remote Island (Sandwip Island)

There are number of coastal locations in the Bay of Bengal which are in need of power and also experience both high levels of irradiation and regular wind regimes which might be exploited for wind power. Such islands have no access to the Bangladesh power grid system and mostly dependent on diesel power generation. Sandwip is one of such island which is located at 22°22'-22°34'N and 91°26'-91°34'E[13], where diesel power is in use. Due to its location it has available renewable resources that are discussed below.

A. Solar Energy :

Sandwip is blessed with solar irradiation. Its monthly global Radiation is shown graphically in figure 4 [14].

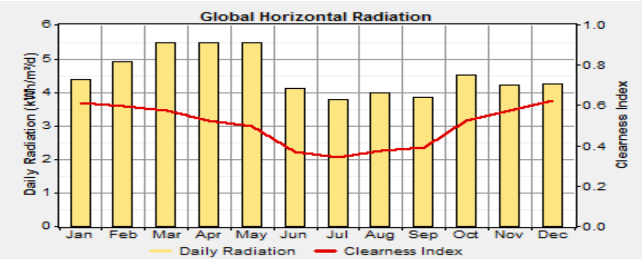


Fig. 4 Solar Radiation variation curve.

B. Wind Energy:

Due to its geographical location Sandwip wind speed vary all the time. Average wind speed is not favorable for wind turbine installation. The wind speed in different months at 50 m height is shown in figure 5 [15].

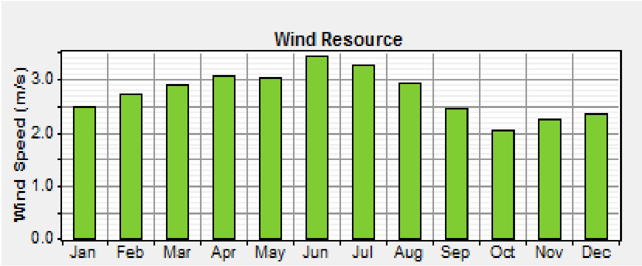


Fig.5 Average wind speed variation.

C. *Biomass Energy:*

Due to it being a rural area the people are accustomed to rearing cattle and chicken. Here people depend on agriculture. Daily domestic waste and seasonal crops (‘Boro’ season spans from November to May, ‘Aus’ season from April to August, ‘Aman’ from July to December.) can be good source of biomass energy. Considering all these fact the biomass resource are shown below in figure 6.

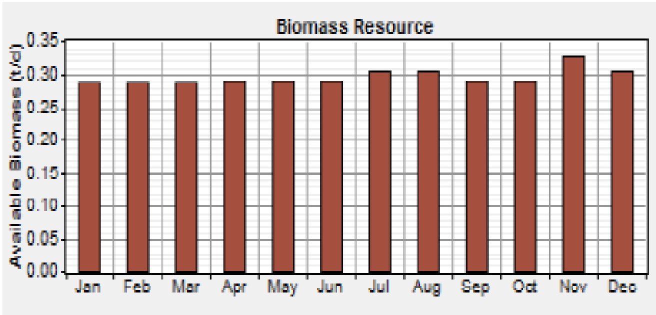


Fig.6 Average collected biomass.

VI. Estimated Load

The evolution of the load can also affect the share of each energy source in the total power supply of the hybrid system. This can affect the payback period as well. Generally a load increase would mean a reduction of renewable energy stored and an increase of renewable energy injected directly to battery, and thus a reduction in storage power. It is important to make the correct load profile as it affects the battery bank size. For our convenience we have consider only home appliance of Rahmatpur village of Sandwip island. We have considered load for 50 homes where light, fan, TV, mobile charger are used. The estimated load profile for the month of April shown in figure 7.

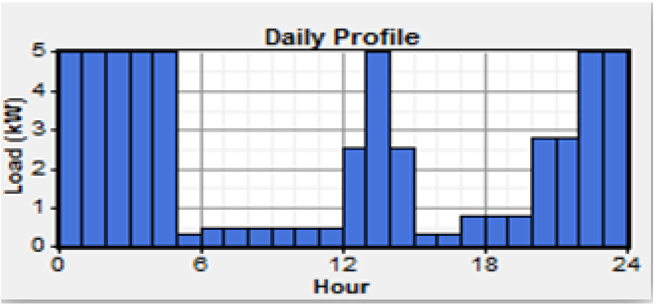


Fig. 7 Load profile for April month.

VII. FEASIBILITY STUDY OF THE HYBRID SYSTEM

HOMER software is used as a tool to carry out the research. The main objective of the research is to assess the feasibility and economic viability of utilizing hybrid PV–Biomass–diesel–battery based standalone power supply system to meet the load requirements of Rahmatpur village of Sandwip Island. A schematic diagram of the standalone hybrid power supply system‘s representation by HOMER is shown in fig.8.

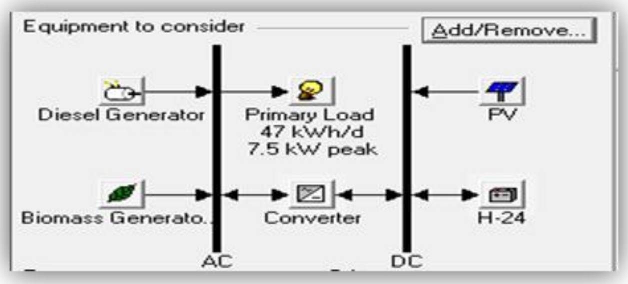
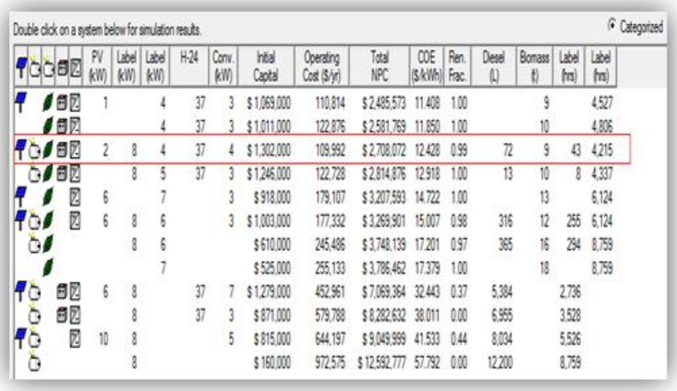


Fig. 8 System architecture using PV, biomass and diesel with battery backup.

VIII. SIMULATION RESULT

After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by Net Present Cost (NPC) that can be used to compare system design options. Optimization result of our proposed design is shown in figure 9.



Double click on a system below for simulation results. Categorized

PV (kW)	Label (kW)	Label (kW)	H-24	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Biomass (t)	Label (hrs)	Label (hrs)
1		4	37	3	$ 1,069,000	110,814	$ 2,485,573	11.408	1.00		9		4,527
		4	37	3	$ 1,011,000	122,876	$ 2,581,769	11.850	1.00		10		4,806
2	8	4	37	4	$ 1,302,000	109,992	$ 2,708,072	12.428	0.99	72	9	43	4,215
	8	5	37	3	$ 1,246,000	122,728	$ 2,814,876	12.918	1.00	13	10	8	4,337
6		7		3	$ 918,000	179,107	$ 3,207,593	14.722	1.00		13		6,124
6	8	6		3	$ 1,003,000	177,332	$ 3,269,901	15.007	0.98	316	12	255	6,124
	8	6			$ 610,000	245,486	$ 3,748,139	17.201	0.97	365	16	294	8,759
		7			$ 525,000	255,133	$ 3,786,462	17.379	1.00		18		8,759
6	8		37	7	$ 1,279,000	452,961	$ 7,069,364	32.443	0.37	5,384		2,736	
	8		37	3	$ 871,000	579,788	$ 8,282,632	38.011	0.00	6,955		3,528	
10	8			5	$ 815,000	644,197	$ 9,049,999	41.533	0.44	8,034		5,526	
	8				$ 160,000	972,575	$ 12,592,777	57.792	0.00	12,200		8,759	

Fig. 9 Optimized result for PV, biomass and diesel hybrid system.

In this case the demand is supplied by diesel generator, biomass generator PV with battery backup, and for conversion converter is also used. Among all the optimized result we have chosen the third combination. Though in case of first combination the cost of energy is least but as all energy from renewable sources, so system may be unbalance and may be blackout in bad weather. So considering this third combination is the best one, as diesel generator is used here for backup purpose and it may supply the load at bad weather when power from renewable energy sources less. Cost of energy is 12.428Tk.which is favorable for that locality (table-1).

TABLE I
COST COMPARISON OF DIFFERENT CONFIGURATIONS

System configuration	Initial cost(Tk.)	Operating cost(Tk.)	Cost of energy (Tk./kWh)
Diesel only	160,000	972,575	57.79
Diesel + Battery	871,000	574,287	38.26
PV + Battery	5,190,000	215,85	36.49
PV+ Battery+ Diesel	936,000	443,673	30.79
PV + Battery+ Diesel+ Biomass	1,302,000	109,992	12.43

The cost of energy now decreased drastically among all other combination, since renewable energy from all available sources is utilized. About 99% energy from renewable energy sources are supplying the load. But initial cost is 1,302,000Tk.which is huge but this cost may be offset by less cost of energy.

The contribution of power from different sources is shown graphically in fig.10.

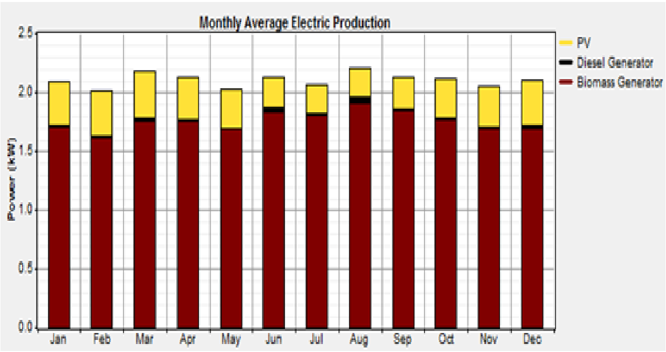


Fig. 10 Monthly average electricity production from different source.

IX. CONCLUSION

Reaching the non-electrified rural population is currently not possible through the extension of the grid, since the connection is neither economically feasible, nor encouraged by the main actors. Further, the increases in oil prices and the unbearable impacts of this energy source on the users and on the environment, are slowly removing conventional energy solutions, such as fuel generator set based systems, from the rural development agendas. Therefore, infrastructure investments in rural areas have to be approached with cost competitive, reliable and efficient tools in order to provide a sustainable access to electricity and to stimulate development. Hybrid systems have proved to be the best option to deliver high quality community energy services to rural areas at the lowest economic cost, and with maximum social and environmental benefits. Indeed, by choosing renewable energy, developing countries can stabilize their CO_2 emissions while increasing consumption through economic growth. Due to least per unit cost of electricity is in case of renewable energy based electricity generation, our policy maker can implement such kind of decentralized mini grid in island as well as other remote localities. Recently 3G mobile internet has been introduced in our country that requires constant power supply in the towers. Mini-grid can provide a good solution to this.

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