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Photovoltaic Hybrid Systems for remote villages

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ABSTRACT. Electricity access in remote areas of Sub-Saharan Africa is limited due to high costs of grid extension to areas characterised by low population and low energy densities. Photovoltaic hybrid systems can be computed using an energy balance equation involving one unknown. For hypothetical village with an average daily energy demand of 153.6 kWh/d, the monthly energy output of photovoltaic modules at Garoua, Cameroon, enabled the evaluation of feasible photovoltaic hybrid (PVHS) options. An option with a renewable energy fraction of 0.557 having lower initial investments is suggested for electrification of more remote villages in Sub-Saharan African countries which have high solar radiation levels. This option comprises a 23.56 kWp PV array, a 15 kWp PV inverter, a 25 kW bi-directional inverter, a battery bank of capacity 324.48 kWh and a 25 kW diesel generator with an operating time of 1309 h/yr or 3.59h/d. The size of the PV array determined is smaller compared to the sizes of PV arrays which have been evaluated in the range 30-45 kWp using HOMER software for medium villages in Senegal.

Systemes Photovoltaiques Hybrides pour les villages isolés

RESUME. L'access à l'éléctricité en Afrique Sub-saharienne est limité par le cout élevé d'extension des resaux electriques vers les zones isolées caracterisés par une faible densité de la population et une faible densité de consummation de l'energie electrique. Les systemes hyrides photovoltaiques peuvent étre evalués avec une equation energétique à un inconue. Pour un village hypothetique avec une demande énergétique quotidienne de 153.6 kWh/jr, les productions énergetique mensuelles des modules photovotaiques à Garoua, au Cameroun, ont permis l'evaluation des options photovoltatiques hybrides realisables. Une option avec une fraction d'énergie renouvelable de 0,557 ayant un investment initial inféreur est suggerée pour l'électrification de villages plus éloignés dans l'Afrique subsaharienne qui ont des niveaux élevés de rayonnement solaires. Cette option comprend un générateur photovotaique de 23,56 kWc, un onduleur photovoltaique de 15 kWc, un inverseur bidirectionnel de 25 kW, un groupe de batterie *d'une capacité de 324.48 kWh, et un groupe electrogene diesel de 25 kW avec un temps de* fonctionnement de 1309 h/an ou 3.59h/j. La taille du générateur photovoltaique determiné est inférieur à celle des générateurs photovoltaiques dans la plage allant de 30 à 45 kWc à l'aide du logiciel HOMER pour les villages moyenne du Senegal comptant 750 habitants.

MOTS CLÉS: Systemes photovoltaiques hybrides, model energetique, fonctionnement annuel du groupe electrogenes souhaité
KEYWORDS: Photovoltaic hybrid systems, energy model, desired annual generator hours

1 Introduction

Sub-Saharan Africa had the lowest urban and rural electrification rates of 58% and 12% in 2008 [1]. Achieving universal access to electricity in Sub- Saharan Africa is therefore a serious challenge for individual countries because of high costs of extending centralised grid electricity to urban and rural areas which are characterized by low population and energy densities. Microgrids powered by photovoltaic/diesel hybrid systems (PVHS) which can be expanded as energy demand increases could be used to ensure the economic development of such underprivileged localities.

In literature HOMER software is widely used to to design of off-grid systems for remote villages. However, this software has input modules that require real-time data which is often not available in most developing countries of Sub-Saharan Africa. HOMER has been successfully been used to design micro-grids for Senegalese villages having populations in the range 200-1500 inhabitants and daily energy demands in the range 47.26 – 379.29 kWh/d . However, the design required the creation of a daily load profile through the study of the ownership of electric appliances and usage patterns as well as the classification of households into energy service levels. This required the deployment of a multi-disciplinary research them in three villages of Senegal near the capital Dakar. [2-4]. The approach used in Senegal involved expenditure that most Sub-Saharan countries may not be able to mobilize to realize similar studies in all non-electrified villages. Studies on the design and optimal operation of either PV-diesel micro-grids with battery or multiple generators and PV-battery hybrid systems under grid scheduled blackouts have been proposed for increasing energy access in developing countries [5-7]. These studies focus on real-time models which depend on real-time data like HOMER. Although the results obtained are interesting, this approach is also difficult to use in Sub-Saharan Africa where most power utilities only record monthly electricity consumption data. Furthermore real-time resource data is also not available for such in-depth studies for most locations.

The power system components of the PVHS can be evaluated using an *energy balance* model with one unknown and an iterative method while the cost of energy of the PVHS can be evaluated using the Net Present value technique [8-10] or alternatively using HOMER software. In previous studies the energy balance model was elaborated and use to size photovoltaic/battery/diesel hybrid systems for the energy demand of eight grid-connected households in range 0.18-7.08 kWh/d using the computed energy output of solar modules at Garoua, Cameroon [11-12]. The Net Present Value technique was used to find the energy cost and the breakeven grid distances for feasible photovoltaic/battery/diesel options for desired renewable energy fractions for multi-user mini-grid applications with an energy demand of 7.08kWh/d [8]. In [9], an iterative approach based on the desired hours of diesel generator hours is proposed and applied to hourly load profiles of 33 MTN transceiver base stations with estimated daily energy demand in the range 17.76 – 59.31 kWh/d. In this study photovoltaic/battery/diesel options were found to be the optimal energy option. Similar results were obtained in [10] using the daily load profile of a student hostel having morning and night power peaks of 4.33 kW and 5.32 kW respectively and a daily energy demand of 72.6 kWh/d with the impact of fuel escalation and falling solar module prices.

In most of the previous studies, optimal PVHS were found to have high renewable energy fractions in the range 80-100% with 100% energy storage requirements [8-10]. The objective of this current work is to show that PVHS with a renewable energy fraction of about 60% should be considered for the electrification of more remote villages in Sub-Saharan Africa instead of PVHS with high renewable energy fractions. The energy balance model and the numerical approach based on desired annual number of diesel generator operatings hours shall be tested on the monthly energy demand of a hypothetical village of 50 low voltage grid-connected customers. Energy storage requirements in such PVHS should take into account the renewable energy fraction since the diesel generator in PVHS supplies peak loads at night and charges the battery bank.

2 PVHS energy model

An AC-bus configuration of a PVHS system is shown in Figure 1. Photovoltaic modules convert variable solar radiation into a DC power that is often optimised with a maximum power point tracking device. The optimised DC power is converted to AC ***power*** by a string inverter and supplied to AC loads through an AC-bus. A battery inverter connected to the AC-bus and battery bank charges the battery in the case of excess power from solar panels or diesel generator. The battery inverter also converts stored energy in the battery to AC-power when the battery bank is sufficiently charged. In Figure 1, $S(k)$ is the energy output of the solar generator SP in the *k*th month, η_{mppt} is the efficiency of the maximum power point tracker MPPT, η_{stri} is the efficiency of the string inverter SI, η_{batt} is the round trip efficiency of the battery bank BB, η_{inv} is the efficiency of battery inverter BI, $G(k)$ is the energy output of the diesel generator DG in the *k*th month and $D(k)$ is the energy demand of AC-loads in the *k*th month.

The energy demand of the AC loads in the *k*th month is satisfied in the solar hybrid system by the relation [11]:

$$D(k) = \eta_{mppt}\eta_{srti}S(k) + G(k) \qquad (1)$$

The energy balance equation ignores the energy from the battery because the battery releases energy that is stored either from the photovoltaic array or the diesel generator.

The monthly energy supplied by the diesel generator is given by:

$$G(k) = P_g \times q \times h(k) \qquad (2)$$

where P_g is the rated power of the generator, q is the constant load fraction at which the generator is operated and $h(k)$ is the number of hours the generator is operated in the *k*th month [11]

The energy deficit in the *k*th month that is supplied by the generator can be expressed as:

$$R(k) = D(k) - \eta_{mppt}\eta_{batt}\eta_{inv}S(k) \tag{3}$$

If the minimum parallel and serial connection numbers of solar modules that make up the solar generator are denoted N_{pvp} and N_{pvs} respectively, then the energy output of the solar generator in the *k*th month is of the form:

$$S(k) = N_{pvp} \times N_{pvs} \times W(k) \tag{4}$$

where $W(k)$ the energy output of a solar module in the *k*th month and is expressed as [11,12]

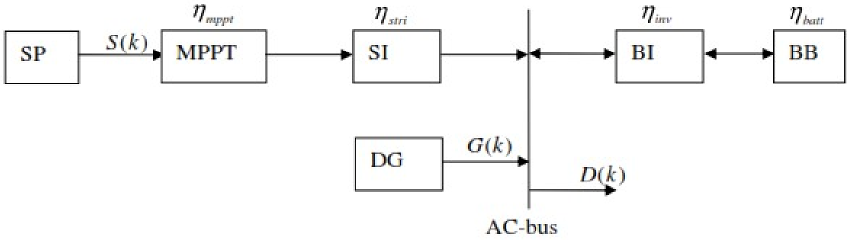

Figure 1: **Energy flows in PVHS hybrid system [11]**

$$W(k) = F_c F_o d(k) \int_{t=6}^{18} I_{pv}(t) \times V_{pv}(t)dt \tag{5}$$

where W (k) is the energy generated by the PV module in the *k*th month, Fc is the factor representing connection loss, Fo is the coefficient representing power loss caused by other factors, d (k) is the number of days in the *k*th month, Ipv (t) the optimum operatingpoint current of a PV module at the *t*th hour, and Vpv (t) is the optimum operating point voltage of a PV module at the *t*th hour [8].

From equation (4) the energy deficit in the *k*th month is re-written as:

$$R(k) = D(k) - \eta_{mppt}\eta_{batt}\eta_{inv}N_{pvp}N_{pvs}W(k) \tag{6}$$

From equations (6) and (2), the number of generator operating hours in the *k*th month due to insufficient renewable energy generation is derived as:

$$h(k) = \begin{cases} 0 & R(k) < 0 \\ R(k)/qP_g & R(k) > 0 \end{cases} \tag{7}$$

where q is the diesel generator load factor and P_g in the rating of the diesel generator. From equations (6) and (7) the annual number of generator operating hours due insufficient renewable energy generation is given by [8]:

$$h = \mathrm{int}\left[\sum_{k=1}^{12}\left(\frac{D(k) - N_{pvp}N_{pvs}\eta_{mppt}\eta_{stri}W(k)}{P_g \times q}\right)\right] \tag{8}$$

If the energy demand of the AC loads is supplied uniquely by the solar generator, equation (6) reduces to:

$$D(k) = \eta_{mppt}\eta_{srti}N_{pvp}N_{pvs}W(k) \tag{9}$$

From which the minimum parallel connection number of PV module strings is determined as [8]:

$$N_{pvp} = \max\left[\mathrm{int}\left(\frac{D(k)/\eta_{stri}\eta_{mppt}}{N_{pvs}W(k)}\right)\right] \tag{10}$$

with the serial connection number of PV modules defined by:

$$N_{pvs} = V_{op}/V_{np} \tag{11}$$

where V_{op} is the maximum input of the PV inverter, V_{np} the nominal output voltage of PV module.

When a diesel generator is included, the power rating of the generator in PVHS can be computed with the relation [10]:

$$P_g = \frac{L_f L_{\max}}{365 q_{\max}}\sum_{k=1}^{12} D(k) \tag{12}$$

where L_f is load factor accounting for unexpected variations in maximum demand, L_{max} is maximum hourly load contribution to daily energy demand, q_{max} is the maximum load factor. The rating bi-directional inverter is also assumed to be same as that of the diesel generator rating in Ref. [10].

The maximum number of desired annual generator hours in PVHS can be determined with the relation [9-10]:

$$hh_{\max} = \frac{(1 - rf_{\min})}{q \times P_g} \sum_{k=1}^{12} D(k) \tag{13}$$

where $hh_{\max}$ maximum desired generator hours in PVHS, $rf_{\min}$ is the minimum desjred renewable energy fraction. The PV array size required in PVHS options can be determined by solving the following inequality derived from equation (8) [9, 10]:

$$\sum_{k=1}^{12} \left| \frac{D(k) - N_{pvp} N_{pvs} \eta_{mppt} \eta_{stri} W(k)}{q \times P_g} \right| \leq hh \tag{14}$$

$$0 \leq hh \leq hh_{\max}$$

The numerical solution of equation (14) is initialised with the initial value of N_{pv1} computed with equation (10) [8-10]. The final value of N_{pv}, N_{pv2} for a selected value of hh is an interger determined without roundup. The value of N_{pv2} is then used to compute the PV array power with the relation:

$$P_{pv} = N_{pvp2} N_{pvs} P_{mp} \tag{15}$$

where P_{mp} is the nominal rating of the PV module. The PV array capacity computed with equation (15) is then used to evaluate the monthly energy outputs of the PV array leading to the calculation of the annual operational time of the diesel generator with the relation:

$$h_2 = \operatorname{int}\left[\sum_{k=1}^{12} \left(\frac{D(k) - N_{pvp2} N_{pvs} \eta_{mppt} \eta_{stri} W(k)}{P_g \times q} \right) \right] \tag{16}$$

The renewable energy fraction of the PVHS is found with the relation:

$$RF = N_{pvp2} N_{pvs} \sum_{k=1}^{12} W(k) / N_{pvp2} N_{pvs} \sum_{k=1}^{12} W(k) + q \times P_g \times h_2 \tag{17}$$

3 Energy storage model

In previous studies the battery bank capacity in Figure 1 was sized to supply energy to loads when there is no energy generation from PV and diesel generators for desired days of autonomy. As such the battery bank capacity was the same in all feasible PVHS. In this study the battery bank capacity takes into account the renewable energy fraction determind in feasible PVHS. The average daily energy demand of the AC loads supplied by the battery bank can be obtained with the relation:

$$X = RF \times \sum_{k=1}^{12} D(k) / \sum_{k=1}^{12} d(k) \tag{18}$$

where X is the daily energy demand on the battery bank computed as a fraction of the annual energy demand and the number of days in a year.

The battery bank capacity required for desired autonomy is given by:

$$C_{bank} = \frac{d \times X}{DOD \times \eta_{dch} \times \eta_{inv}} \tag{19}$$

where C_{bank} is the battery bank capacity, d is the number of days of autonomy required, DOD is the depth of discharge of the battery bank, η_{dch} is the discharge efficiency of the battery bank and η_{inv} is the efficiency of the battery inverter.

From equations (18) and (19) the battery bank capacity is obtained as:

$$C_{bank} = \frac{d}{DOD\eta_{dch}\eta_{inv}}\left(\sum_{k=1}^{12} D(k) / \sum_{k=1}^{12} d(k)\right) \tag{20}$$

An alternative expression for the battery bank capacity is of the form [8,9]:

$$C_{bank} = N_{bp} N_{bs} C_{batt} \tag{21}$$

where N_{bp} is the minimum parallel connection number of battery cell strings, N_{bs} is the serial connection number of battery cells and C_{batt} is the nominal capacity of battery cell. The minimum parallel connection number of battery cell strings in the battery bank can be computed from equations (20) and (21) as:

$$N_{bp} = \mathrm{int}\left[\frac{d}{N_{bs} C_{batt} DOD\eta_{dch}\eta_{inv}}\left(\sum_{k=1}^{12} D(k) / \sum_{k=1}^{12} d(k)\right)\right] \tag{22}$$

with the serial connection number of battery cells computed as:

$$N_{bs} = \frac{V_{ob}}{V_{nb}} \tag{23}$$

where V_{ob} is operating voltage of battery bank and V_{nb} is the nominal output voltage of battery cell.

4 Data for sizing of PVHS

The electricity consumption data of a hypothetical village with 50 low voltage grid-onnected customers is shown in Table 1. This data is derived from the characteristics of AES-SONEL electricity consumption data recorded in 2007 for 2019 grid-conneted customers in Bandjoun, a rural council located in the West Region of Cameroon.

Table 1: Electricity consumption of a village with 50 low voltage customers

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Typical	4571.1	3830.5	4373.5	4567.3	4401.5	4868.4	5080.7	4421.8	4657.3	4741.3	4873.9	4920.1	4609.0
Average	152.37	127.68	145.78	152.24	146.72	162.28	169.36	147.39	155.24	158.04	162.46	164.00	153.63

To obtqin the monthly energy demand for the village, four energy blocks namely [0-50[kWh/month, [50-110[kWh/month, [110-200[kWh/month and]200 kWh/month were considered and the typical monthly energy demand and the proportion of customers in each energy block were computed. The typical monthly energy demand and the proportion of customers in each energy block and the number of customers were then used to derive the monthly energy demand of the village. The derived monthly energy demand of the village indicates that the highest energy demand of 169.36 kWh occurs in July.

The monthly energy output of PV modules at Garoua used for the evaluation of feasible PVHS for village energy demand is presented in Figure 2.

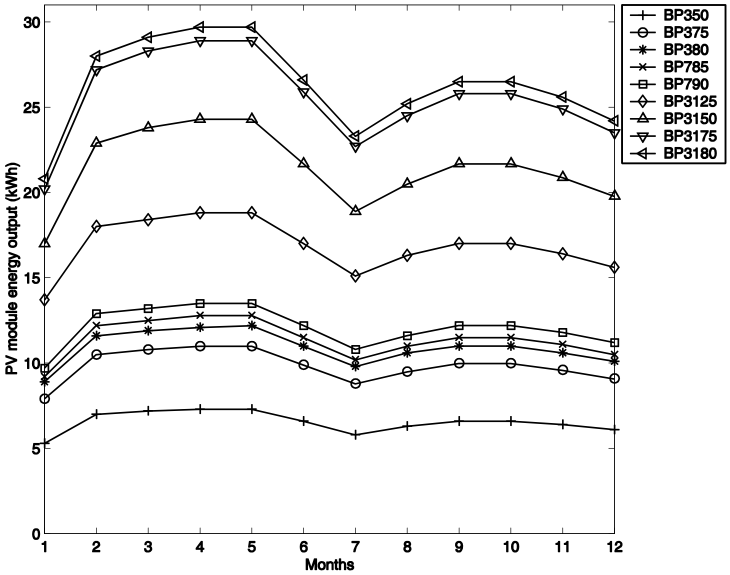

Figure 2: Monthly energy output of selected PV modules [8]

The monthly energy outputs of solar modules at Garoua, Cameroon are selected for the computation of the PV array size in the feasible photovoltaic/battery/diesel hybrid option. For the site considered the minimum output of solar modules is noted to be July which coincides with the rainy season in Cameroon.

Information of diesel generators which can be selected in feasible power configurations is shown in Table 2.

Table 2: Diesel generator cost and fuel consumption rates for selected load factors

		F_{cr} (l/hr)		
P_g (kW)	C_g (€/kW)	25%	50%	75%
2.5	375	0.6	0.9	1.3
5.0	265	1.0	1.4	1.9
7.5	175	1.4	1.9	2.5
10.0	158	1.7	2.3	3.1
12.5	149	2.1	2.9	3.6
15.0	142	2.4	2.6	4.2
17.5	136	2.6	3.8	4.8
20.0	129	2.9	4.4	5.5
22.5	124	3.2	4.9	6.2
25.0	122	3.5	5.5	6.7

Sunny Boy PV string inverter Model SB3000 is selected for AC-coupling of strings of PV modules. A battery bank with an operating voltage of 48 V is selected and a bidirectional inverter is selected for connection to the AC-bus as in previous studies. Solar batteries of 260 Ah/12 V as considered in some studies is retained for sizing the battery bank [8, 10].

5 Results and discussions

The feasible power system configurations obtained for the monthly electricity consumption profile of the village is shown in Table 3. In Table 3, C represents feasible power option, hh the desired number of annual generator hours, h the number of annual operating hours of diesel generator in PVHS, P_{pv} PV array power, P_s PV string inverter power, P_b bi-directional inverter capacity, D annual energy demand, Eg annual energy output of diesel generator, Epv energy output of PV array, E total energy generated.

It is noted in Table 3 that the 180 Wp solar module which has the highest daily energy output in Figure 2 is selected to create the PV array irrespective of the number of desired diesel generator hours. It can be seen in Table 3 that when a PV only system is desired the solution obtained requires that the 25 kW diesel generator should operate for at least 9h/yr.

The variation of PV array size and the renewable energy fraction with annual number operating hours of diesel generator are shown in Fig 3.

The PV array size decreases exponentially for annual generator hours between 0-1300 hours and the renewable energy fractions are in the range 0.557-0.998. The maximum PV array size of 43.56kWp determined is in the range of 30 – 45 kWp which have been found using HOMER software for three medium size villages in Senegal having a population of 750 inhabitants and estimated energy demands in the range 127.67 – 178.82 kWh/d [2-4]. These results were obtained using an estimated hourly load profile characterised by morning power peaks in the range 10 – 13 kW, day time power peak of 10 kW, late evening power peaks in the range 16 – 17 kW and night power peaks in the range of 19 – 24 kW. The diesel generator rating determined with HOMER Software is 5 kW and the converter rating is in the range 25 – 30 kW.

Table 3: Feasible power options for a village with 50 low voltage customers

C	hh	P_{mp}	P_{pv}	P_s	C_{bank}	P_g	P_b	H	D	E_g	E_{pv}	E	RF
1	0	180	43560	33000	561.6	25	25	9	55307	168.8	67965	68133	0.998
2	10	180	39600	30000	561.6	25	25	65	55307	1218.8	61786	63005	0.981
3	70	180	35640	27000	536.64	25	25	170	55307	3187.6	55608	58795	0.946
4	175	180	31680	24000	499.2	25	25	377	55307	7068.9	49429	56498	0.875
5	380	180	27720	21000	449.28	25	25	649	55307	12169.0	43250	55419	0.780
6	650	180	23760	18000	386.88	25	25	978	55307	18338.0	37072	55410	0.669
7	980	180	19800	15000	324.48	25	25	1309	55307	24544.0	30893	55437	0.557
8	8850	0	0	0	0	25		8854	55307	55338.0	0	55338	0.000

If a PV only system is desired, PVHS components computed include a 43.56 kWp PV array, a 33 kWp PV inverter, a battery bank with capacity 561.6 kWh, a 25 kW bidirection inverter, and a 25 kW diesel generator with very low operating time of 9 hr/yr. The diesel generator determined ensures power supply reliability during prolonged hours of low solar radiation and unexpected variations in power demand or growth in energy demand [13]. However, ff the desired generator hours are increased to 980 h/yr, the PVHS computed include a 19.8 kWp PV array, a 15 kWp PV inverter, a battery bank with capacity 324.48 kWh, a 25 KW bidirection inverter, and a 25 kW diesel generator with operating time of 1309 h/yr or 3.59 h/d. This operating time may correspond to the period of highest peak power demand at night for a Senegalese village with 750 inhabitats [4]. The battery bank capacity determined is 57.8% of the battery bank required in the PVHS option with a renewable energy fraction of 100%. Given that the bi-directional battery inverter capacity is assumed to be equal to the rating of the diesel generator rating in the PVHS, it will meet the morning power peaks. During the day when solar radiation increases the power output of the 15 kW photovoltaic string inverter will supply AC loads and also charge the battery bank. In the late evening when solar radiation reduces the 25 kW bi-directional inverter supplies the AC loads with the energy stored in the battery bank during the day. Considering that reductions in the sizes of components will reduce the initial investments required for PVHS more villages could be electrified. Additional PV array fields or other diesel generators could eventually be installed to either minimise operational costs or cope with an increase in daily energy demand [13]. Thus initial investmements and operational costs associated with PVHS could therefore be reduced to increase the number of remote villages that can be electrified in Far North Cameroon or in Sub-Saharan African countries which are characterised by high solar radiation levels.

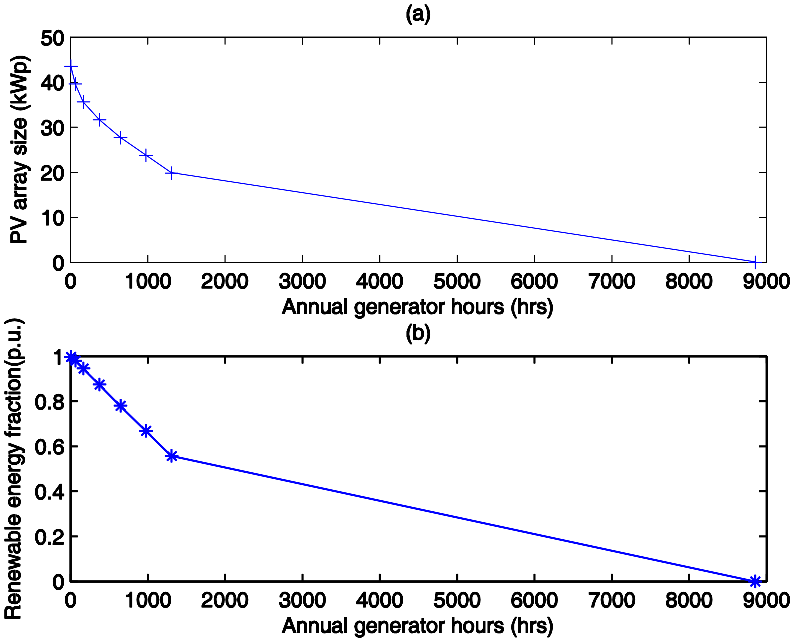

Figure 3: Annual generator hours versus (a) PV array size (b) Renewable Fraction

6 Conclusion

Energy access in remote areas of Sub-Saharan African countries is limited partly due to high costs of grid extension and partly due to low population densities and low energy densities. Lack of real-time data for energy resources and village electricity power consumption data limits the use of software or methods based on real-time models [1-7]. An energy balance model is presented in this study and tested on a monthly energy demand profile for a hypothetical village with 50 low voltage grid-connected customers and the energy outpur of solar modules at Garoua. The energy demand profile having a daily energy demand of 153.6 kWh/d is derived from the energy consumption data of 2019 low-voltage grid-connected customers recorded in 2007 for a rural council in Cameroon. An inequality in one unknown is resolved using a numerical approach based on desired annual number of diesel generator hours. PVHS were obtained for all desired annual generator hours in the range 0 – 8760 h/yr and only options with distinct renewable fractions were retained. The results obtained in this study also propose PVHS as in previous studies and suggest that initial investments and operational costs of PVHS could be reduced if diesel generator operates at least 3.59 h/d to satisfy peak load at night and charges battery bank.

For a renewable energy fraction of 0.998, the PVHS option included a PV array rating of 43.56kWp, a PV stringer rating of 33 kW, a bi-directional inverter rating of 25kW, a battery bank capacity of 561.6kWh and a 25 kW diesel generator with an operational time of 9h/yr or 0.025h/d. For a renewable energy fraction of 0.557, the PVHS option included a PV array rating of 23.76kWp, a PV stringer rating of 15 kW, a bi-directional inverter rating of 25 kW, a battery bank capacity of 324.48 kWh and a 25 kW diesel generator with an operational time of 1309h/yr or 3.59 h/d. PVHS components determined at a renewable energy fraction of 0.557 can meet the energy requirements of the hourly load profile estimated for a medium village in sengal with 750 inhabitants and the monthly energy demand derived for a hypothetical village in this study .This approach would allow more villages with similar monthly energy demand to be electrified in Far North Cameroon and in Sub-Saharan African countries which have high solar radiation levels. A pilot PVHS can be implemented in Bambui, Cameroon (6° 01’ N, 10° 17’ E) which has a solar insolation estimated at 5.36 kWh/m^2/d. The pilot project is feasible because, a 100 Wp solar home system implemented to supply energy to DC LED strips and energy efficient AC loads in a grid-connected home operates satisfactorily since 2015 [14]. The integration of a pilot PVHS project s with a 25 kVA single phase transformer connected to the grid at Mile 10 in Bambui would supply electrical energy to rural schools, rural industries, and rural businesses during the day and to about 40-60 rural homes which are often deprived of electricity as a result of unscheduled or prolonged grid failures.

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Biography

Dr. E. M. NFAH obtained a Bachelor's of Engineering Second Class Upper Division in 1995 and also a Master's of Engineering in Electrical/Electronics Engineering in 1997 from the University of Benin, Nigeria. In the grade of Assistant Lecturer at the FOTSO Victor Institute of Technology Bandjoun of the University of Dschang, Cameroon, he obtained the Diplome d'Etudes Approfondies and PhD in Electrical Engineering from the National Advanced School of Engineering of the University of Yaounde I in 2003 and 2007 respectively. In December 2008, he was promoted to grade of Lecturer and was appointed as the Head of Department of Electrical and Power Engineering at the Higher Technical Teacher Training College and Head of Development Division in the Directorate of Development, Physical Plant and Infrastructure of The University of Bamenda in December 2011. In November 2015 he was promoted to the grade of Associate Professor and was appointed Head of Department of Electrical and Electronic Engineering at the College of Technology of The University of Bamenda. In March 2017 he was appointed the Deputy Director of the National Higher Polytechnic Institute of The University of Bamenda.

He is a researcher in the area of Renewable Energy. The results of his research findings have resulted in nine publications in international peer reviewed journals. He has attended national and internal conferences to present his research findings in the area of Renewable Energy. The national and sub-regional dimension of his research contributed to the award of a 10-month post-doctoral study at Université catholique de Louvain-la-Neuve, Belgium by "Agence Universitaire de la Francophonie" for the 2009-2010 academic year. His current research activities involve evaluation of photovoltaic systems for energy security of urban homes and public buildings and industries. The economics of these systems for poverty alleviation is also of interest since this will facilitate the deployment of these technological options which have high initial costs.