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Novel LoadProGen procedure for micro-grid design in emerging country scenarios: application to energy storage sizing

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Abstract

This paper is devoted to describe the development, implementation and application of a novel procedure to properly design the electrification process in rural areas of Emerging Countries (EC). The procedure exploits a *bottom-up* approach, i.e. target applications are related to micro-grids devoted to satisfy the electrical needs of small communities. The procedure starts from microscopic data (i.e. single electric appliances) to effectively catch the customer needs (i.e. *bottom*) and it matches them with the available energy sources in the target area. In particular, a tool named *LoadProGen* developed by the Energy4Growing research group of Politecnico di Milano, is presented: the mathematical approach proposed is detailed and a real field case study relevant to a micro-grid deployed in Tanzania is provided. The tool is based on the gathering of information about the target area, i.e. to get information from interview and field audit, and on a stochastic approach to build up realistic estimation of the electric load profile of the considered uses. The energy needs forecast (cfr. load profile) is then adopted in a second procedure devoted to design a micro-grid capable to properly feed the loads. In this work, for sake of exemplification, this latter is supposed to be a photovoltaic based micro-grid integrated with an electrochemical storage.

Keywords: Microgrid; Emerging Countries; Electrochemical Energy Storage; Photovolatic; Energy Design.

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1. Introduction

Small-scale off-grid power systems (hundreds of kW) represent probably the most viable solution, in the short scenario, to the problem of access to electricity in rural areas of emerging countries (ECs). Despite a centralized electrification could be more efficient and cost-effective, governmental weaknesses and utilities indifferences towards the less productive areas of their countries have speed up the diffusion of decentralized off-grid systems in the last decades. Discussing about rural areas electrification process, one of the most critical problem is the evaluation of the energy needs and, consequently, the design of an electrical infrastructure capable to properly feed the loads.

In literature several approaches are proposed, nevertheless a common accepted approach is still missing. Sinha and Chandel [1] suggest to size carefully an energy system when based on real load variation, to limit the risk of under- or oversizing. In situations of rural electrification programs, Cabral et al. [2,3] and Kivaisi [4] stress the importance to correctly estimate electricity demand. Celik [5] discusses about the need of sizing off-grid photovoltaic systems using detailed load profiles, while Mandelli et al. [6] suggest how the optimum off-grid PV system configurations are significantly affected by load profiles. In this context, the need to identify a robust approach to forecast daily load profile clearly emerges. Theo et al. [7] reviews several works that determine load demand often using hourly time resolution and time frames of one day, and onsite measurement, as data source. Daily load profiles are often generated using arbitrary and unstructured approaches [8], without clearly indicating where they come from [9], or employing or adapting load curves of similar contexts ([10,11]), or by relying on some consideration about the functioning periods of electric appliances and/or load factors ([12–14]). Such an approach could drive to consistent underestimation or overestimation of the energy needs and, consequently, to an ineffective design of the micro-grid.

Pflugradt [16] developed a modelling tool for residential energy consumption (i.e. electricity, gas, residential hot and cold water) in developed regions, which simulates the behaviour of people in a household to generate load curves. Since it is focused at individual household level, the software does not provide any load curves for commercial buildings, and it is not appropriate for simulating populations above about a 1000 people. In the specific context of developing countries, Boait and Gammon [15] rely on the central limit theorem and Monte Carlo simulation to aggregate and then derive a possible electricity demand arising from a pool of intermittent and stochastic profiles. Mandelli et al. [8] introduce a novel new mathematical bottom-up stochastic procedure, which they formalized in the software LoadProGen (Load Profile Generator) implemented in MATLAB®, whose developments and implementation are presented in this paper.

2. LoadProGen Mathematical model

LoadProGen is a tool devoted to formulate daily load profiles, properly describing users' energy consumptions uncertainty (i.e. properly representing the stochastic nature of the load profiles).
LoadProGen is based on a bottom-up approach: load profiles are built from users' electric needs and habits that can be estimated or collected by interviews, audits, etc. . To do this, users are divided into different classes so that within each class users have the same type and number of appliances, and they use them with a similar behaviour. Considering the coincidence behaviour of the appliances, the tool defines the switching on instants for each appliance within each class and it obtains a daily load profile for the single user class; repeating this process for each user class, at the end it sums the profiles of the classes to find the total load profile. Specifically, a single user class profile is computed by means of the procedure schematically depicted in figure 1 that is shortly explained in the following paragraphs. With regards to the definition of the inputs of the procedure, in rural areas of emerging countries the data gathering is supposed to be based on audits and interviews devoted to identify the needs and to evaluate the possible energy behaviour of the users. Obviously, the collected data are characterized by high uncertainty in some parameters; consequently the modelling approach is not based on "crisp" variables, but on a statistical-like description of the needs.

In particular, the adopted model to evaluate the needs is based on the following inputs:

- Users are classified in classes and for each class j the total number of users represented (N_j) is detailed;
- Each appliance i in use by a single user in the class j is described by:
    - Nominal power of the appliance (P_{ij});
    - Number of appliance i used by a single user (n_{ij});

  - Specific power profile (SP_{ij}); in case the information is undetermined an average constant power profile is considered;
- User's behaviour is detailed in order to model how and when the appliances are used, the model is based on the following variables:
  - Total functioning time of the appliance in a day (h_{ij});
  - Minimum functioning cycle for the appliance (d_{ij});
  - Functioning windows in which the appliance in commonly used ($w_{F,ij}$);
  - Uncertainty on the functioning time (Rh_{ij});
  - Uncertainty on the functioning windows ($Rw_{F,ij}$).

The stochastic approach is based on the assumption that the sum of the functioning windows for each appliance can be longer than its total functioning time in a day, equation (1), in this way there are multiple combinations of functioning profile for each appliance.

$$\sum duration(w_{F,ij}) \geq h_{ij} \qquad \forall\ app\ i\ class\ j \qquad (1)$$

To set up the input data for the load curve computation, they are modified in order to consider the uncertainty on the functioning windows $w_{F,ij}$ and time h_{ij}. In this way, it is possible to increase the variability of the profile among different days, obtaining a more realistic distribution of the load profiles. The values of uncertainty are defined, respectively, as a percentage of the functioning time and a percentage of the functioning windows duration, so that the input values are modified according with equations (2), (3) and (4).

$$h_{ij} = h_{ij} \pm random(h_{ij} \cdot Rh_{ij}) \qquad (2)$$
$$w_{F,ij}^{start} = w_{F,ij}^{start} \pm random(w_{F,ij} \cdot Rw_{F,ij}) \qquad (3)$$
$$w_{F,ij}^{end} = w_{F,ij}^{end} \pm random(w_{F,ij} \cdot Rw_{F,ij}) \qquad (4)$$

The procedure builds up the coincidence behaviour of the appliances and the power peak value ($P_{L,j}$) with regards to the empirical correlation between number of users N_j, coincidence factor $f_{c,j}$ and load factor $f_{L,j}$ of the class [eq 7]; where a represents the limit case of rate between coincidence factor for infinite users and the load factor of the j class [8].

In accordance with input data and equations (5, 6, 7), it is possible to proceed to estimate the peak power value for each class with an iterative process:

1) the initial load factor $f_{L,j\,0}$ can be computed by the set of input data;
2) the coincidence factor $f_{C,j}$ can be computed via equation (7);
3) the peak power $p_{L,j}$ can be computed via equation (5);
4) the new load factor can be computed via equation (6);

Then repeating step from 2) to 4) convergence can be reached to a couple of load and coincidence factor for the given user class.

$$f_{c,j} = \frac{p_{L,j}}{p_{max,j}} \qquad (5)$$
$$f_{L,j} = \frac{E_{c,j}}{24h \cdot p_{L,j}} \qquad (6)$$
$$f_{c,j} = a \cdot f_{L,j} + \left(1 - a \cdot f_{L,j}\right) \cdot N_j^{1-\alpha} \qquad (7)$$

In equation (6) the daily electric energy consumption for a single user class $E_{c,j}$ is computed as:

$$E_{c,j} = \sum_i n_{ij} \cdot P_{ij} \cdot h_{ij} \qquad (8)$$

In order to define the peak time, a power peak window is evaluated; this window corresponds to the period in which the maximum peak could theoretically occur if all the appliances were switched on at the same time. Then the power peak time is randomly chosen within the peak window. The profile computation is then based on an iterative process that defines the instant t_{kij} in which each appliance k of the type i within the considered class j is switched on. Once defined the switching instants, the load profile can be computed considering that the appliance will be on for a time equal to the minimum functioning cycle period d_{ij} (if it has a specific functioning profile SP_{ij}, the duration of the minimum functioning cycle d_{ij} will be equal to the duration of its specific profile), see equation (9). Iterations are necessary because the power peak value has to result equal to the one previously estimated. In order to achieve this, the switching instants are sampled with different distribution probability: uniform probability distribution if the appliance does not contribute to the peak, normal probability if the appliance contributes to the peak. The standard deviation of the normal probability distribution is redefined in every iteration in order to obtain the power peak value that respects the correlation between coincidence factor and load factor.

$$LP_j(t) = \sum_i \sum_{k=1}^{n_{ij}} P_{ij} \cdot state_{kij}(t) \tag{9}$$

$$\text{Where} \begin{cases} state_{kij}(t) = 1 \; if \; \exists \; t_{kij} : \; t_{kij} \leq \; t < t_{kij} + d_{ij} \\ state_{kij}(t) = 0 \; if \; \nexists \; t_{kij} : t_{kij} \leq \; t < t_{kij} + d_{ij} \end{cases}$$

The procedure above considers that during the functioning time every appliance absorbs the nominal power for the functioning cycle period d_{ij}. This is not realistic for some appliances that vary the absorbed power during the functioning cycle, such as washing machines or other specific appliances. In this case the specific profile for the appliance (SP_{ij}) is considered with two steps: the load profile is initially computed considering a constant functioning cycle absorbing nominal power (in this way the convergence of the peak value is not compromised); at the end of the iterations, the profile with nominal power is subtracted from the load profile of the class and the specific profile is added, as detailed in equation (10).

$$LP_j(t) = LP_j(t) - P_{ij} + SP_{ij}(t - t_{ij}) \qquad \forall \;\; t_{ij} \leq t < t_{ij} + d_{ij} \tag{10}$$

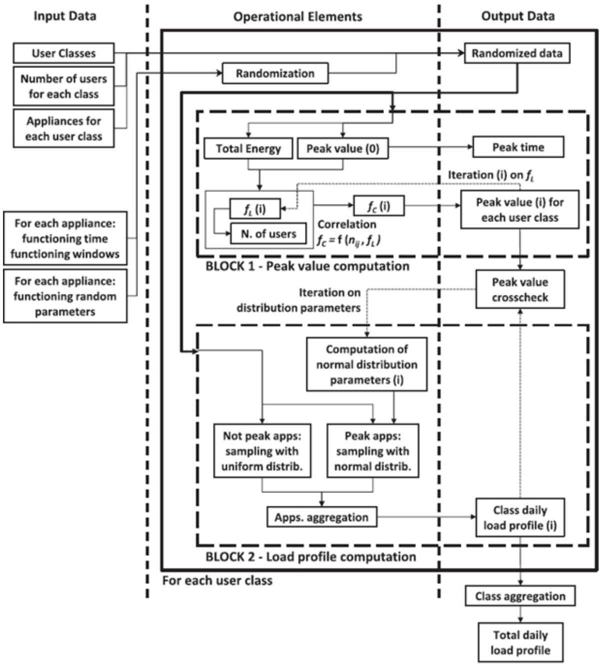

Fig. 1. LoadProGen procedure logical structure

This is a simple way to consider specific operation profiles, and it works when the number of appliances with specific profiles is limited compared with the total number of appliances. A high number of specific profiles could compromise the convergence for the power peak value. When all the classes are computed, the profiles generated for each user class are summed and the total load profile is obtained. Due to the stochastic approach in defining the peak time and the switching on times of each appliance, the algorithm computes a different load profile each time it runs, so that *LoadProGen* allows formulating different possible load profiles all complying with the given input data.

LoadProGen MATLAB tool is public available on a Facebook based repository (*www.facebook.com/energy4growing2014*); in particular, the procedure has been recently provided with new functionalities and with a graphical user interface (GUI) (figure 2). In the last version, the possibility to change the time step of the profile is considered: the user can decide it among one second, one minute, fifteen minutes or one hour. It is possible to run the tool directly from the user interface and the user can decide to load the input data from a spread sheet or adding them directly through the GUI. To increase the flexibility of the tool, it is also possible to run it from the MATLAB command line, in this way an integration of the tool with other procedures is possible and simple.

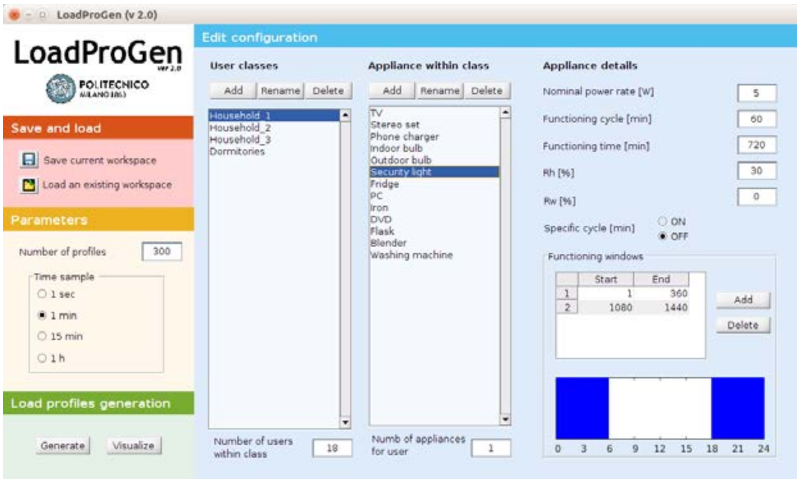

Fig. 2. *LoadProGen* User Graphical Interface (GUI)

3. Ngarenanyuki Study Case

In order to validate the model proposed, we provide a real-life study case based on a micro-grid deployed in Tanzania on April 2014. For such a study case, the interviews and audit developed by NGO operator ex-ante to the micro-grid deployment and the data log of energy flows measured in the micro-grid are available, from May 2014 to December 2016. Consequently it results an ideal test for the procedure proposed. In particular, the micro-grid under study has been developed within the Energy4Growing project by Politecnico di Milano Dept. of Energy in Ngarenanyuki Secondary School (Arusha, Tanzania). The architecture deployed is based on an advanced interface converter and control switchboards designed to manage the school 10kW hybrid micro-grid comprising: micro-hydro system, genset, PV-inverter and lead-acid battery bank (detailed information on the project are reported in https://it-it.facebook.com/energy4growing2014/).

The project was developed to exploit Ngarenanyuki School as a research laboratory: for instance, actual micro-grid functioning parameters (voltage, current, frequency, etc.) are sampled each second and logged via an industrial PLC; finally, thanks to a satellite connection, all the data are shared and stored with the Politecnico di Milano ICT facilities. Such data are crucial for scientific research and to monitor the behaviour of the installed system in order to ensure quality of supply, reliability, etc. .

Focusing on the energy needs of the school, figure 3 reports the total energy consumption of about 550 days (from May 2014 to December 2015, some days are missing due to faults in data collection). It can be observed that the load profile shows four main trends: during the nights (from 10/11 p.m. to 5 a.m.) the power required is almost constant and normally less than 500 W (dark blue area); in the early morning, when people wake up (from 5 to 6 a.m.), there is a first peak of absorption of energy and the power required is between 1 and 2 kW (the light blue area around 6 a.m.); during the morning and the afternoon the consumptions are really unpredictable because there are appliances switched on and off not related to scheduled activities (the area between 6 and 18 where the colours are more mixed); the last trend is visible in the evening, when the power required remains more or less stable between 1 and 2 kW (the light blue area from 7 p.m to 10/11 p.m.). This behaviour can be observed also in **Errore. L'origine riferimento non è stata trovata.** which reports the mean daily energy profile for each month. **Errore. L'origine riferimento non è stata trovata.** clearly depicts how the energy needs are affected by seasonal variation: the mean profile varies greatly from one month to another; such a behaviour is correlated both to the climate conditions and to the activities in place in the school (e.g. lectures, exams, holiday), resulting in a quite irregular power profile. **Errore. L'origine riferimento non è stata trovata.** reports the average daily energy need: starting from 2015 in Ngarenanyuki Secondary School people had regular energy provision and, consequently, some new appliances have been deployed in order to improve the quality of life. Nevertheless such a growth resulted to be limited because of the limited capacity of the micro-grid deployed. Actually, the data collected in Ngarenanyuki clearly depicts how in a real life scenario there is not a single, clear, load profile, but loads change over time with respect to several factors. Despite this issues, it is necessary to summarize all these information in order to design a micro-grid capable to feed at best the needs: this is the challenge of *LoadProGen*.

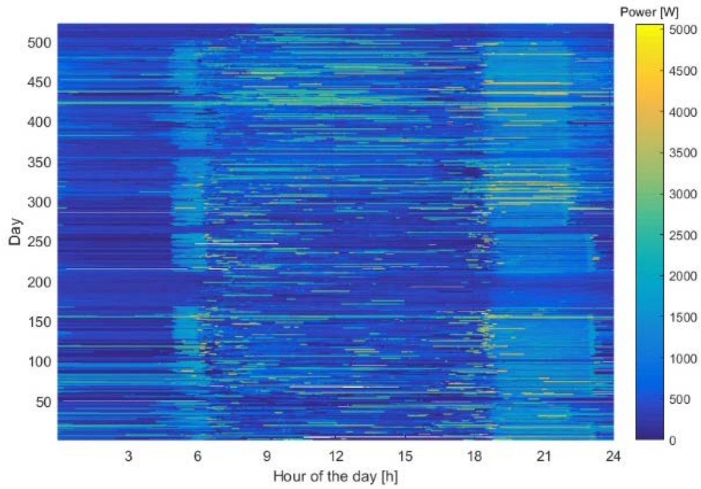

Fig. 3. Carpet plot of the power profiles acquired in Ngarenanyuki

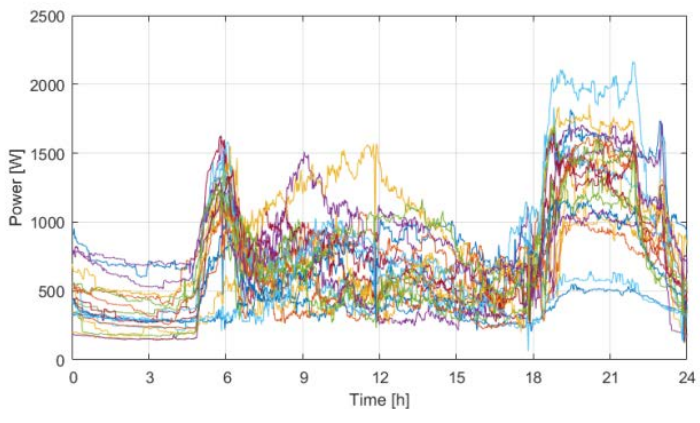

Fig. 4. Daily load power profile (mean value per months) in Ngarenanyuki Secondary School (measured values)

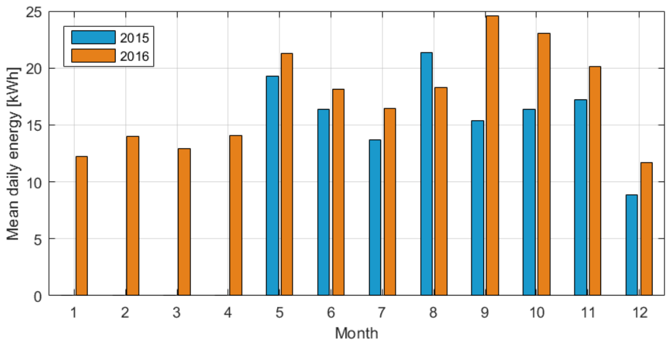

Fig. 5. Daily energy needs (mean value per month) in Ngarenanyuki Secondary School (measured values)

4. *LoadProGen* Model Validation

In order to depict the capabilities of *LoadProGen* this section reports the numerical simulation performed for the Ngarenanyuki case study. In 2014 (ex-ante the micro-grid deployment) field surveys were performed collecting data about: the number and the type of appliances in use, their nominal power, and some qualitative information about users' behaviour with respect to each appliance (see Appendix 1). In order to generate the profiles, the collected data are organized and provided as input to *LoadProGen*. Some assumptions result necessary, in particular to define the functioning time and the functioning windows of the appliances: in some cases, these values are well known, but frequently the information is qualitative or missed. In these cases, parameters are estimated according with the main known activities of the school.

LoadProGen is a stochastic procedure, i.e. it generates several load profiles up to respect a convergence criterion based on the power mean value.If, for each time step, the mean value from iteration N to iteration N+1 (viz. adding one more curve to the already N simulated curves) changes less than 0.1%, the procedure is stopped (for the Ngarenanyuki study about 200 iterations – i.e. 200 curves – are required). **Errore. L'origine riferimento non è stata trovata.** depicts in grey the aggregation of all the N profiles generated by the procedure, whilst in blue it reports the mean profile (red lines are relevant to the standard deviation around the average value). Eventually, the profiles generated with *LoadProGen* has been compared with the measured ones. Indeed, in **Errore. L'origine riferimento non è stata trovata.** (top plot) the average profile generated with *LoadProGen* is compared with the measured average profile (the latter results to be the mean profile sampled from May 2015 to December 2016). Profiles are similar, even if during the morning the *LoadProGen* load profile underestimates the real load and in the late evening the load profile is overestimated. This may follow from the functioning windows not properly estimated or from unknown appliances not considered in the inputs. Moreover, in **Errore. L'origine riferimento non è stata trovata.** (bottom plot) a similar comparison is reported between the mean *LoadProGen* profile and the mean profiles for each month. The estimated mean profile is almost in the center of the family of real profiles, this meaning that we are able to describe in an effective way the average behavior of the curve.

Actually, it is worthwhile to stress the stochastic behaviour of the load profile in a real life micro-grid, this motivate the approach proposed with *LoadProGen*. Obviously the load profile forecast (estimation) error is correlated with the reliability of the information collected on the field (e.g. surveys, interviews), that is, *LoadProGen* users are quite important in order to properly set the model parameters. The proposed procedure simplifies the role of the human expert and results to be effective in the management of the challenging case study .

5. Energy Storage sizing based on *LoadProGen* approach

Energy storage solutions are supposed to be a cornerstone for an effective rural area electrification; authors in ([6], [17]) proposed an algorithm specifically designed for emerging countries, similarly in [18] a review about emerging countries scenarios for energy storage application is presented. In the following, such procedures have been coupled with *LoadProGen* tool and adopted to design of a "theoretical" new micro-grid capable to "optimally" feed the

Ngarenanyuki Secondary School. The new micro-grid is supposed to be based on PV generators coupled with electrochemical batteries. By extending the *LoadProGen* concept, the tool can be used to create different sets of daily load profiles that include intra-week and seasonal variability. Combining the different sets, it is possible to create realistic yearly load profiles. Then, each of the yearly load profile can be projected over the time, in accordance with different load evolution scenarios. In this way, *LoadProGen* can be exploited for the robust design of off-grid systems that properly takes into account a large set of possible load conditions. In the following the procedure adopted is summarized:

1. *Energy needs estimation:*
   LoadProGen has been employed to formulate a number of stochastic yearly load profiles (as described in the previous sections). Then each of the yearly load profile has been extended over the entire PV+BESS plant lifetime (20 years) in accordance with six linear load evolution scenarios.
2. *Techno-economic modelling:*
   The models for the simulation stage of the PV+BESS system are based on energy steady-state simulation approaches [17]. Specifically:
   - The PV array power output depends on the solar radiation, on the effect of the PV cell temperature, and on the balance of system efficiency;
   - The battery bank model considers charge/discharge efficiencies, minimum threshold in the state of charge (SOC), power/energy ratio, and it employs the rainflow counting method to evaluate battery life-time. In details, battery bank life-time depends on its SOC evolution and hence replacement cost depends on the particular load profile simulated.
   - All the system components (including inverters) are economically modeled by means of investment and replacement costs based on their size. Yearly operation and maintenance costs are given as an overall value for the whole system in accordance with the PV array size.

   Technical and economical parameters are reported in Table 1. Cost information about PV modules, batteries, and off-grid inverters are the result of a survey in the Arusha region.
3. *Robust sizing method:*
   The robust sizing of the PV+BESS micro-grid under load profiles uncertainty works as follows:
   - For a given lifetime load profile, ranges of PV array sizes and battery capacities are defined. Then the lifetime operations are simulated for all of them with a minute time-step. The PV-battery combination that results in having the minimum Net Present Cost (NPC) while respecting the maximum Loss of Load Probability (LLP: defined by the designer) is the optimum solution**.**
   - The same simulation process is repeated for the next lifetime load profile. The most robust solution (PV_{rbt} ; $BESS_{rbt}$) is computed as the weighted average of all the obtained optimum solutions, given their frequencies of occurrence.

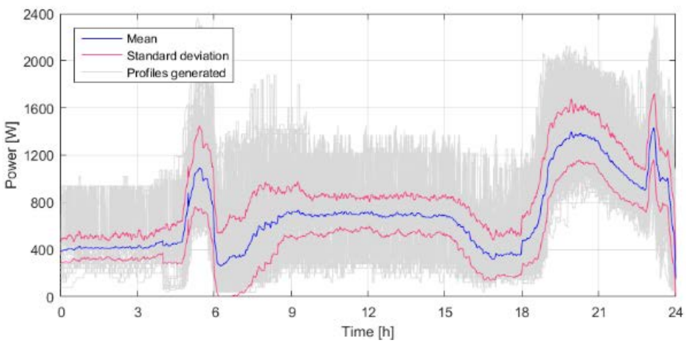

Fig. 6. Load profiles generated with *LoadProGen*

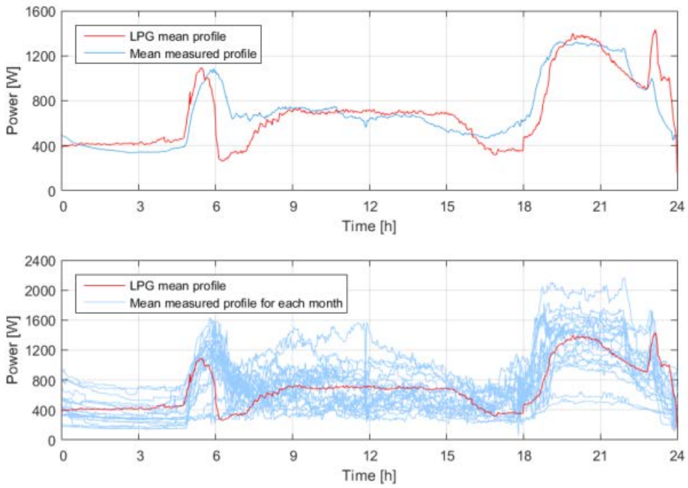

Fig. 7. Comparison between LPG mean load profile and measured monthly average profiles

Figure 8 shows the obtained results and highlights the opportunities provided by *LoadProGen* in the design of off-grid systems. By taking into account variability on the load consumptions, the design of the PV+BESS micro-grid is given in term of an area of optimum solutions rather than a single deterministic solution. By assuming different load evolution scenarios, a map of solutions is created that shows how the design changes due to future variations in the electric consumptions. In particular, the rainbow colormap identifies with different colors the frequency at which a specific configuration (PVsize; BESSsize) has resulted in being the optimum one (PVopt; BESSopt) among the N simulated lifetime load profile. We normalized the frequency according to the most frequent combination in the considered scenario. Moreover, six linear load evolution scenarios have been simulated. Each robust solution (PVrbt ; BESSrbt) is computed as the weighted average (given the frequencies of the optimum points) within the related area of solution. As expected, the sizes of the components increase as the yearly load demand increasing factor raises. The NPC and LCOE raise as well because we are assuming to fulfill the same level of load during the plant lifetime (LLP fixed at 5%).

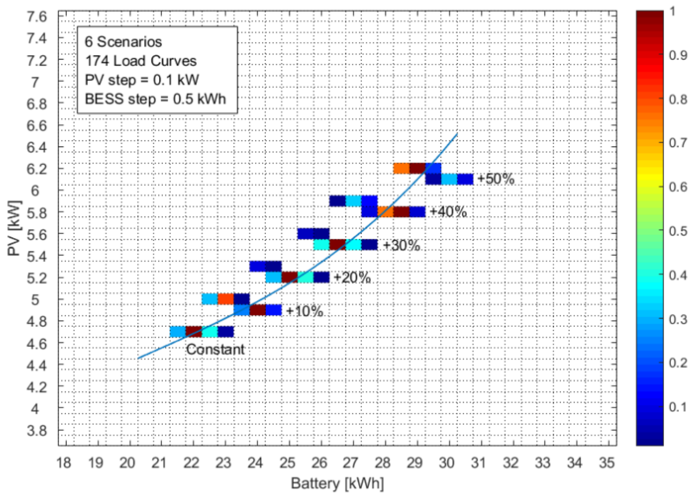

Fig. 8. PV+BESS micro-grid robust design: map of solutions (the rainbow colormap helps in normalizing the frequency of occurrence of each PV-BESS combination with respect to the most frequent optimum plant in each scenario).

6. Conclusion

This paper addresses the electrification problem in emerging countries; in particular a new release of a tool named *LoadProGen* is presented. The tool is devoted to generate realistic load profiles for off-grid micro-grids, managing in a stochastic approach the information collected by on-site surveys.

In order to demonstrate the capabilities of the approach, numerical simulations for a real life case study are reported; such a study case is relevant to a secondary school in Tanzania where the research team deployed a micro-grid. Thanks to the availability of ex-ante (on-site surveys) and ex-post (micro-grid data logging) data, the case study results to be an ideal testing case for *LoadProGen*.

The positive results validate the approach proposed and, on top of that, clearly depicts how in real life scenario there are many factors affecting the load behavior, consequently such a challenging task require strong studies and tools in order to be properly evaluated.

Eventually, the load profiles generated thanks to *LoadProGen* have been adopted to optimally design a micro-grid based on PV generator coupled with an electrochemical storage system. This latter resulted to be a numerical example on the capabilities of the stochastic approach proposed for the energy storage sizing.

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Appendix A. Ngarenanyuki Secondary School Audit

In this appendix is detailed the table reporting the data collected with interviews and audit in Ngarenanyuki Secondary School (Arusha, Tanzania) in 2014. Actually the school was previously electrified thanks to an un-efficient and un-reliable diesel generator devoted just to feed the mandatory needs. Most of the appliances hereinafter reported was not working or resulted to be not available (i.e. desiderata) in the school.

Location	*Appliance*	*Unit*	*Power*	*Functioning hours per day*	*Usage*
Building 2					
Office Headmaster	Laptop PC	1	40	from 08:00 to 19:00, sometimes 19:00-22:00	
Office HM Secretary	Desktop PC	1	400	from 08:00 to 16:00	continuously
Office HM Secretary	Laptop PC	1	40	from 08:00 to 16:00	continuously
Office Headmaster	Neon Light	1	40	5 days per week, from 08:00 to 19:00, sometimes 19:00-22:00	
Office HM Secretary	Neon Light	1	40	6 days per week, from 08:00 to 16:00	
Office HM Entrance	Neon Light	1	40	7 days per week, from 08:00 to 16:00	
Laboratory 1	*Fluorescent Light*	*5*	*9*	*not common, from 19:00 to 23:00 before exams*	*continuously*
Laboratory 2	*Fluorescent Light*	*5*	*9*	*not common, from 19:00 to 23:00 before exams*	*continuously*
Laboratory 3	*Fluorescent Light*	*5*	*9*	*not common, from 19:00 to 23:00 before exams*	*continuously*
Office HM Secretary	*Photocopy Machine*	*1*	*1500*	*during examination period, from 08:00 to 16:00*	
Office HM Secretary	Printer	1	150	from 08:00 to 16:00	continuously
Security Light	Neon Light	4	40		
Building 3					
Library Computer Room	Laptop PC	3	40	once a week, closed at night	
Library Book Room	Desktop PC	1	40	every two weeks, not at night	
Library Toilet	Fluorescent Light	7	9		
Library Study Room	Neon Light	9	40	19:00-23:00	continuously
Library Computer Room	Fluorescent Light	1	9	19:00-23:00	continuously
Library Book Room	Fluorescent Light	1	9	19:00-23:00	continuously
Library Study Room	*Projector*	*1*		*once a week, closed at night*	
Library Study Room	*TV set*	*1*	*300*	*once a month*	*2 hours*
Building 4					
Offices Burser	Laptop PC	1	80	from 06:00 to 21:00	always operating
Offices Science Teacher	*Laptop PC*	*1*	*80*	*once a week, sometimes 19:00-23:00*	*2-3 hours*
Offices Staff	*Fluorescent Light*	*10*	*9*	*not common, sometimes 19:00-23:00*	*continuously*
Offices Staff	Neon Security Light	2	40		
New Computer Room	*TV set*	*1*	*250*		
Building 5					
Classes	Fluorescent Light	8	9	from 19:00 to 23:00	continuously
Classes	Neon Security Light	1	40	from 19:00 to 05:00	continuously
Building 6					
Classes	Fluorescent Light	16	9	from 19:00 to 23:00	continuously
Classes	Neon Security Light	4	40	from 19:00 to 05:00	continuously
Building 7					
Office Second HM	Laptop PC	1	80		
Classes	Fluorescent Light	16	9	from 19:00 to 23:00	continuously
Office Second HM	Fluorescent Light	1	9	not common, sometimes 19:00-	continuously

				23:00	
Academic Room	Fluorescent Light	1	9		
Common Room	Fluorescent Light	1	9		
Classes	Neon Security Light	2	40	from 19:00 to 05:00	continuously
Dormitory Girls					
Dormitory	Fluorescent Light	31	9	from 05:00 to 06:00, from 23:00 to 23:15	continuously
Common Room	Neon Light	2	40		
Offices		2			
Laundry	Fluorescent Light	2	9		
Showers	Fluorescent Light	2	9		
Toilets	Fluorescent Light	2	9		
Security Light	Fluorescent Light	4	9		
Dormitory Boys					
Dormitory	Fluorescent Light	12	9	from 05:00 to 06:00, from 23:00 to 23:15	continuously
Toilets	Fluorescent Light	3	9		
Security Light	Fluorescent Light	4	40	from 19:00 to 05:00	continuously
Kitchen	Fluorescent Light	6	9	from 04:00 to 06:00, from 19:00 to 23:00	
	Security light	2	40		
Dining Room	Light	8	9		
Garden	Water pump	1	700	every day, 05:00-09:00	continuously
	Egg incubator	1	40	all day	continuously
Shop	Fridge	1	500	all day	
	Fluorescent Light	1	9	19:00-21:00	continuously
Restaurant	Fluorescent Light	1	9		
Kitchen (shop)	Fluorescent Light	1	9		
	Security light	3			
Residential	Fridge	1	80		
	Fluorescent Light	52	9		
	TV set	1	250		
	Security Light	17			
Rest house	Light	15			
	Neon Security Light	2	40		
Toilets	*Neon Light*	*1*	*40*		