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Optimizing Distributed Energy Resources: Strategies for Electrical Network Optimization

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Abstract

When it comes to Bangladesh's economic growth and development, the energy issue is a big concern. The disparity between the supply and demand for electricity is widening daily. Additionally, there is a possibility that most power plants may be phased out in the future since they rely on fossil fuels. Distributed energy resources (DER) are the primary emphasis of this article as it seeks to address these issues by regulating the smart environment's power supply and demand. The majority of the DER system is made up of power stations that make use of renewable energy sources (RES). Since RES are sporadic, the final model included backup from fossil fuel-based facilities to make the system more reliable. During off-peak hours, the planned storage structure will be used to store RES leftover energy. In the planned smart bidirectional network, Proactive demand-side customers, or consumers, would be able to sell this energy that they have conserved to the national grid at peak hours. It is believed that the prosumer would have more leeway to manage their energy use and expenses now that an enhanced control mechanism and grid monitoring and metering interface have been built.

Keywords: solar; wind; biomass; smart-grid; smart-meter

I. Introduction

Due to dwindling supplies of raw materials, the global energy crisis is becoming worse by the day. As a result, scientists are trying to find new ways to power our homes and businesses. Potentially useful for future bottom-up electrical system transitions from top-down ones are renewable energy sources (RES). Solar, wind, and biomass power plants are examples of renewable energy sources that can be used to supply electricity to homes and businesses in both grid-connected and non-grid areas [1, 2].

The client may encounter challenges in demand-side system monitoring in a RES-based smart grid due to the complex ICT integrated environment. Here, a smart meter may be installed to make the smart grid more user-friendly [3].

The goal of this project is to create a smart grid system for a community in Bangladesh's offshore areas. The main subjects of this article are the design and study of the national grid, which is linked to a small hamlet in the Bangladeshi city of Chittagong. It is now possible to use a simulation-based model to optimise the local power supply and demand of a small-scale power system. Using HOMER Legacy (2.68 Beta), easily accessible meteorological and technical data are used to illustrate the smart grid. A MATLAB-based model and a GUI-based smart metre named "sMeter_v2015a" were developed following the HOMER prototype concept.

Ii. A Smart Grid's Analysis

An electrical network that can track and regulate the flow of power from all production sources and adapt to changing customer requirements is referred to as a "smart grid." The demands and capacities of all players in the energy market, including generators, grid operators, end-users, and the electricity market itself, are coordinated by smart grids in order to maximize system dependability, resilience, and stability while simultaneously reducing costs and the negative effects on the environment. Due to factors like preexisting technology, regulatory frameworks, and investment frameworks, the deployment rates of smart grids, which are a collection of emerging technologies, will vary across various environments and contexts [4].

An intelligent grid is one that can integrate various energy sources and is autonomous in its balancing and monitoring processes. In order to maintain a steady flow of electricity, smart grids can respond to changes in demand and include new technology that might make energy storage devices possible [5].

It would be easy to mistake a smart meter for a regular water, gas, or electricity meter installed in a home or company. Metrology is provided by both smart and classic meters, which convey data to the utility company about voltage, current, pressure, velocity, temperature, and flow rate. As a result, grid-wide advancements and new technology may be more easily integrated [6]. An intelligent meter has the potential to improve the smart grid. In response to data collected in real-time, smart meters may provide prosumers with statistical information.

Iii. Model Architecture

Three primary renewable energy sources—solar photovoltaics (PV), wind, and biomass—were used prior to smart grid modeling. The system is built with a 30-unit complex in mind. In order to calculate the load, we have assumed that each apartment has eight lights, four fans, one TV, one freezer, three laptops, one iron, one blender, and one pump. Two lights and one fan are considered fixed loads per apartment, whereas all other loads for household appliances are considered variable loads. The device in question is a converter, which serves dual purposes as an inverter and rectifier. To store the excess energy generated by the grid and release it when it is required, a battery is used as the storage mechanism. Figure 1 is a schematic of the smart grid that incorporates energy storage and monitoring into its architecture. Two kinds of load are used in conjunction with three resources: a bidirectional converter and a battery for storage [7], [8].

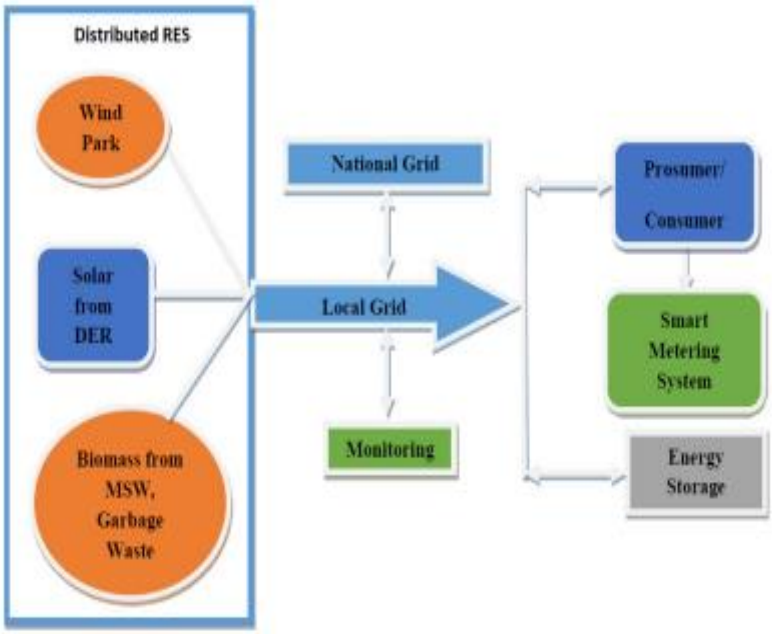

Fig 1 Block diagram of the proposed smart grid.

First things first: When the design is finished, run the simulations in HOMER Legacy (2.68 beta). Prior research serves as the foundation for research on biomass, and the NASA surface meteorology and solar energy website provides statistics on solar and wind energy [9]. Common utility forms are used for the load estimations. Optimization of both power generation and consumption and maintenance of a steady state are primary goals of the HOMER-based study. In Figure 2, we can see the model being applied by HOMER.

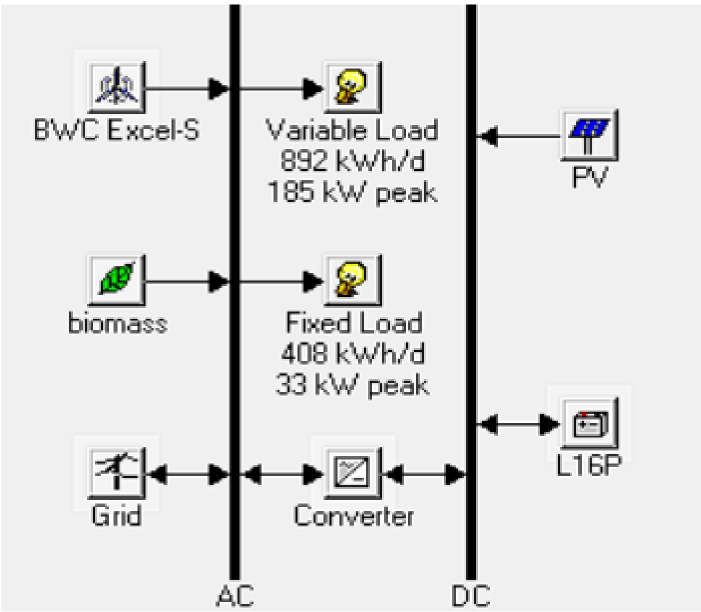

Fig 2 HOMER implementation of the smart grid.

We use MATLAB to do further analyses on the defined model. A smart meter simulation model that is easy to use is then created using the GUI. The "sMeter_v2015a" GUI model can display total consumption, production, sales, and purchases based on real-time data. It was built with input from time data variables. The user can easily change the time and see the result in real time because of this. A rough estimate of the amount of power that can be stored or delivered will also be provided to the user.

Iv. Gathering Data

Data collecting for various RES and equipment is detailed in this section. In order to conduct precise simulations, executable data was collected from several sources. Model construction primarily makes use of three forms of renewable energy: solar, wind, and biomass [9, 10], [11]. Figure 3 shows the matching graph to Table I, which displays data on Chittagong city's solar resources.

Table I. CHITAGONG CITY'S DAILY AVAILABLE SOLAR RAYS

Month	Daily Radiation ($KWh/m^2/day$)	Clearance Index
Jan	4.404	0.626
Feb	4.912	0.606
Mar	5.637	0.599
Apr	5.786	0.553
May	5.706	0.519
Jun	4.242	0.381
Jul	3.817	0.346
Aug	4.038	0.380
Sep	4.022	0.413
Oct	4.776	0.564
Nov	4.346	0.599
Dec	4.293	0.643

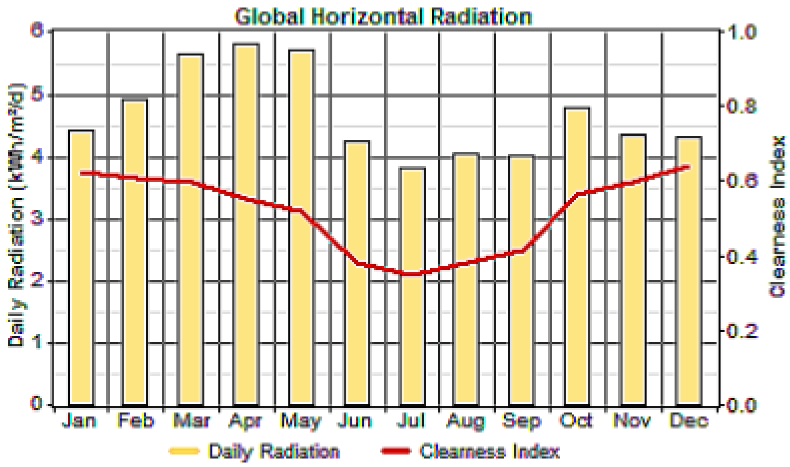

Fig 3 Solar data resources for Chittagong City (Latitude 22.3667°N /Longitude 91.8000° E)

Figure 4 and Table II, respectively, display the data and graphs for wind resources.

TABLE 2: Chittagong City's wind speed

Month	Wind Speed (m/s)
Jan	4.900
Feb	5.100
Mar	7.600
Apr	7.800
May	8.200
Jun	7.600
Jul	8.100
Aug	7.400
Sep	6.900
Oct	6.400
Nov	5.600
Dec	5.100

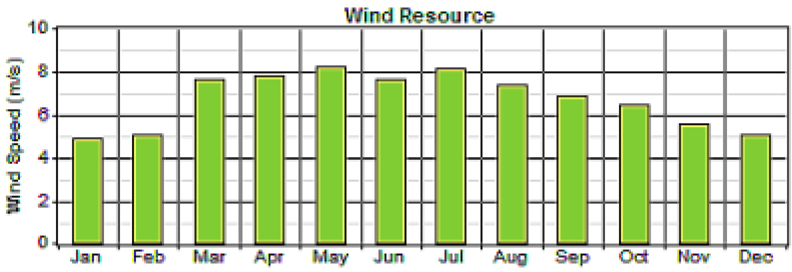

Fig 4 Daily Wind Speed Variations

Both Table III and Figure 5 provide data about biomass resources, with Figure 5 providing visual representations of the same.

TABLE III. BIOMASS DATA FOR CHITTAGONG CITY

Month	Available biomass (tonnes/day)
Jan	4.000
Feb	4.000
Mar	4.000
Apr	4.000
May	4.000
Jun	4.000
Jul	4.000
Aug	4.000
Sep	4.000
Oct	4.000
Nov	4.000
Dec	4.000

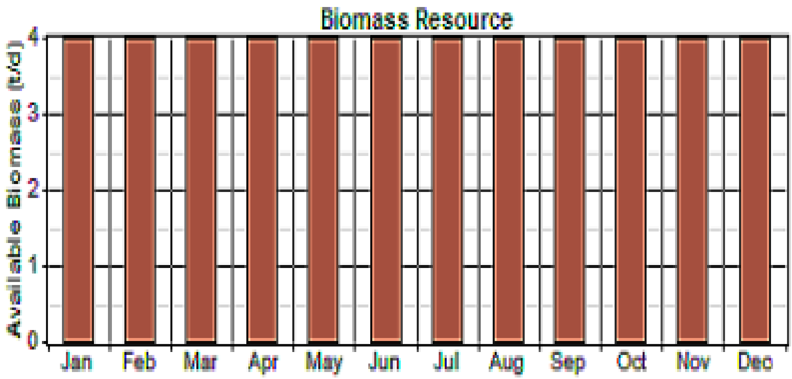

Fig 5 Available biomass resources

V. Simulation And Analysis

A. Utilizing HOMER Legacy in Simulations (2.68 beta)

The smart grid model implementation by HOMER is shown in Figure 2, as indicated in Section III. The DC grid is used by photovoltaic cells, or PV, whereas the AC grid is used by wind and biomass resources. The graphic depicts a biogas generator with a wind turbine. The biogas generator uses biogas as fuel and the wind turbine is a BWC Excel-S. The device in question is a bidirectional converter, which has dual functionality as an inverter and rectifier. A Trojan L16P battery serves as the system's storage component when linked to a DC grid; it can both receive and transmit excess grid energy. There is a connection between fixed loads and variable loads. The AC grid is connected to both loads [12]. The annual production of PV is shown in Figure 6. The annual output of the wind turbine is shown in Figure 7. Figure 8 depicts the production of biomass annually.

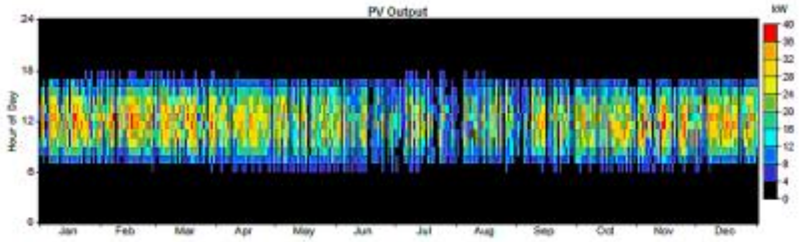

Fig 6 Solar Output

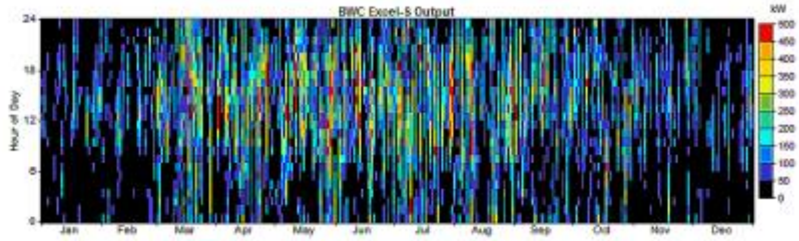

Fig 7 Wind Output

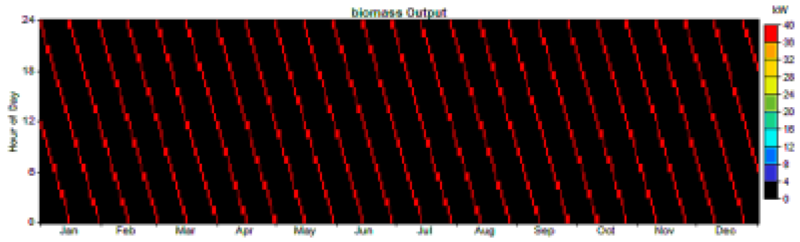

Fig 8 Biomass Output

Power consumption and output are both generated by Homer. Table V displays the rates of electrical consumption, while Table IV displays the rates of electrical production. The output of this combination in terms of electrical power is seen in Figure 9.

TABLE IV. ELECTRICAL PRODUCTION

Production	KWh/yr.	%
Photovoltaic array	59,172	6
Wind Turbines	690,829	72
Biogas Generator	30,160	3
Grid purchases	178,712	19
Total	958,873	100

TABLE V. ELECTRICAL CONSUMPTION

Consumption	KWh/yr.	%
AC Load	474,500	50
Grid Sales	478,457	50
Total	952,957	100

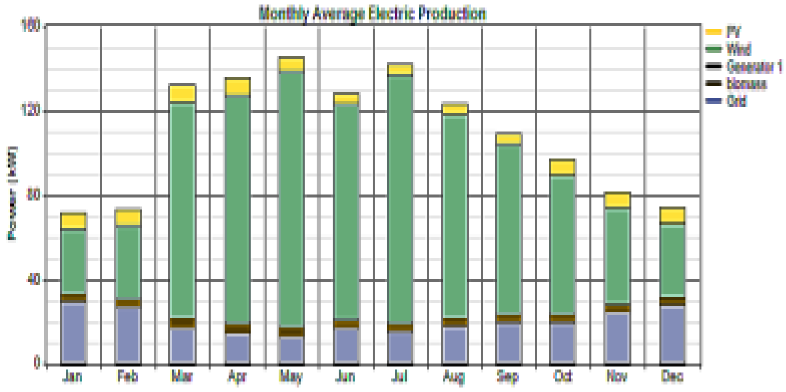

Fig 9 Monthly Average Electrical Production

A total of 958,873 kWh/yr is produced by the planned smart grid, with a consumption of 952,957 kWh/yr. 478,457 kWh/yr of storage capacity is available in the system. The system suffers a cumulative annualized loss of 5,916 KWh. Figure 10 depicts the cost analysis's Net Present Cost (NPC).

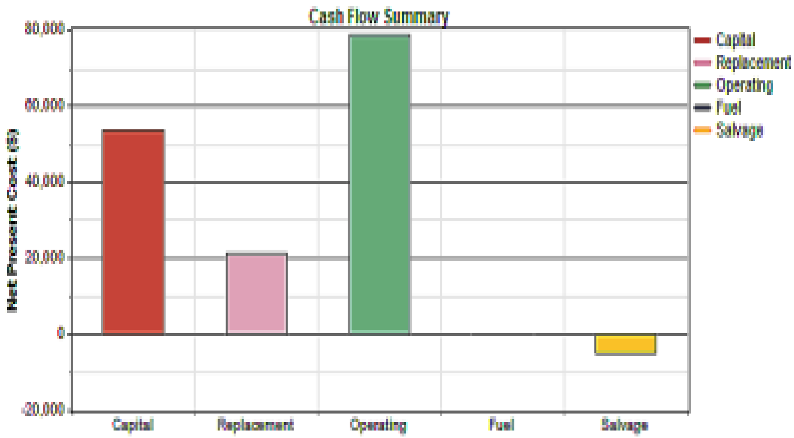

Fig 10 Net Present Cost

When 40 KW of PV, 40 BWC Excel-S wind turbines, a 40 KW biogas generator, 1 Trojan L16P battery, and a 218 KW inverter that also functions as a 218 KW rectifier are taken into account, the system's Net Present Value comes to $148,909. The yearly running cost of the unit is $7,438 and its production cost is $0.012/KWh.

B. Smart-Meter Simulations in MATLAB with a Graphical User Interface

The suggested smart grid now features a MATLAB-based smart meter model to make the system more user-friendly. Matlab was used to program the first interaction mechanism. We then built the'sMeter_v2015a' model, which is GUI oriented. In Figure 8, we can see the model in action using the data we have for the city of Chittagong in Bangladesh. A user may insert variable data on the top pane. The graphical user interface's right figure shows the total production, total consumption, and based on real-time data, total sales and purchases, total output from solar and wind, and total biomass. Figure 11 displays the'sMeter_v2015a' example. To help prosumers make informed decisions, the software model'sMeter_v2015a' displays real-time statistics on sales and purchases. The output screen will also show the user the load fluctuation during the day.

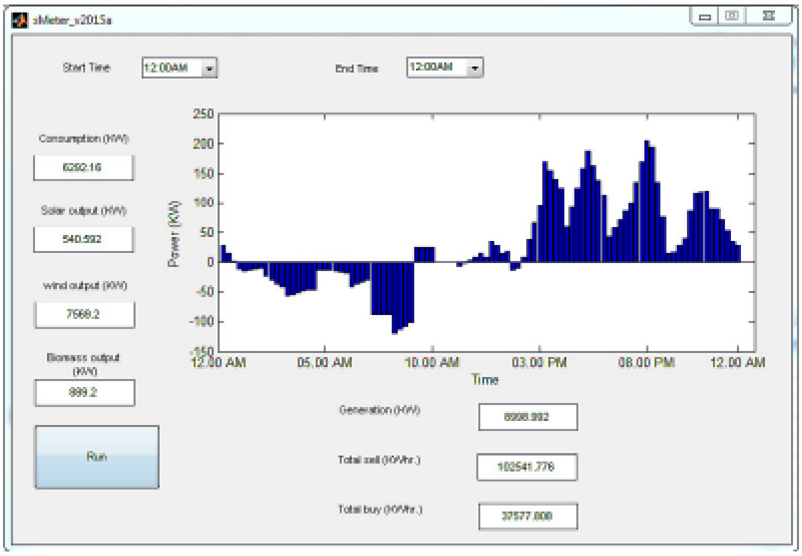

Fig 11 Demonstration of 'sMeter_v2015a'

VI. Conclusion

With the help of HOMER Legacy (2.68 Beta), we were able to accurately simulate the smart grid that runs on renewable energy sources including solar, wind, and biomass. Through the use of HOMER Legacy software, various component combinations are tested and evaluated. Finally, the system will make use of a Trojan L16P battery, 40 KW of photovoltaic (PV), 40 KW of biogas (Gas Generator), and a 218 KW inverter that also serves as a rectifier for a total of 218 KW. The net present value of each unit is $148,909, with a production COE of $0.012/KWh and an annual operating cost of $7,438. The suggested approach makes use of MATLAB to program a smart meter. An application called "sMeter_v2015a" was developed with the help of the MATLAB GUI editor. Based on real-time data provided by time-related variables, the model can be used to display total consumption, production, sales, and purchases. Bangladesh's small supply-demand balancing issue can be resolved by means of this kind of smart grid-based power plant. Additional weather and RES data ought to be taken into consideration for a longer-term investigation. One improved method for coordinating local electricity supply and demand is an agent-based model for consumer interaction [13]. Additional off-grid and semi-off-grid areas in Bangladesh ought to be investigated as well.

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