DESIGN AND ANALYSIS OF A HYBRID POWER SYSTEM FOR ST. BRENDAN'S, NL.

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***Abstract*— The village of St. Brendan's, which formerly went by the name of Shoal Cove, is located in Bonavista Bay on Cottel Island in Newfoundland and Labrador, Canada. This community is cut out from a significant part of the province and must use a ferry to bring in the necessary resources to function correctly. One of the resources brought in is diesel used in operating the power plant to generate power for the community. When we combine the diesel consumed by the commercial ferry and the diesel consumed by the power plant, we know that this poses an expensive task and is detrimental to achieving the net zero goals. Proper use of renewable energy sources, particularly solar panels and wind turbines with diesel generators, could reduce diesel use. This paper will propose a site and an on-ground hybrid system will be designed and analyzed using Homer pro to help reduce the diesel consumption rate in the St. Brendan's, NL, Canada community.**

I. INTRODUCTION

The leading causes of the rising energy demand are the expanding global population and the advancement of industrialization[1]. The traditional power generation methods involve non-renewable resources like oil, coal, and gas. However, employing these methods contributes to increased dangerous emissions for the environment. Fossil fuel consumption has detrimental repercussions, including air and coastal pollution, biodiversity loss, and general degradation[2]. These problems push countries to explore alternate energy options. To limit the use of conventional energy sources, which reduces emissions, researchers, environmentalists, and policymakers worldwide are now looking for alternative renewable energy solutions [3].

Using renewable energy to meet energy demand has a lot of promise. Systems to reduce global warming and carbon emissions should be implemented since conserving natural resources should be the top priority. The country will cut costs by transitioning to renewable sources rather than coal or other fossil fuels to produce electricity. Utilizing this renewable resource to generate energy is projected to reduce CO2 emissions.[4]. As previously mentioned, various renewable energy sources exist, but wind and solar energy are more popular. Even with their popularity and abundance, when we discuss environmentally friendly power sources, these are the primary things that ring a bell. Due to climate change, longer days than the night, which involves more sunlight, the monsoon season, and fluctuations in wind speed, single power sources like wind and PV are not entirely dependable[5].

Although solar and wind energy are frequently used independently to produce power, both have disadvantages. Climate change impacts these systems as it does on our environment every day. Wind speed and solar radiation changes can affect how effective these systems are. Integrating them into a hybrid approach can decrease the costs necessary for a single system. As a result, rather than relying on a single system, the combination of solar and wind energy will help each other in reducing losses. Like when a solar PV system generates power and a wind turbine system draws energy from a wind source during the sunshine hour. When wind conditions are insufficient to generate electricity, a backup generator powered by the solar system will be available to meet the load demand. Many researchers have used various combinations to improve the comfort of the hybrid wind-solar system. In addition to using wind-solar hybrid systems, they also deployed wind-diesel-PV, wind-diesel, and diesel-PV hybrid systems[6].

II. LITERATURE REVIEW

Many research papers on developing and using environmentally friendly energy are written about in the literature. Modern, highly efficient solar PV modules have helped solar energy become the most widely used form of electrical power. Solar PV modules are now commonly used in telecommunication towers in off-grid areas and solar home systems in poor nations [7], [8]. Additionally, solar PV modules have been used to electrify various locations worldwide.

To reach the electrical power requirements as well as support the financial costs of a medium-sized hotel on Kish Island, Iran, Fazelpour et al. [9] demonstrated in 2014 that a wind-diesel-battery hybrid system is the most viable option among photovoltaic (PV)-diesel-battery, PV-wind-diesel-battery, and wind-diesel-battery systems. A 600 kW diesel engine, five conventional 20 kW wind turbines, and 35 batteries make up the system, with a cost of energy of US$0.318/kWh and a total net present cost (NPC) of US$7,236,000. Rahimi et al.[10] They have recommended using a hybrid system to save and conserve excess energy like hydrogen. Based on solar radiation levels and fuel cost in a remote Malaysian area, Lau et al. juxtaposed a PV-diesel-battery hybrid system to a solo diesel. They found out that it had much lesser values of NPC and COE[11].

A. Wind Island

As stated earlier, the village of St. Brendan's, formerly Shoal Cove, is located in Bonavista Bay on Cottel Island in Newfoundland and Labrador, Canada (Figure 1). Most people reside in the northern portion of Cottel Island, as depicted in Figure 2. The study's fundamental statistics are listed in Table 1. Fishing, seal hunting, and construction were the primary early businesses on Cottel Island. Early in the 1950s, the fishery collapsed, which caused the population to decrease.

Nevertheless, despite the high expense of living, the community has persisted. Three manually operated diesel generators comprise St. Brendan's current electrical power system. The wind resources on Cottel Island are excellent. Since 2010, the wind speed in Bonavista (Latitude: 48°40'02.000" N, Longitude: 53°06'51.000" W, Elevation: 25.6 m), which is close by, has been measured. The yearly average wind speed there is 9.07 m/s at a height of 10 m[12]. Although there aren't any complete wind data for St. Brendan's, the average yearly wind speed was calculated to be 8.6 m/s after consulting with AWTS and using data from the Atmospheric Environment Service. According to calculations made using the straightforward model for the vertical wind speed profile with a power law exponent of 1/7 [13], this number extrapolates to 9.7 m/s at 25 m height (hub height of a typical 50 kW wind turbine). In essence, this is the same as the value of 10 meters in Bonavista in 2010.

Table 1: Statistics about St. Brendan's Island

Data of St. Brendan's Community	
Population in 2021	125
Population in 2016	145
Land Area of Cottel Island	9.76km2
Number of Private dwellings	122
Average Annual Wind Speed	8.6 m/s at 10m (estimated)
Current Generation	Installed Diesel Capacity of 712 kW (210 kW + 225 kW + 277 kW)
Diesel Price Subsidized	CD$1.90/Liter (2023)

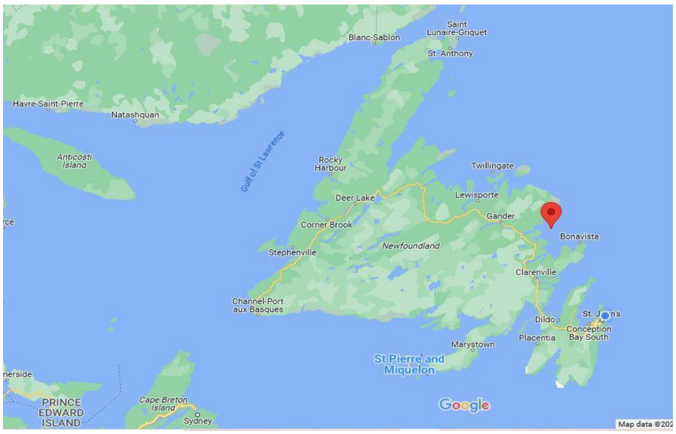

Figure 1: Location of St. Brendan's on the map of Newfoundland and Labrador

Figure 2 represents Bonavista's monthly average wind speed distribution from 1981 to 2010, with January (11.28 m/s) being the windiest and July (7.08 m/s) being the least breezy. The peak wind speed anticipated each hour is around 27 m/s at a height of 25 m. At Bonavista, the highest wind gust recorded was 47 m/s [12]. A typical wind turbine's survival wind speed is typically 70 m/s, whereas the cut-out wind speed is 25 m/s. As a result, the high wind speeds in St Brendan's and Bonavista fall within the typical operating range of most wind turbines. The wind turbine may be shut down for one or two hours within a whole year because of higher-than-normal wind speed, but apart from that, it will continue to produce power above the cut-in wind speed.

In conclusion, (a) the population on Cottel Island is dispersed, and the land is nearly flat, (b) basic infrastructure for the construction of wind turbines and solar PV panels is already in place, (c) suitable turbine sites are available, and (d) as a result, the region is very attractive for hybrid (wind/diesel & solar) opportunity.

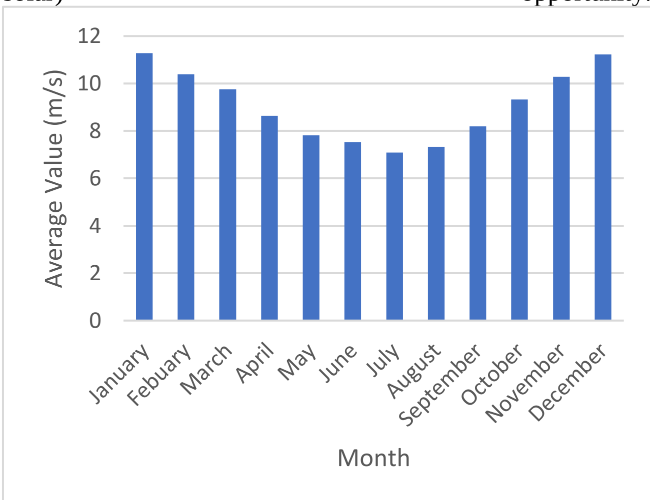

Figure 2: Monthly Wind Average Speed in 2023

III. Present Energy Supply Status and Options

Three manually controlled diesel-powered generators (210 kW, 225 Kw, and 277 Kw), run by Newfoundland Hydro, comprise the current power system in St. Brendan. Data on St. Brendan's electricity usage from January 2020 to April 2022 were gathered from Newfoundland Hydro. The only years a complete set was accessible were 2020 and 2021. With a yearly average electricity consumption of 2781.01 kWh/day, the peak load is roughly 250 kW. According to fuel usage records, the diesel gensets at St. Brendan's typically produce 3.3 kWh per litre of fuel. The Hybrid Optimization of Multiple Energy Resources (HOMER) programme is used to size and optimize the system. A PV, Wind, Battery hybrid system is proposed based on the available resources. Here, the load is an AC load. The suggested hybrid system's HOMER pro model is shown in Figure 3, and the system's expenses and components are listed in Table 2. The parts have a USD price. Our technology uses wind turbines and solar panels as renewable energy producers. Due to the unpredictability and irregularity of renewable energy sources, we also have batteries to store power. Renewable energy sources are used to recharge these batteries. The monthly average load profile for St. Brendan's is depicted in Figure 3. The typical daily load profile for St. Brendan's, Newfoundland, is shown in Figure 4. Power usage peaks in December and troughs in June and July.

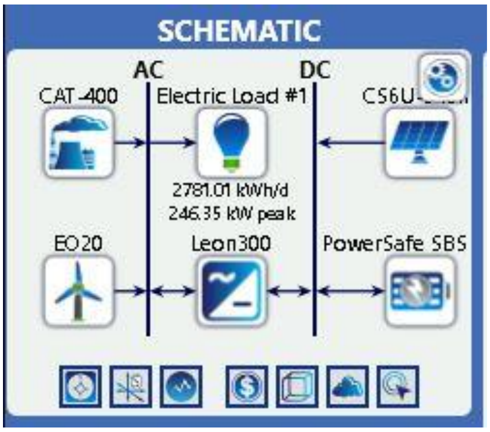

Figure 3: System Schematic on Homer Pro

Table 2: System Components and Costs

Architecture/CS6U-340M (kW)	57.96
Architecture/EO20	3
Architecture/CAT-400 (kW)	320
Architecture/PowerSafe SBS 1500	30
Architecture/Leon300 (kW)	7.71
Architecture/Dispatch	LF
Cost/NPC ($)	8647811
Cost/COE ($)	0.659015
Cost/Operating cost ($/yr)	528880.8
Cost/Initial capital ($)	1810695
System/Ren Frac (%)	23.56
System/Total Fuel (L/yr)	237408.7
CAT-400/Hours	8760
CAT-400/Production (kWh)	775955.2
CAT-400/Fuel (L)	237408.7
CAT-400/O&M Cost ($/yr)	131400
CAT-400/Fuel Cost ($/yr)	384602.1
CS6U-340M/Capital Cost ($)	85232.84
CS6U-340M/Production (kWh/yr)	72575.8
EO20/Capital Cost ($)	411600
EO20/Production (kWh/yr)	320838.7
EO20/O&M Cost ($)	450
PowerSafe SBS 1500/Autonomy (hr)	3.02
PowerSafe SBS 1500/Annual Throughput (kWh/yr)	18538.47
PowerSafe SBS 1500/Operating hours (hours)	0
PowerSafe SBS 1500/Nominal Capacity (kWh)	500.519
PowerSafe SBS 1500/Usable Nominal Capacity (kWh)	350.363
Leon300/Rectifier Mean Output (kW)	0.860
Leon300/Inverter Mean Output (kW)	3.275

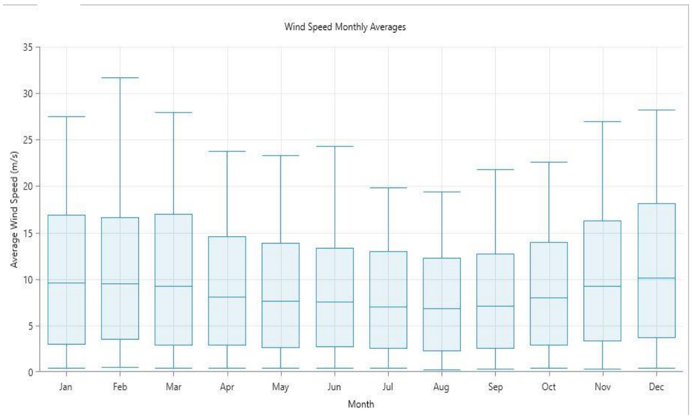

Figure 4: Monthly Average Load Profile in St. Brendan's, NL For The Year 2021

Presently, as the world moves to tackle the problem of climate change and the adverse environmental effects of fossil fuels, it is essential to develop more renewable technologies. The most effective, clean alternative to fossil fuels for supplying energy to communities is energy production from renewable sources. The amount of energy that a power system can use is the primary consideration when choosing between solar and wind energy. In this sense, a PV system certainly cannot create as much energy during the night, on cloudy days, or in the winter, limiting the quantity of energy produced [14], [15]. Additionally, wind turbines can only produce energy with significant wind speed. When using electricity from wind turbines, the power system can produce considerable amounts of energy at certain times and insufficient amounts of energy at other times because the wind speed varies throughout the year. There are distinct peak hours for the Production of solar and wind energy. Therefore, these hybrid systems' asynchronous nature makes them more ideal and reliable power systems to generate the required electricity [16]. Furthermore, a battery energy storage system will be used when solar and wind energy cannot be accessed. The batteries must be sufficiently sized to supply enough power when not charged.

IV. Dynamic Modeling in MATLAB

Research relies heavily on electrical dynamic modelling, which explains how a system functions in the real world. We could better comprehend how a PV system would operate and adapt to environmental changes if we had a dynamic model of the system. We may simulate the system under different scenarios that an electric vehicle must work under with the aid of our dynamic model. For the hybrid system, our renewable energy sources include solar panels and wind turbines. The model employs a grid-connected PV and wind energy system. PV system consists of a photovoltaic array generating 100 kW of power by connecting 15 series and 11 parallel connected modules. The wind energy system uses an induction generator-based wind turbine generating 60 kW of electrical power, which is supplied to the 600 V transmission line through a step-up transformer. If renewable resources cannot power the load, a diesel generator is deployed. Figure 5 displays the intended system's MATLAB/Simulink model.

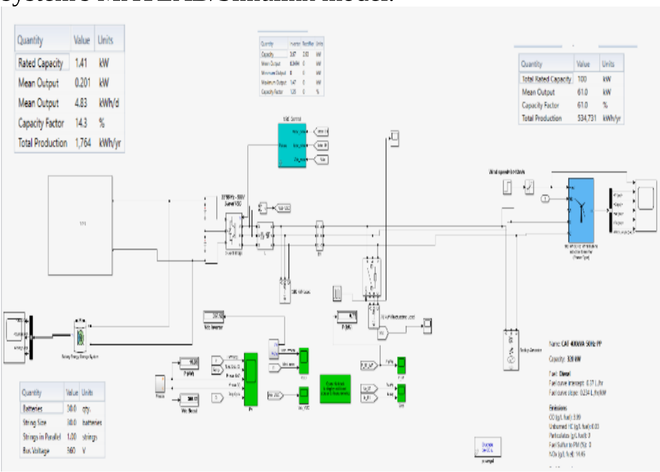

Figure 5: System Design in MATLAB/Simulink

Three energy sources make up the intended model:

1. PV modules for solar energy harvesting
2. Wind turbines use the wind for energy
3. A traditional energy source, such as a generator powered by diesel

The DC bus connects the PV modules, and the operational voltage is 800V. The purpose of the batteries is to serve as a storage medium, providing the load with consistent power. A converter connects the solar module to the DC bus. The ac bus is linked to the wind turbine. A converter connects the wind turbine subsystem and can be classified as the output to connect to the DC bus and charge the battery. The load is connected to the diesel generator. An MMPT controller is used to operate the solar panel. The PLL algorithm is intended to be implemented by the MPPT controller.

V. Simulation Results

The MATLAB/Simulink simulation results are covered in this section. To provide a steady and intended voltage of 600V for the DC bus, the PV panel is linked to a DC buck converter circuit managed by the MPPT-PLL algorithm control for charge management.

PV panels are connected to the batteries in this way. The simulation allows for observing the current change as the load varies dynamically and the recent rises and falls in response to the load reduction.

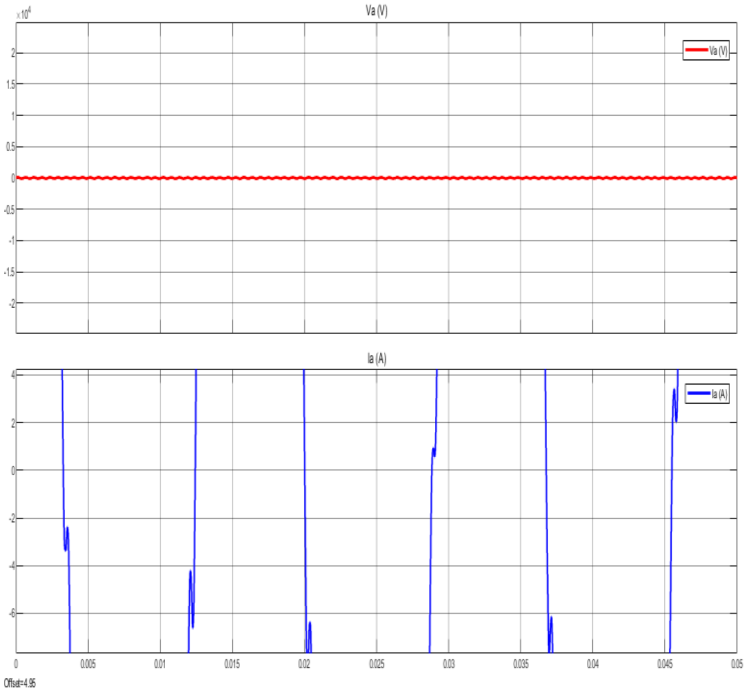

Figure 6: Grid Plots

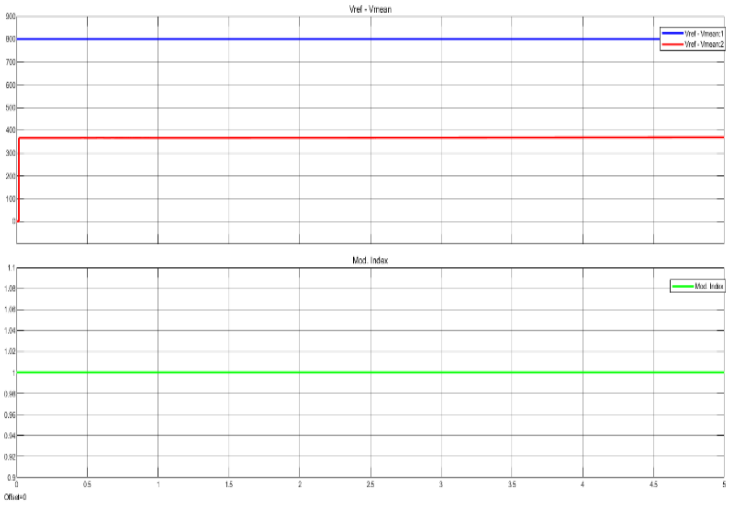

Figure 7: VSC Plot

VI. Conclusion

To provide the Island of St. Brendan's in Newfoundland and Labrador with reasonably priced electricity, this study has looked at a hybrid power generation system that combines solar panels, wind turbines, diesel generators with battery banks, and inverter units. One optimization and simulation tool employed is the HOMER simulation programme. The PV/wind/diesel hybrid system with battery storage was selected from a wide range of solutions based on the results analysis and some important variables, such as a high penetration of renewable energy sources, a low annual diesel consumption, and a low Leveled energy cost. Following the HOMER study, MATLAB/Simulink was used to simulate the hybrid system dynamically. The dynamic model comprised wind turbines and solar panels that utilized MPPT to produce the most significant amount of power. Due to the system's dynamic model, we could completely understand the system's operation in various modes, settings, and scenarios, as well as how it will react to changes in external parameters such as temperature and irradiance.

VII. REFERANCES

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