Assessment of Carbon Credits for Power Generation Systems at GSM Base Station Site

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Received: 16.08.2013 Accepted:14.10.2013

Abstract- Electricity production is often a source of CO2 emissions, for instance when fossil fuel is combusted in power plants. Therefore the root cause of pollution coming from telecommunication industry is the source of energy (diesel genset) the network operators used in running their Base station sites. Energy consumption of using diesel to power base station by telecom networks is a contributor to global greenhouse gas (GHG) emissions. This paper presents the comparative carbon credits of hybrid (PV/wind/hydro/Diesel) power systems for base station site. The assessment is based on theoretical model of the power stations using Hybrid Optimization Model for Electric Renewables (HOMER) software. The proposed Hybrid (Solar, Wind & Hydro) + DG system was simulated using the model which results in eight different topologies: Hybrid (Solar, Wind & Hydro) + DG, Hybrid (Solar & Hydro) + DG, Hybrid (Wind & Hydro) + DG, Hydro only + DG, Hybrid (Solar & Wind) + DG, Solar only + DG, Wind only + DG, DG. From the simulation results, it is shown that the designed Hybrid PV/wind/hydro/Diesel system has the highest carbon credits of $14509.16 relative to the case of a diesel-only system of zero. Details of the comparisons are presented.

Keywords: Greenhouse Gas (GHG), Carbon Credits, Global warming, Climate Change, Nigeria.

1. Introduction

Greenhouse gas (GHG) emissions have been identified as a major driver of changes to the climate, and human activity has been identified as the probable cause of rising GHG emissions, particularly carbon dioxide (CO2) emissions. If climate change results from rising greenhouse gas emissions that are mostly attributable to human activity, then cutting greenhouse gas emissions will require that humans make changes to these activities [1]. Carbon credits are a key component of national and international attempts to mitigate the growth in concentrations of greenhouse gases (GHGs). If the alternative is to use fossil fuels, renewable energy projects reduce GHG emissions and therefore can generate carbon credits [2].

Carbon Credits are a tradable permit scheme under UNFCCC (United Nations Framework Convention for Climate Change) which give the owner the right to emit one metric tonne of carbon-dioxide (CO2) equivalent. They provide an efficient mechanism to reduce the green house gas emissions by monetizing the reduction in emissions. The GSMA is evaluating the potential for the telecommunication industry as an aggregate to benefit from carbon credit trading. At a site level, carbon credits produced by replacing an off-grid diesel generator site with green power range from US$450-US$1,500 per site, per year. Although this amount is too small to warrant the overhead of carbon trading at a site level, the economics of aggregating network credits are immense. The programme has evaluated suitable carbon trading methodologies to support trading through the UN Framework Convention on Climate Change (UNFCCC) and plans to move to a pilot phase are underway [3]. The purpose of this paper is to theoretically assess the carbon credits of using hybrid power systems in a base station site.

Base station site Power Requirement

The electric power needed for the base station site equipment in and the energy required to remove heat from the shelter (cabin) are stated below [4].

Base station site Equipment power requirement =8,060W/h
Climate Equipment power requirement = 2,590W/h

Hourly load demand (Macro Base Station Site perspective) has been given as an input in HOMER and then it generates daily and monthly load profile for a year [5]. It has been found that this site consumes energy around 254Wh/day with a peak demand of 10.7kW as shown in figure 2.

1.1. Renewable Resources

For this work, a base station site situated at Nembe in Bayelsa state, Nigeria was considered. The data for solar and wind resources were obtained from the NASA Surface Meteorology and Solar Energy web site [6], while the hydro resource were measured at the site. The specific geographical location of Nembe (Bayelsa State) are of 4° 17' N latitude and 6° 25' E longitude with annual average solar daily radiation of 4.12kWh/m²/d, annual average wind of 3.0m/s and annual average stream flow of 17.3L/s. Figures 1a, 1b and 1c show the solar, wind and hydro resource profile of this area.

For the HPS, a diesel generator that is hybridized with a PV/wind/hydro system were used. The details of the power generating set and the weather conditions of Nembe are used as input data in the simulation software used for this study.

1.2. Carbon Emissions Estimation

Global warming is caused due to the emission of greenhouse gases which get trapped in the atmosphere. The most important environmental indices are fuel consumption and pollutant emissions. It is well known that the hazards of diesel exhaust and fumes from the use of diesel generators can cause both serious health and environmental problems according to numerous resources [7 - 8]. The potent green house gases are carbon-dioxide. In general, CO2 emissions are calculated by multiplying fuel consumption by the corresponding emission factor. Fuel consumption for each carbon emission source is calculated by multiplying its production by the provincial average fuel consumption per unit production [9].

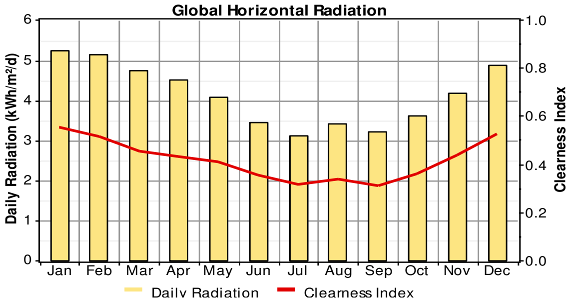

Fig. 1a. HOMER output graphic for solar radiation profile [5].

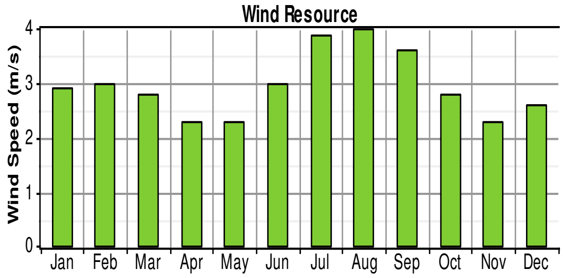

Fig. 1b. HOMER output graphic for the Wind Speed profile [5].

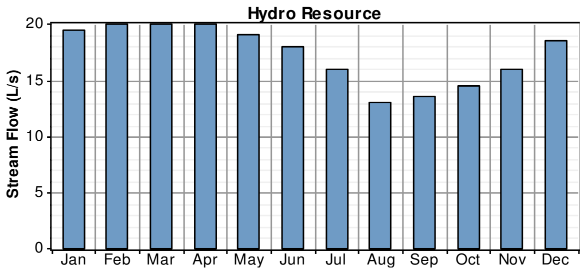

Fig. 1c. HOMER output graphic for the stream flow profile [5].

1.3. Model for Calculating Emission

Many studies on the environmental impact of systems now use National Renewable Energy Laboratory (NREL)'s, Hybrid Optimization Model for Electric Renewable (HOMER). It contains a number of energy component models and evaluates suitable technology options based on emissions. The Hybrid Optimization Model for Electric Renewables (HOMER) software was used by Kamel et al, Khan et al [10, 11], and Lambert et al [12] to find optimum sizing and minimizing cost and emission for power system with specific load demand in stand-alone applications. A simulation work on contaminating emissions (CO2, NOx and particles) of a diesel generator was presented by Wies et al [13] using Simulink and comparing the results with those obtained by means of HOMER [14] software.

The equation for the calculation of cost of generated emissions stated by Lambert, Ani, and Ani et al [15, 16, 17] is as follows:

$$C_{emissions} = \frac{c_{CO_2} M_{CO_2} + c_{CO} M_{CO} + c_{UHC} M_{UHC} + c_{PM} M_{PM} + c_{SO_2} M_{SO_2} + c_{NO_X} M_{NO_X}}{1000} \quad (1)$$

Where:

c_{CO_2} = cost for emissions of CO_2 [$/t]

c_{CO} = cost for emissions of CO [$/t]

c_{UHC} =cost for emissions of unburned hydrocarbons (UHC) [$/t]

c_{PM} =cost for emissions of particulate matter (PM) [$/t]

c_{SO_2} =cost for emissions of SO_2 [$/t]

c_{NO_x} =cost for emissions of NO_x [$/t]

M_{CO_2} =annual emissions of CO_2 [kg/yr]

M_{CO} =annual emissions of CO [kg/yr]

M_{UHC} =annual emissions of unburned hydrocarbons (UHC) [kg/yr]

M_{PM} =annual emissions of particulate matter (PM) [kg/yr]

M_{SO_2} =annual emissions of SO_2 [kg/yr]

M_{NO_x} =annual emissions of NO_x [kg/yr]

1.4. Cost of Emissions

World governments are working rapidly to place a mandatory price on the emissions of greenhouse gases, including the carbon dioxide (CO2) which is produced by the use of diesel fuel [4]. In future, businesses will be required to reduce emissions or buy offset credits to offset CO2 emissions [17]. There is currently a market for voluntary offsetting, with the price of emissions in the range of $6-$11 per tonne of CO2 emitted [18]. There is general agreement that the price of emissions must rise to at least $200 /t CO2e [18] in order to have the desired effect of reducing the GHG emissions worldwide. The Canadian government is currently recommending a target price of $250 /tonne CO2e by the year 2025. For a network containing today's typical diesel-powered cell sites, the $200/t price of emission adds up to an additional operating expense of $10,800 (CDN) per year per site [18].

2. Methodology

2.1. Experimental System Description

HOMER is an optimization program based on energy (Cost and Environmental) calculations. The Hybrid System Components description can be found in Ani [5]. The system architecture employed in the hybrid system is DC coupled where the solar PV, wind turbine, hydro turbine and the diesel generator all feed into the DC side of the network as depicted in Fig. 2. This is the network arrangement used for this study.

This base station site energy consumption is a 254kWh / day with a 10.7kW peak demand load, and the energy system used for the simulation consists of 16kW diesel generator, 10.7kW solar PV array, 10kW wind turbine, 10.3kW hydro turbine, 96 Surrette 6CS25P Battery Cycle Charging, and a 25 kW AC/DC converter.

In the present work, the amount of possible pollutants arising from the use of diesel fuel in powering the GSM Base Station Sites was simulated with HOMER software using the above mentioned data. The simulated results are discussed and shown in table 1.

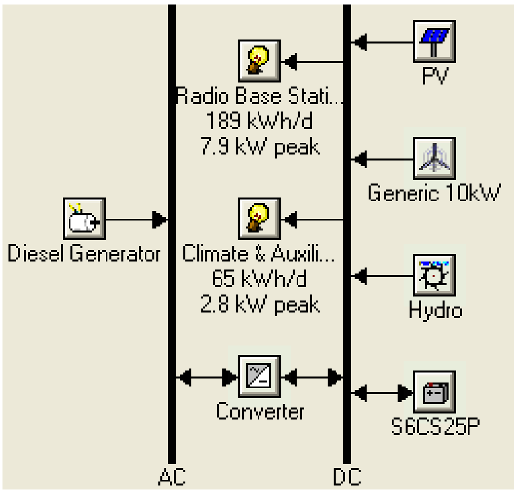

Fig. 2. The network architecture for the HOMER simulator

3. Results and Discussion

3.1. Simulation Results

This is to carry out eight energy component configurations for power supply to GSM Base Station Sites located at Nembe (Bayelsa State) for the project lifetime of one year. This enables comparisons between options based on environmental factors. These scenarios are also compared with the diesel only option. The results of the analysis of eight possible system configuration scenarios considered in this study are shown in table 1.

Environmental Costs

The $200/t price of emission giving by World governments was used in this study to cost the emissions.

Using Eq. (1), the carbon credits were calculated and tabulated. All costs are in USD ($) as shown in table 2.

Table 1. Comparisons of Simulation results of the Environmental Impact

Parameter	Diesel	Wind-Diesel	PV-Diesel	PV/Wind-Diesel	Hydro-Diesel	Wind/Hydro-Diesel	PV/Hydro-Diesel	PV/Wind/Hydro-Diesel
Carbon dioxide (t/yr)	98.5	98.361	86.053	85.553	43.256	42.297	28.448	27.864
Carbon monoxide (t/yr)	0.244	0.243	0.212	0.211	0.107	0.104	0.0702	0.0688
Unburned hydrocarbon (t/yr)	0.027	0.0269	0.0235	0.0234	0.0118	0.0116	0.00778	0.00762
Particulate matter (t/yr)	0.0184	0.0183	0.016	0.0159	0.00805	0.00787	0.00529	0.00518
Sulphur dioxide (t/yr)	0.198	0.198	0.173	0.172	0.0869	0.0849	0.0571	0.056
Nitrogen oxides (t/yr)	2.176	2.166	1.895	1.884	0.953	0.932	0.627	0.614

Table 2. Comparisons of Environmental Costs for Power Generation Systems at the cost of $200/t/yr

Parameter	Diesel	Wind-Diesel	PV-Diesel	PV/Wind-Diesel	Hydro-Diesel	Wind/Hydro-Diesel	PV/Hydro-Diesel	PV/Wind/Hydro-Diesel
Carbon dioxide ($200/t/yr)	19700	19672.2	17210.6	17110.6	8651.2	8459.4	5689.6	5572.8
Carbon monoxide ($200/t/yr)	48.4	48.6	42.4	42.2	21.4	20.8	14.04	13.76
Unburned hydrocarbon ($200/t/yr)	5.4	5.38	4.7	4.68	2.36	2.32	1.556	1.524
Particulate matter ($200/t/yr)	3.68	3.66	3.2	3.18	1.61	1.574	1.058	1.036
Sulphur dioxide ($200/t/yr)	39.6	39.6	34.6	34.4	17.38	16.98	11.42	11.2
Nitrogen oxides ($200/t/yr)	435.2	433.2	379	376.8	190.6	186.4	125.4	122.8
Total	20232.28	20202.64	17674.5	17571.86	8884.55	8687.474	5843.074	5723.12

3.2. Discussion

Hybrid (PV, Wind & Hydro) + Diesel Generator

PV/wind/hydro-diesel system - Diesel generator operates for 2,004h/annum with fuel consumption of 10,581L/annum. This system emits 27.864 tonnes of CO2, 0.0688 tonnes of CO, 0.00762 tonnes of UHC, 0.00518 tonnes of PM, 0.056 tonnes of SO2, and 0.614 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 69% decrease in each pollutant is noticed for a 69% renewable penetration into the diesel only power system. The reduction (69% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $14127.2 for CO2, $34.64 for CO, $3.876 for UHC, $2.644 for PM, $28.4 for SO2, and $312.4 for NOx. Thus, the system has a total of $14509.16 carbon credits when compared to diesel only option.

Hybrid (PV & Hydro) + Diesel Generator

PV/hydro-diesel system - Diesel generator operates for 2,046h/annum with fuel consumption of 10,803L/annum. This system emits 28.448 tonnes of CO2, 0.0702 tonnes of CO, 0.00778 tonnes of UHC, 0.00529 tonnes of PM, 0.0571 tonnes of SO2, and 0.627 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 68% decrease in each pollutant is noticed for a 68% renewable penetration into the diesel only power system. The reduction (68% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $14010.4 for CO2,

$34.36 for CO, $3.844 for UHC, $2.622 for PM, $28.18 for SO2, and $309.8 for NOx. Thus, the system has a total of $14389.206 carbon credits when compared to diesel only option.

Hybrid (Wind & Hydro) + Diesel Generator

Wind/Hydro-diesel system - Diesel generator operates for 3,042h/annum with fuel consumption of 16,062L/annum. This system emits 42.297 tonnes of CO2, 0.104 tonnes of CO, 0.0116 tonnes of UHC, 0.00787 tonnes of PM, 0.0849 tonnes of SO2, and 0.932 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 54% decrease in each pollutant is noticed for a 54% renewable penetration into the diesel only power system. The reduction (54% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $11240.6 for CO2, $27.6 for CO, $3.08 for UHC, $2.106 for PM, $22.62 for SO2, and $248.8 for NOx. Thus, the system has a total of $11544.806 carbon credits when compared to diesel only option.

Hydro only + Diesel Generator

Hydro-diesel system - Diesel generator operates for 3,111h/annum has a fuel consumption of 16,426L/annum. This system emits 43.256 tonnes of CO2, 0.107 tonnes of CO, 0.0118 tonnes of UHC, 0.00805 tonnes of PM, 0.0869 tonnes of SO2, and 0.953 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 53% decrease in each pollutant is noticed for a 53% renewable penetration into the diesel only power system. The reduction (53% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $11048.8 for CO2, $27 for CO, $3.04 for UHC, $2.07 for PM, $22.22 for SO2, and $244.6 for NOx. Thus, the system has a total of $11347.73 carbon credits when compared to diesel only option.

Hybrid (PV & Wind) + Diesel Generator

PV/wind-diesel system - Diesel generator operates for 6,154h/annum with fuel consumption of 32,488L/annum. This system emits 85.553 tonnes of CO2, 0.211 tonnes of CO, 0.0234 tonnes of UHC, 0.0159 tonnes of PM, 0.172 tonnes of SO2, and 1.884 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 13% decrease in each pollutant is noticed for a 13% renewable penetration into the diesel only power system. The reduction (13% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $2589.4 for CO2, $6.2 for CO, $0.72 for UHC, $0.5 for PM, $5.2 for SO2, and $58.4 for NOx. Thus, the system has a total of $2660.42 carbon credits when compared to diesel only option.

PV only + Diesel Generator

PV-diesel system - Diesel generator operates for 6,190/annum has a fuel consumption of 32,679L/annum. This system emits 86.053 tonnes of CO2, 0.212 tonnes of CO, 0.0235 tonnes of UHC, 0.016 tonnes of PM, 0.173 tonnes of SO2, and 1.895 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 12% decrease in each pollutant is noticed for a 12% renewable penetration into the diesel only power system. The reduction (12% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $2489.4 for CO2, $6 for CO, $0.7 for UHC, $0.48 for PM, $5 for SO2, and $56.2 for NOx. Thus, the system has a total of $2557.78 carbon credits when compared to diesel only option.

Wind only + Diesel Generator

Wind-diesel system - Diesel generator operates for 7,075h/annum has a fuel consumption of 37,352L/annum. This system emits 98.361 tonnes of CO2, 0.243 tonnes of CO, 0.0269 tonnes of UHC, 0.0183 tonnes of PM, 0.198 tonnes of SO2, and 2.166 tonnes of NOx annually into the atmosphere of the location under consideration as shown in table 1, which their costs are all shown in table 2.

Almost 1% decrease in each pollutant is noticed for a 1% renewable penetration into the diesel only power system. The reduction (1% renewable penetration into the diesel only) in different air pollutants were calculated and monetized (carbon credits) as thus: $27.8 for CO2, $-0.2 for CO, $0.02 for UHC, $0.02 for PM, $0 for SO2, and $2 for NOx. Thus, the system has a total of $29.64 carbon credits when compared to diesel only option.

Diesel Generator

Diesel only generates 98.5 tonnes of CO2, 0.244 tonnes of CO, 0.027 tonnes of UHC, 0.0184 tonnes of PM, 0.198 tonnes of SO2, and 2.176 tonnes of NOx as shown in table 1.

The costs of emission of different air pollutants for diesel only are thus: $19700 for CO2, $48.4 for CO, $5.4 for UHC, $3.68 for PM, $39.6 for SO2, and $435.2 for NOx. Thus, the system has a total cost of emission of $20232.28 with no carbon credits.

In conclusion, the different configurations of power generation system PV/wind/hydro-diesel system, PV/hydro-diesel system, Wind/Hydro-diesel system, Hydro-diesel system, PV/wind-diesel system, PV-diesel system, and Wind-diesel system have the ability for reducing the emissions emitted by diesel generator to 69%, 68%, 54%, 53%, 13%, 12% and 1%, respectively, thereby give an opportunity for carbon credits of $14509.16, $14389.206, $11544.806, $11347.73, and $2660.42, $2557.78, respectively.

4. Conclusion

HOMER software was used to find the possible combination of renewable energy schemes. These combinations show the environmental analysis of adopting each energy resource over a period of one year. The reduction (% renewable penetration into the diesel only) in the total air pollutants were calculated and monetized (carbon credits). The result shows that the configuration with highest renewable penetration (69%) has the highest carbon credit ($14509.16) when compared to diesel only option.

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