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Mitigating Climate Change Through Community-Based Microgrid

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***Abstract*— GreenHouse Gasses' (GHG) emission control is the greatest environmental challenge facing the world. The energy sector accounts for the highest percentage of environmental pollution. Emissions from internal combustion power generators are high and these emissions are responsible for the fast depletion of the ozone layer. Though there are other measures put in place to control the emission from power generating systems, the best method however, is to reduce the number of active power generating systems that burn fossil fuels through retrofitting of existing cluster of power generators into a community- based microgrid. Efficient optimization and capacity management technique can be applied since most of the stand alone power generators operate below capacity. The result obtained from an experimental test case carried out in a location shows a 27% reduction in fuel consumption for the period considered, with the load demand satisfied, which also translates into 31.8% reduction in the amount of greenhouse gasses emitted into the environment by these power generators.**

***Keywords*— Emissions, Environmental Pollution, GreenHouse Gases, Microgrid, Mitigating.**

I. INTRODUCTION

There is an increasing negative impact on the climate due to increase in the emission of GreenHouse Gases (GHG) by virtue of fossil fuels burning, agricultural practices, industrial processes and deforestation. The world's energy supply has been dominated by fossil fuels in the first half of the last century and will almost certainly continue to be so in the second half with oil as the major source. In 2007, 81.4% of the world's energy was produced from fossil fuels, which included 20.9% from gas, 26.5% from coal, and 34% from oil, with almost all of the remainder coming from renewables and waste (9.8%), nuclear (5.9%), and hydro (2.2%).[1] . Electrical power generation and green house gas emissions are seemingly inseparable therefore, the only way to reduce GHG is by reducing the amount of power we consume through efficient conservation techniques and this will reduce the burning of fossil fuel required for electrical energy production. Consequently, this will reduce the emission of GHG into the environment.

Approximately 1.6 billion people have no access to electricity. Eighty-percent of these people live in rural areas in the developing world, mostly in South Asia and sub-Saharan Africa [2]. Nigeria is the most populous country in Africa. Its population currently stands at about160 million people and is expected to grow to 230 million by 2030 [3]. The country's generating capacity is still less than 4000MW [4]. The rule of thumb for any developed industrial nation is that at least 1 Gigawatt (i.e. 1,000 Megawatts) of electricity generation and consumption is required for every 1 million head of population [5].

This extreme electricity shortage challenge facing Nigeria has led to the closure of several businesses while those still open for business struggle to stay afloat. Sequel to this situation, many individuals and companies depend on personal generators and supplement them with electricity provided by the grid system. According to World Bank report of 2005 [6], well over 90% of businesses in Nigeria have generators.

The aggregated noise pollution as well as GHG emission is yet to be quantified and these power generators are located all around the neighborhood close to where the generated power is to be utilized. Figure I shows a typical neighborhood in Nigeria where a cluster of portable single-phase power generators with capacities ranging from 0.5kW to 5kW made by different manufacturers emitting GHG and polluting the environment.

II. THE COMMUNITY-BASED MICROGRID

Most operators of these private power generating plants do not carry out proper assessment and optimization analysis before embarking on acquiring power generating plants [7]. Consequently, the power generators operate below rated capacity as larger portion of the energy generated is above the required electrical energy for the operator's consumption. There are no considerations of the possibility of using one or more generators to serve a group of loads probably because of the technical capacity of the operators.

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Since these power generators are located near the load, a community-based microgrid can be formed whereby sources can be interlinked and the loads connected to it

FIGURE 1: A CLUSTER OF STAND -ALONE POWER GENERATORS

A microgrid can be described as a small-scale power supply network that is designed to provide power for a small community which may range from a typical housing estate, isolated rural communities, to mixed suburban environments, academic or public communities such as universities or schools, to commercial areas, industrial sites and trading estates, or municipal regions. The main concept that differentiates this method of power supply from a conventional power utility is that the power generators are small (often referred to as micro-generators, of a similar size as the loads within the microgrid), they are distributed and located in close proximity to the loads. [8,9,10,11,12]

III. FACILITY DESCRIPTION AND LOCATION

The test facility is made up of three 3-bedroom flats and one semi-detached duplex. The three 3-bedroom flats are labeled as 1, 2, and 4 while the duplex is labeled as 3.

The distances between the facilities are as shown in Figure II. Each facility is supplied by a dedicated power generator whose description and characteristics are as shown in Table I. The power generators are dissimilar and not synchronizable in the AC platform hence a DC microgrid with suitable converters (rectifiers and inverters) was utilized.

IV. THE COMMUNITY LOAD PROFILE ANALYSIS

The average daily load profiles of the test facilities were obtained by manual measurement every hour using voltmeters and ammeters connected to the load point for a period of Three months (July 2013- September 2013) and the averages taken as shown in Table II. Analysis of the load profile shows that excess capacity which is the difference between the generators' capacity and the actual power used by the attached load is as shown in Figure 3. It was discovered that creating a microgrid from these sources will make it possible for the contributions of one or two generating units to sustain the load. This implies that one or two generating units could be on stand-by at that period. With this done, the fuel that could have been utilized is saved and the associated GHG emission and pollution that could have been released into the environment are eliminated.

V. POWER PLANT ENGAGEMENT

Applying optimization and unit commitment technique [13] using the generating sources data and the load profile, the power generators were scheduled to run as shown in Table III within the 24-hour period.

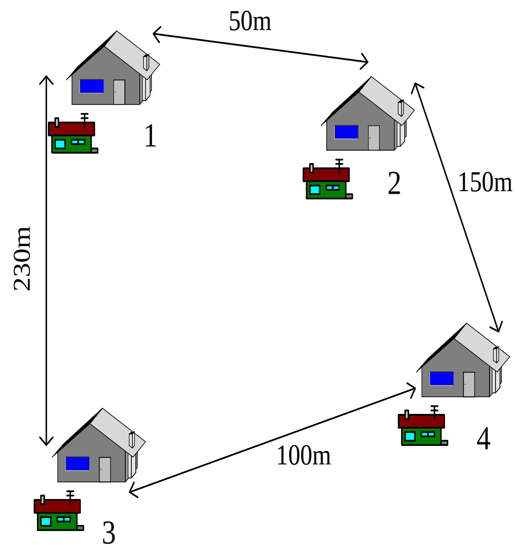

FIGURE II: PHYSICAL LOCATION OF THE TEST FACILITIES

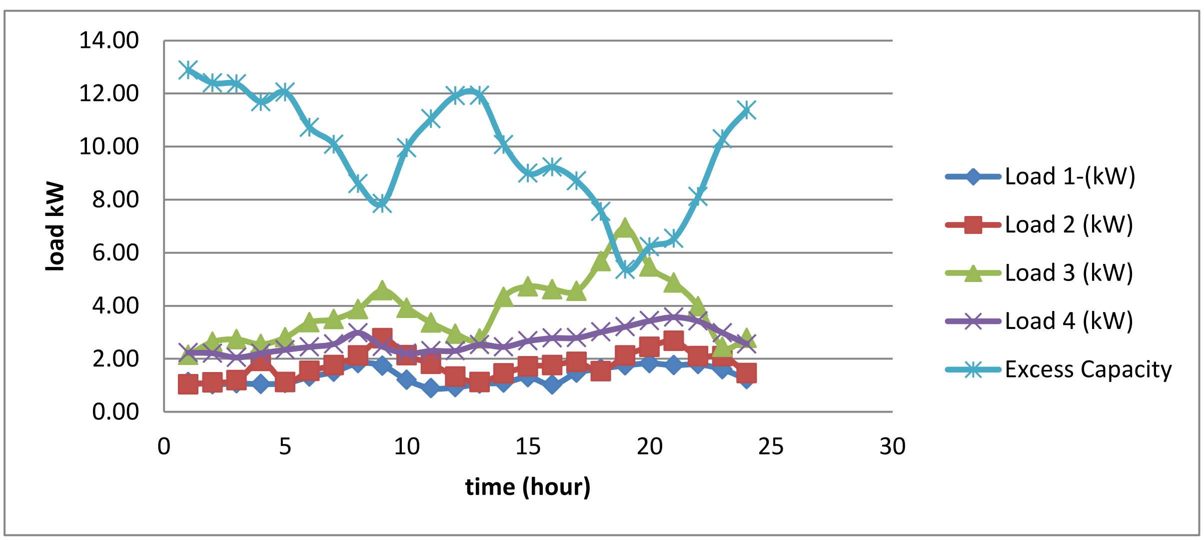

FIGURE III: A PLOT OF HOURLY TEST FACILITY LOAD PROFILE AND THE EXCESS CAPACITY.

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TABLE I
CHARACTERISTICS OF THE GENERATING SETS (SOURCES)

s/no	parameters	Generator type 1	Generator type 2	Generator type3	Generator type 4
1	make	Suzuki – TEC Japan	Honda	Lister	Yamaha-Japan
2	model	2.5GF-3	EG3600	FM-16DI	EF5200
3	Rated voltage (Volts)	220	230	230	220
4	Rated current (Amps)	10	14	43	22
5	Rated output (kVA)	2.5	3.6	10	4.5
6	Rated power (kW)	2.2	3.2	8.8	5.2
7	Rated frequency	50	50	50	50
8	Phase type	Single	Single	Single	Single
9	Generator type	Sync. AC	Sync. AC	Sync. AC	Sync. AC
10	Fuel type	PMS (petrol)	PMS (petrol)	AGO (Diesel)	PMS (petrol)
11	Full tank fuel capacity (litres)	12	24	25	25
12	Cost of purchase (N)	45,000	230,000	275,000	155,000
13	Lifespan	10 years	10 years	10 years	10 years

VI. CARBON DIOXIDE (CO2) EMISSION ANALYSIS

Carbon dioxide emitted under the existing and the microgrid configurations is as shown in Tables IV and V. In Table IV, the generators were operated continuously for 24 hours. The fuel used per hour was recorded and prorated to a year of continuous operation. The total annual CO_2 emission was calculated. In Table V, the generators were operated for 24 hours but in the microgrid configuration and an optimization technique applied. The generators' operating hours were less than 24 hours (column4) and the loads were adequately served. The total CO_2 emission per annum was also computed. The plot of the total emission by all microsources in the set up is as shown in Figure IV. The benefit of the integration as a means of mitigating GHG emission is evident in the following analysis.

The mass of CO_2 emitted during the combusting of a carbon- based fuel is given as [14]

$M_{CO2} = 3.67 \text{ x } C_c \text{ x } M_{fuel}$

where C_c = carbon content of the fuel (mass based)

M_{fuel} = mass of the fuel

The carbon content of diesel is 85.7% while petrol is 87% , Density of diesel is 0.84kg / litre [15].

Burning 1litre of diesel as fuel gives

$M_{CO2} = 3.67 \text{ x } 0.857 \text{ x } 0.84$, Therefore,

$M_{CO2\ (diesel)} = 3, 15 \text{ x } 0.84 = 2.64$kg / litre

Following the same analysis for petrol, the

$M_{CO2\ (petrol)} = 2.34$kg / litre.

EXPLORING RESEARCH AND INNOVATIONS

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TABLE II
A 24-HOUR LOAD PROFILE OF THE TEST FACILITIES

Time (Hour)	Load 1-(kW)	Load 2 (kW)	Load 3 (kW)	Load 4 (kW)	Total (kW)	Excess Capacity (kW)=ΣGenerators' Capacity-ΣLoad
00:00 - 01:00	1.12	1.03	2.14	2.23	**6.52**	**12.88**
01:00 - 02:00	1.04	1.11	2.64	2.21	**7**	**12.4**
02:00 - 03:00	1.07	1.19	2.73	2.05	**7.04**	**12.36**
03:00 - 04:00	1.05	1.91	2.55	2.21	**7.72**	**11.68**
04:00 - 05:00	1.08	1.12	2.81	2.34	**7.35**	**12.05**
05:00 - 06:00	1.32	1.54	3.37	2.45	**8.68**	**10.72**
06:00 - 07:00	1.51	1.76	3.49	2.56	**9.32**	**10.08**
07:00 - 08:00	1.83	2.12	3.87	2.98	**10.8**	**8.6**
08:00 - 09:00	1.74	2.77	4.58	2.46	**11.55**	**7.85**
09:00 - 10:00	1.2	2.13	3.92	2.2	**9.45**	**9.95**
10:00 - 11:00	0.89	1.81	3.36	2.3	**8.36**	**11.04**
11:00 - 12:00	0.92	1.33	2.94	2.3	**7.49**	**11.91**
12:00 - 13:00	1.06	1.12	2.76	2.53	**7.47**	**11.93**
13:00 - 14:00	1.1	1.45	4.33	2.45	**9.33**	**10.07**
14:00 - 15:00	1.3	1.71	4.73	2.67	**10.41**	**8.99**
15:00 - 16:00	1.02	1.76	4.62	2.78	**10.18**	**9.22**
16:00 - 17:00	1.47	1.88	4.56	2.79	**10.7**	**8.7**
17:00 - 18:00	1.63	1.53	5.68	3.01	**11.85**	**7.55**
18:00 - 19:00	1.75	2.12	6.95	3.21	**14.03**	**5.37**
19:00 - 20:00	1.83	2.45	5.47	3.43	**13.18**	**6.22**
20:00 - 21:00	1.76	2.67	4.87	3.57	**12.87**	**6.53**
21:00 - 22:00	1.79	2.09	3.98	3.42	**11.28**	**8.12**
22:00 - 23:00	1.6	2.1	2.44	2.98	**9.12**	**10.28**
23:00 - 00:00	1.23	1.46	2.78	2.56	**8.03**	**11.37**

TABLE III
PLANT ENGAGEMENT CHAT AFTER OPTIMIZATION OF THE MICROGRID

s/no	period	Total hours	GEN 1	GEN 2	GEN 3	GEN 4
1	22.00 - 05.00	7	OFF	ON	ON	OFF
2	05.00 – 09.00	4	OFF	OFF	ON	ON
3	09.00 – 14.00	5	ON	ON	OFF	ON
4	14.00 – 22.00	8	ON	OFF	ON	ON

Considering the annual volume of fuel used by the generators, the total mass of CO_2 emitted per annum under the existing method is 187,580.86-kg.

Using the community- based microgrid approach; the mass of CO_2 has reduced to 127,997.99-kg which gives a reduction of 59,582.87-kg (31.8%) annually. Figure IV shows the plot of the total emission in each operating model.

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TABLE IV
CO_2 EMISSION USING THE EXISTING METHOD

s/no	Source (Gen.) capacity **(kW)**	Fuel used per hour **(litres)**	CO_2 emitted per litre (kg/l)	Hours run	CO_2 emission per day (kg)	CO_2 emission per annum (kg)
1	2.2	0.802	2.34	24	45.04	16,439.72
2	3.2	2	2.34	24	112.32	40,996.80
3	8.8	3.276	2.68	24	210.71	76,910.00
4	5.2	2.597	2.34	24	145.85	53,234.34
Total						**187,580.86**

TABLE V
CO_2 EMISSION USING THE COMMUNITY-BASED MICROGRID METHOD

s/no	Source (Gen.) capacity **(kW)**	Fuel used per hour **(litres)**	Hours run (after application of optimization technique)	CO_2 emitted per litre (kg/l)	CO_2 emission per day (kg)	CO_2 emission per annum (kg)
1	2.2	0.802	13	2.34	24.40	8,904.85
2	3.2	2	12	2.34	56.16	20,498.40
3	8.8	3.276	19	2.68	166.81	60,887.08
4	5.2	2.597	17	2.34	103.31	37,707.66
Total						**127,997.99**

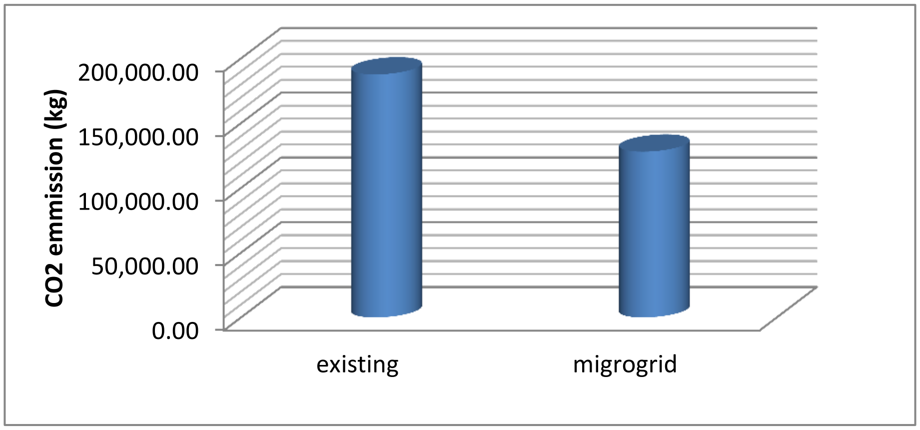

FIGURE IV: GRAPHICAL REPRESENTATION OF CO_2 UNDER THE TWO OPERATING SCENARIOS

VII. CONCLUSION

To mitigate climate change, a community-based microgrid was suggested and applied to a region with cluster of fossil-fueled micro-generators. The method implemented involves the inter-connection of a group of micro-generators in a locality to form a microgrid where all sources and loads are tied together through appropriate interfaces. Using optimization and energy management techniques, the micro-generator engagement, fuel consumption and emission of pollutants into the environment were greatly reduced. Consequently, the adaptation of the community-based microgrid in regions where cluster of micro fossil-fueled power generators is operated will yield more efficient system, encourage greenness and reduce environmental pollution.

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