Smart Grid Method for the Lubumbashi Distribution Network Based on Provision of Renewable Energy Resources

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Abstract: The development of smart grids (SG) in the electrical network is the subject of many studies nowadays. This new technology seems to be as an additional tool and the perfect solution which the D.R. Congo could use to achieve the objectives of the efficient management of electrical energy, electrical network security, and the inclusion of renewable energy sources. The rise of these new networks brings together many economic issues.

This study is essentially focused on the incapability of the National Electricity Company (SNEL) which still retains the monopoly of production and distribution of energy to individuals, industries and mining companies. The incorporation of a system of control and management of the two-ways energy flow between the sources of electricity production and users via an intelligent distribution network, considering several specific constraints and performance required, will allow us to highlight the influence of intelligence in a distribution network as complex as that of the city of Lubumbashi. This study reviews the challenges of renewable energies in the environment of the city of Lubumbashi, the modeling of the distribution network, the introduction of intelligence control in the network and simulation using computer tools to see the contribution of these results to the entire electrical system. Finally, the integration of new renewable energy sources associated with its monitoring system is planned to stabilize this network by increasing the efficiency of the system with 25 percent in power quality.

Keywords: Smart electrical network, Optimization, Monitoring and control, Renewable energy resources.

1. INTRODUCTION

Together, energy efficiency, real-time management are major issues in today's distribution networks. The same is true of issues related to the optimal use of electrical energy, especially in the context of countries in the South [1]. In Katanga alone today there is a deficit of 1,200 MW hence the management of this problem has led to several alternatives including load shedding. Electrical energy being only slightly storable, the same goes for the more economical and profitable management of the latter based on the principle of balance between consumption and demand [2, 3]. From the above, it appears that the optimization of the system has caught the attention of various researchers and has made it possible to highlight various techniques ranging from conventional to digital. So, it is convenient to apply these techniques to solve these problems. On the other hand, ecological problems and the migration to sustainable and clean energies have increased the demand for renewable energies which are the energies of tomorrow; to prevent the problems caused in recent years in the use of fossil fuels. [7-9]. Fossil fuels have caused several environmental problems. In the city of Lubumbashi as in the whole world, the problem of pollution arises, endangering the very future of our planet [10]. With a potential of 39,000 MW in renewable energy, the DRC has an advantage in its use. The challenge remains because the cost of such projects is still high. [11] The industry must overcome several technical challenges to supply renewable energy in significant quantities [12]. Smart grids better integrate renewable energies. It allows us to increase overall energy efficiency by reducing consumption peaks, which reduces the risk of widespread breakdowns. Finally, they limit the environmental impact of electricity production by reducing losses [13]. It is thanks to combined computer and communication technologies that the smart grid manages to optimize production, distribution, and consumption [14-16]. The use of Automatic Voltage Regulators and Automatic Voltage Regulators (AVR) helps to counter the effects of disturbances that continuously shake power grids. The use of new FACTS technologies is a way likely to provide relief that seems better in the stability of the network. FACTS systems allow transmission circuits to be used at their maximum thermal capacity and provide the power system with greater flexibility. Many generators would quickly lose synchronism without the damping provided by Power System Stabilizers (PSS) [17, 18]. Several advantages are brought to the electrical networks

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among others the reliability thanks to the use of power electronic controller characterized by a great speed of reaction, the flexibility in the control of the power transient stability. For real-time supervision, many measurements must be taken from the system, analyzed, and monitored remotely using SCADA (Supervisory Control and Data Acquisition [19, 20]. Automatic Generator Control (AGC) is a distributed high-ratio closed-loop control scheme that optimally reprograms generator power setpoints to maintain frequency and tie line rates at their specified values [21-23]. and thanks to these advances in research, it is therefore topical in the world of the rapid implementation of smart grids [24]. Smart grids, a booming market in the era of climate change and the urgency of ecological transformations, according to the market reports of Specialist in Business Information, its growth is 20% per year, [25] and for these reasons, this work has implemented the solution solving together the problems of load shedding and blackout in the MG electrical system [26].

2. PROBLEM FORMULATION

The MG structure used in this work is presented in Figure **1**. The system is composed of four renewable energy sources (RES), namely, a small hydropower, solar (PV), wind energy (WT) and battery storage systems (BSS). Additionally, from the consumer's side, there are two main groups of loads which are *n* non-critical loads *(*P_{L1}... P_{Ln}) and *m* critical loads characterized by hospitals can be found in the Lubumbashi region ($P_{L1}{}^{C}$). The representation of the power system under study is given Figure **1** as follow:

3. MULTI-OBJECTIVE FUNCTION

The problems of energy deficit led to the establishment of the load shedding system. However, the demand remains high so that the connection of renewable energy sources; in this case: the wind turbine and the photovoltaic will make it possible to compensate for this deficit. In addition, the system must be able to follow the variation in output of the power demand according, of course, to the demand. Thus, we will obtain a stability and a balance of the MG. To compensate for the major drawback of renewable energies, which is availability, a thermal source is inserted into the system and will therefore only be a backup source for short periods of time depending on whether the main sources are not operational or are not at the level normal supply.

The system thus considered can provide users with neither more nor less energy, but the optimum. Solving this type of problem in this way amounts to maximizing the availability of energy under the constraints of non-critical equilibrium and network stability. It is compatible with energy efficiency and can significantly generate very high savings and allow great returns on investment.

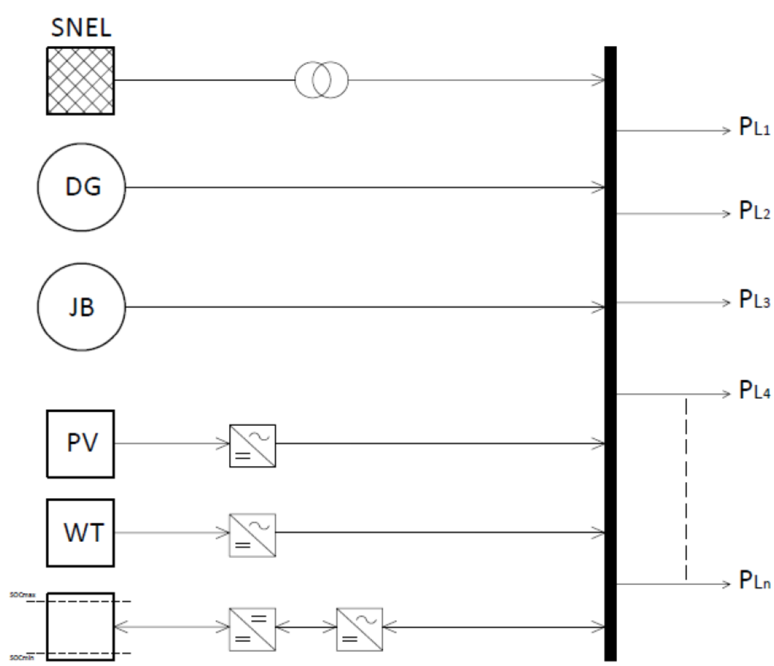

Figure 1: Representation of the MG under study.

3.1. First Objective Function

A desirable optimization is determined by analyses of the load shedding time diagram, carried out with an adequate digital system realize the various real-time piloting necessary for this hybrid system. Given that the power generated and consumed varies as a function of time, the objective function of equation (1) solves this mathematical problem by optimizing upstream and downstream these evolutions over time for the thermal generator. This is intended to minimize the cost of using the thermal generator and, by extension, fuel consumption. This part of the problem can be characterized by the first objective function expressed by equation (1) as follows:

$$\mathrm{Obj}_{fx1} = \min \left\{ w_1 \times \sum_{i=1}^{N_s} \sum_{j=1}^{N_s} P_{DG_{ij}}(i) \times \Delta t \right\}, \quad \begin{Bmatrix} 1 \le i, j \le N_s \\ w_1 = 0.10 \end{Bmatrix} \tag{1}$$

Where Δt is the time attributed to the utilisation generators in mining and industry areas; P_{DGij} is the output power from the thermal generator system to the hybrid system; i is the time horizon and N_s is the number of time periods considered for the optimization study of the hybrid system, w_1 is the priority factor considered for the use of the fuel applied to the thermal generator considered in the MG system.

3.2. Second Objective Function

The second objective function is characterized by the reconsideration of the use of the additional power produced (P_{SNEL}) of the national network of the National Electricity Company (SNEL). This parameter expresses on the one hand the deficit in the supply of electricity via the hydroelectric power stations which serve the city of Lubumbashi and on the other hand advice to new users to be considered as unused by the MG distribution system. These main hydroelectric power stations are Nseke and Nzilo on the Lualaba, Mwandigusha and Koni on the Lufira. This value may vary depending on the operating conditions, in particular: the drop height and the hourly demand. At a specific time i, the excess power generated can be expressed by the equation (2) as follows:

$$\mathrm{Obj}_{fx2} = \min \left\{ w_2 \times \sum_{i=1}^{N_s} \sum_{j=1}^{N_s} P_{SNEL_{ij}}(i) \times \Delta t \right\}, \quad \begin{Bmatrix} 1 \le i, j \le N_s \\ w_2 = 0.10 \end{Bmatrix} \tag{2}$$

where P_{SNEL} is the insufficiency of SNEL's electricity production not necessary for MG in the event of a load shedding situation.

3.3. Third Objective Function

The Renewable energy will account for almost 90% of the increase in total electricity capacity in the world in the next decade according to a new report from the IEA (International Energy Agency). This third objective function aims to maximize the renewable energy produced (PRE) by any source such as wind turbines (WTG), photovoltaics (PV), biomass and others. It is characterized by equation (3), and it is expressed as the ratio of the additional consumption considered to maintain the production demand balance during the time t. However, it is calculated by the following equation (3):

$$\mathrm{Obj}_{fx3} = -\min \left\{ w_3 \times \sum_{i=1}^{N_s} \sum_{j=1}^{N_s} P_{RE_{ij}}(i) \times \Delta t \right\}, \quad \begin{Bmatrix} 1 \le i, j \le N_s \\ w_3 = 0.30 \end{Bmatrix} \tag{3}$$

3.4. Fourth Objective Function

The difficulties caused by the load shedding problems in the MG power system will lead us to formulate the fourth objective function which will be based on maximizing the amount of relative additional power generated by the GreenBox technology system (GBS or JB). This is to ensure that in the event of a lack of power, the remaining power value will still respond correctly to MG balancing. For this, the objective function is written by equation (4) as follows:

$$\mathrm{Obj}_{fx4} = -\min \left\{ w_4 \times \sum_{i=1}^{N_s} \sum_{j=1}^{N_s} P_{Add_{ij}}(i) \times \Delta t \right\}, \quad \begin{Bmatrix} 1 \le i, j \le N_s \\ w_4 = 0.50 \end{Bmatrix} \tag{4}$$

Where w_4 is the priority factor attributed to excess energy generated by the RERs and considered for the fourth objective function of the MG system. The combination of equations (1) and (4) will solve the Lubumbashi MG system on the load shedding system presented in this chapter. Ultimately, for the whole system the multi-objective function is the summation of four equations expressed above. It is therefore expressed by equation (5) as follows:

$$\text{Multi-Obj}_{fx} = \begin{Bmatrix} \min\left(w_1 \times \sum_{i=1}^{N_s}\sum_{j=1}^{N_s} P_{DG_{ij}}(i) \times \Delta t \right) + \\ \min\left(w_2 \times \sum_{i=1}^{N_s}\sum_{j=1}^{N_s} P_{SNEL_{ij}}(i) \times \Delta t \right) \\ -\min\left(w_3 \times \sum_{i=1}^{N_s}\sum_{j=1}^{N_s} P_{RE_{ij}}(i) \times \Delta t \right) - \\ \min\left(w_4 \times \sum_{i=1}^{N_s}\sum_{j=1}^{N_s} P_{Add_{ij}}(i) \times \Delta t \right) \end{Bmatrix} \tag{5}$$

The results thus obtained will serve as a basis for the complete resolution of the problem through the establishment of the constraint equations. This will be the subject of the next section of our study.

4. MICROGRID CONSTRAINTS

The approaches for this study must consider a certain number of constraints and must satisfy several criteria. The first constraint is that of the balance between production and demand. The latter goes through the study of the power balance. The second constraint is frequency stabilization for thermal generators, hydroelectric and GreenBox systems. The third constraint is that of the state of charge of the battery system (SOC). The fourth and final constraint is that of the limits of the control variables of the MG system under study.

4.1. The Power Balance Equation

Equation (6) in continuous form, expresses the power balance at any connection point and at any specific time. The power supplied must be greater than or equal to the power requested for each common point:

$$P_{DG_{ij}}(k) + P_{RE_{ij}}(k) + P_{Add_{ij}}(k) + P_{SNEL_{ij}}(k) \geq \sum_{i=1}^{n} P_{Li} \quad , \begin{Bmatrix} 1 \leq i, j \leq n \\ 1 \leq k \leq N_s \end{Bmatrix} \tag{6}$$

where $P_{DGi,j}(k)$ is the power from the i^{th} to the j^{th} diesel generator systems at a specific time, $P_{REi,j}(k)$ is the power supplied from the i^{th} to the j^{th} renewable energy systems, $P_{SNELi,j}(k)$ is the power from the SNEL generation unit system at any period of time, $P_{Addi,j}(k)$ is the additional power to be delivered by the GreenBox systems (GBS) to prevent the disadvantages caused by downtime of renewable energy characterized by the WTG and PV system. The index *i* is regarded as the total number of loads at time t.

4.2. Frequency Constraint Equations

The dynamic equation of the generator is defined according to the frequency. The variables of this equation (7) are the power, and the state variable is the frequency [27]. Moreover, the electrical machine to be considered for producing electricity is the synchronous machine. From the mechanical and electrical powers explained above, we can determine the accelerated power of the synchronous machine equal to:

$$P_a(t) = P_m(t) - P_e(t) = M\omega_r \frac{d^2\delta}{dt^2} = \Delta p_{ref} \tag{7}$$

where $P_a(t)$ and $P_e(t)$ are the mechanical and electrical power from the diesel generator and electrical machine systems at a specific time t, *M* is the moment inertia of the motor and Δp_{ref} is the variation of power delivered by renewable energy systems, ω_r is the angular speed of the electrical motor.

The use of the thermal generator in the MG power supply system implies frequency variation by the fact that the drive speed is variable. The power is also affected since this generator is connected to the network [28]. This constraint can be expressed by the equation of motion of the heat generator in its discrete form in equation (8) [29]:

$$M_{\mathrm{DG}} \frac{\omega_d(k) - \omega_d(k-1)}{\Delta \mathrm{t}} = P_{m1}(k-1) - P_{e1}(k-1) \tag{8}$$

Then, the boundary constraints of the frequency constraints are as follows:

$$\omega_d^{\min} \leq [\omega_d(0) + \frac{\Delta \mathrm{t}}{M_{\mathrm{DG}}} \sum_{\tau=1}^{k} P_{m1}(\tau) - \frac{\Delta \mathrm{t}}{M_{\mathrm{DG}}} \sum_{\tau=1}^{k} P_{e1}(\tau)] \leq \omega_d^{\max} \tag{9}$$

The same applies to the GreenBox System unit providing additional power, the boundary equation (9) can be written as (10) and expressed by the equation as follow:

$$\omega_d^{\min} \leq [\omega_d(0) + \frac{\Delta \mathrm{t}}{M_{\mathrm{Add}}} \sum_{\tau=1}^{k} P_{m2}(\tau) - \frac{\Delta \mathrm{t}}{M_{\mathrm{Add}}} \sum_{\tau=1}^{k} P_{e2}(\tau)] \leq \omega_d^{\max} \tag{10}$$

Where $P_{m1,2}$ are the mechanical power and $P_{e1,2}$ the electrical power of both first and thermal generator and the GBS; the discrete form of time (k), the moment of inertia (M_{DG}, M_{Add}) are defined in the same way as for the case of the equation (8) and (10). Also, regarding to the equation of electrical rotor speed displacement ω_d.

4.3. State of Charge of the Battery Bank

Equation (11) expresses the limits of the SOC in the discrete domain. It gives its upper and lower limit.

$$SOC^{\min} \leq [SOC(0) - \frac{\Delta t}{C_n}\sum_{\tau=1}^{k} P_B(\tau)] \leq SOC^{\max} \quad (11)$$

Where the value, SOC (0) is the initial value of the SOC, C_n is the nominal capacity of the battery bank storage (BBS) and P_B(ґ) is the output power.

4.4. Boundary Constraints of the Control Variables

The active and apparent power represented by the real and imaginary part of the complex variable are physically limited by the construction of the machine. Considering their upper and lower limits for all the sources of the MG system under study, we obtain the following system of equations: (12):

$$\begin{cases} P_{RE}^{\min} \leq P_{RE} \leq P_{RE}^{\max} \\ P_{SNEL}^{\min} \leq P_{SNEL} \leq P_{SNEL}^{\max} \\ P_{DG}^{\min} \leq P_{DG} \leq P_{DG}^{\max} \\ P_{JB}^{\min} \leq P_{JB} \leq P_{JB}^{\max} \\ P_{Add}^{\min} \leq P_{Add} \leq P_{Add}^{\max} \\ P_{epg}^{\min} \leq P_{epg} \leq P_{epg}^{\max} \\ P_{PV}^{\min} \leq P_{PV} \leq P_{PV}^{\max} \\ P_{WT}^{\min} \leq P_{WT} \leq P_{WT}^{\max} \end{cases} \quad (12)$$

The GBS can be connected to the network and plays the role of a power reserve on the one hand and on the other hand of improving the quality of the energy supplied from the MG system. Connected to the network, this quantity can be defined as follows:

$$P_{Add}^{\min}(k) \leq [\sum_{i=1}^{n} P_{Tot} - \eta * P_{Dem}(k)] \leq P_{Add}^{\max}(k), \quad (1 \leq k \leq N_s) \quad (13)$$

5. SIMULATION RESULTS OF THE TYPICAL MG SYSTEM

The system being modeled, the load data of the network of the city under study must be available. This is primarily the accurate load data. Verification of the performance of the system under study and its results will be given in this section.

5.1. Algorithm Applied for this Case Study

The mathematical model of the MG system under study is a non-linear model described in the form of the objective functions above, considering several hypotheses or constraints. There are several methods for solving this type of equation, mostly by iterative processes. The toolbox in the MATLAB R2015 software library, the fmincon function finds the minimum of a constrained nonlinear multivariate function and contributes to the optimization of nonlinear systems. The equation can be solved by this function expressed by:

$$\min f(\mathrm{X}) \quad (14)$$

subject to

$$\begin{cases} \mathrm{AX} \leq \mathrm{b}\,(\text{linear inequality constraint}), \\ \mathrm{A_{eq}X} = \mathrm{b_{eq}}\,(\text{linear equality constraint}), \\ \mathrm{C(X)} \leq 0\,(\text{nonlinear inequality constraint}), \\ \mathrm{C_{eq}}(X) \leq 0\,(\text{nonlinear equality constraint}), \\ \mathrm{L_b} \leq \mathrm{X} \leq \mathrm{U_b}\,(\text{lower and upper bounds}). \end{cases} \quad (15)$$

The vector X present in the expressions above shows the dynamics of the system for all the sampling intervals for optimal control. Linear inequality constraints are built into A and b. Lower and upper boundary stresses (11) to (15) are incorporated into Lb and Ub.

5.2 Typical Application of Lubumbashi Microgrid

For the simulation of the Lubumbashi hybrid system, the diesel generator will be considered as well as the other elements whose details are given in Table **1**:

Table 1: Simulation Parameters

Parameters	Ratings
Diesel generator power, Diesel fuel price	2 MW, η_{DGg}=0.8, 1.1$/litre
Diesel generator parameters	a = 0.246, b = 0.0815, c = 0.4333
Sampling time and priority factors	1 hour; w_1 = 0.1, w_2 = 0.1, w_3 = 0.3, w_4 = 0.5
Accepted MG system frequency, voltage	(50 ±1.5) Hz, (1± 0.05) pu
SNEL Power, GreenBox System	1.5 MW, η_{gSNEL}= 0.8, 22 MW, η_{GB} = 0.98
WTG system	2 MW, η_{WTg} = 0.85
Photovoltaic system unit, Efficiency	2.2 MWmax, η_{PVg} = 20%
Maximum load capacities	3 MW, 3MW, 3.1 MW, 3.5 MW, 6MW, 12 MW

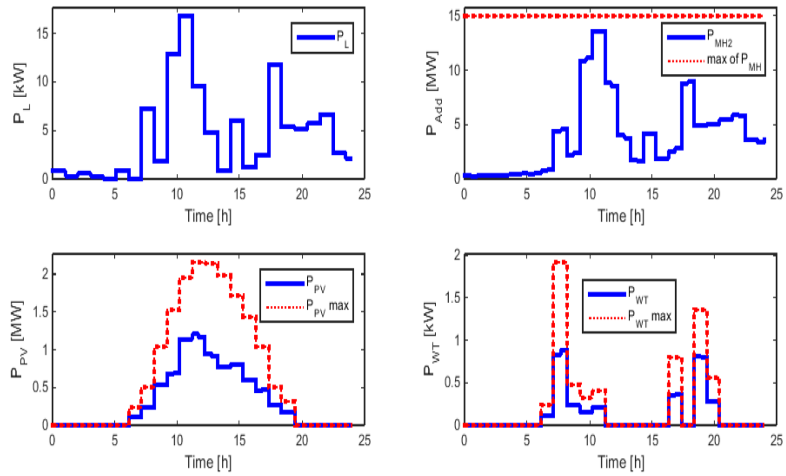

Figure 2: The variations of (**a**) daily load profile, output power from (**b**) PV system, (**c**) Additional Power from GBS and (**d**) Wind Turbine Generator (WTG).

5.3. Results and Discussion of Microgrid

From the Figure **2**, we can note that it is from noon until 2 p.m. that the demand is great, it decreases around 4 p.m. There is significant demand around 6 p.m. Early in the morning the load demand is low. The availability of the PV system is therefore successfully reached during daylight and it gradually evolves to reach its maximum between 11:00 and 14:00. The WT System has particularities for certain hours when the probability of wind is high. The WT system is unable to generate during certain periods due to lack of wind resources. For this hybrid system the additional powers are added to compensate for the low power contributions of the PV and WT systems. It is mainly the batteries and the GBS which can be used continuously to fill the energy deficit necessary for the operation of the system MG.

The first hybrid system simulation results shown in Figures **2** through 5 assume that all power sources are operating at maximum capacity and the load is connected. The capacity of renewable energy resources is inserted into the power system to supply power from PL1 to PLn and some critical loads (PL1C) operate in safe operation of the MG system. The GBS system is considered to initially supply energy to the first group of loads. Associated with the PV and wind system, they characterize the RERs. The diesel generator (DG) system is automatically disconnected due to GBS power compensation and the results of variations in energy resources such as GBS, RERs and power reserve for this part of the study are shown according to this case.

The deficit of the SNEL is considered to disturb the Microgrid system, the results are illustrated in Figures **5**

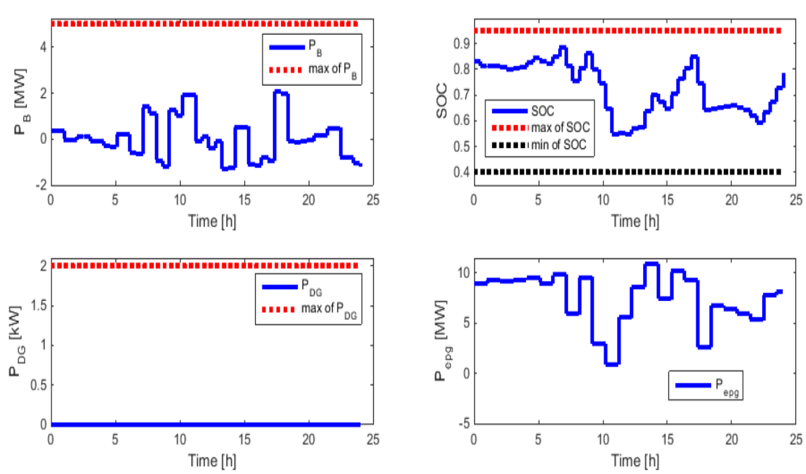

Figure 3: The variations of (**a**) output power from Batteries, output power from (**b**) Diesel Generator (DG) system, (**c**) SOC(k) of Batteries and (**d**) Excess of Power (Pepg).

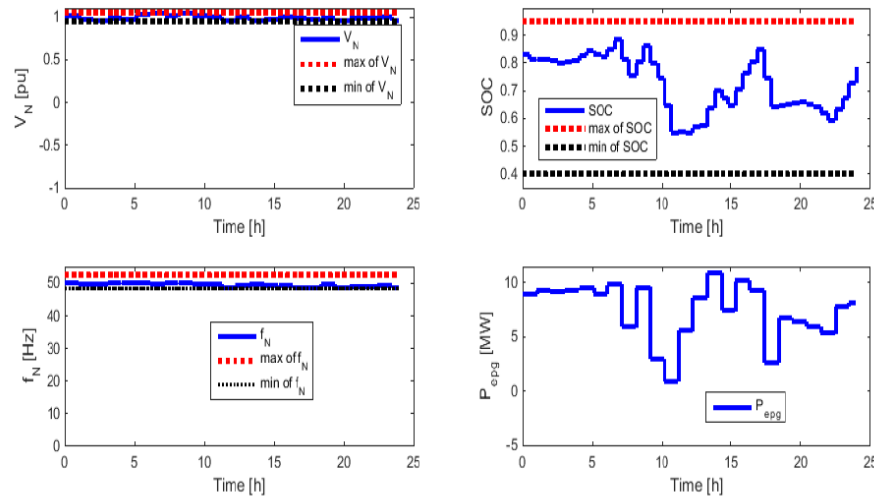

Figure 4: The variations of (**a**) Network Voltage (**b**) Network Frequency, (**c**) SOC(k) of Batteries and (**d**) Excess Power (Pepg).

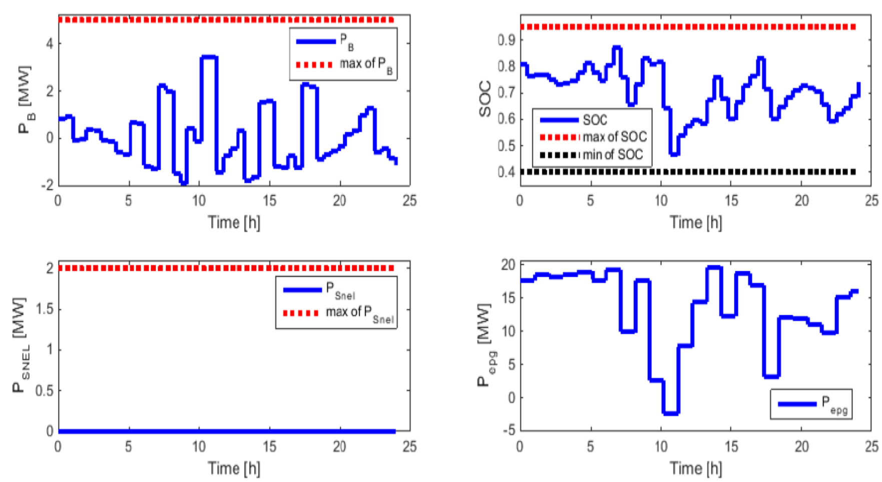

Figure 5: The variations of (**a**) output power from Batteries, output power from (**b**) Diesel Generator (DG) system, (**c**) SOC(k) of Batteries and (**d**) Excess of Power (Pepg).

to **7**. Assuming that all sources of supply are operating at full capacity to supply a certain number of charges. The capacity of renewable energy resources is inserted into the power system to supply power from PL1 to PLn and some critical loads (PL1C) operate in safe operation of the MG system. The GBS system is considered to initially supply energy to the first group of loads. Associated with the PV and wind system, they characterize the RERs. The SNEL power system is automatically disconnected due to power compensation of the GBS and the results of variations in energy resources such as GBS, RERs and power reserve for this part of the study are represented according to this case.

The stability of this network is based on its ability to maintain the magnitudes of frequency and voltage over the entire electrical network. We can observe this in the Figure **4**. The frequency of the MG system is essentially the same at any point of the network for low rates very small variations; it is always at 50 Hz.

The reasons for ensuring voltage stability are quite similar to those for frequency stability. Too high a voltage will cause the load to be destroyed.

Figures **8** and **10** illustrate the evolution of hourly power and frequency. We can observe on the variation graph that between 9:00 a.m. and 11:30 a.m. the power demand is high. In this case, only the GBS system may be able to meet the increasing capacity of additional connected loads. As the SNEL power supply system is insufficient, between 9:00 a.m. and 11:30 a.m., power compensation will be provided, and during

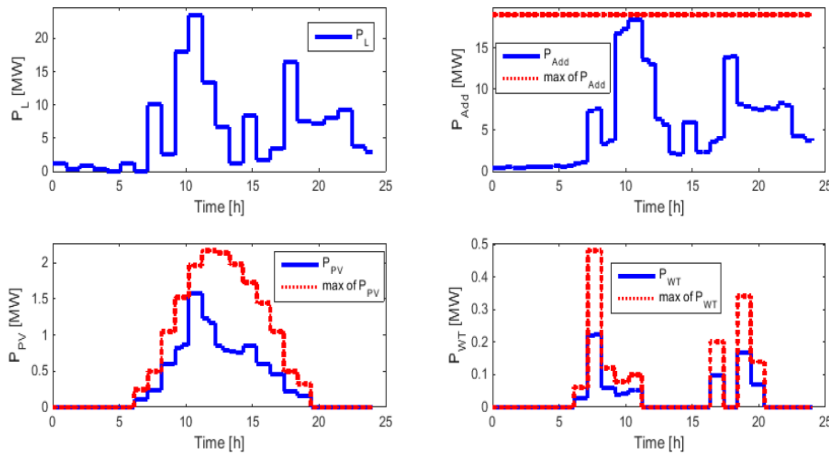

Figure 6: The variations of (**a**) daily load profile, output power from (**b**) PV system, (**c**) Additional Power for GBS and (**d**) Wind Turbine Generator (WTG).

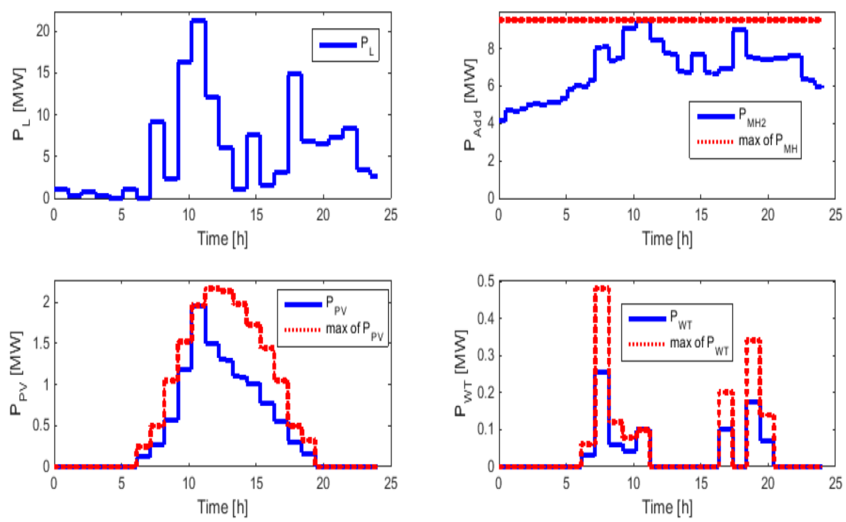

Figure 7: The variations of (**a**) daily load profile, output power from (**b**) PV system, (**c**) Additional Power from GBS and (**d**) Wind Turbine Generator (WTG).

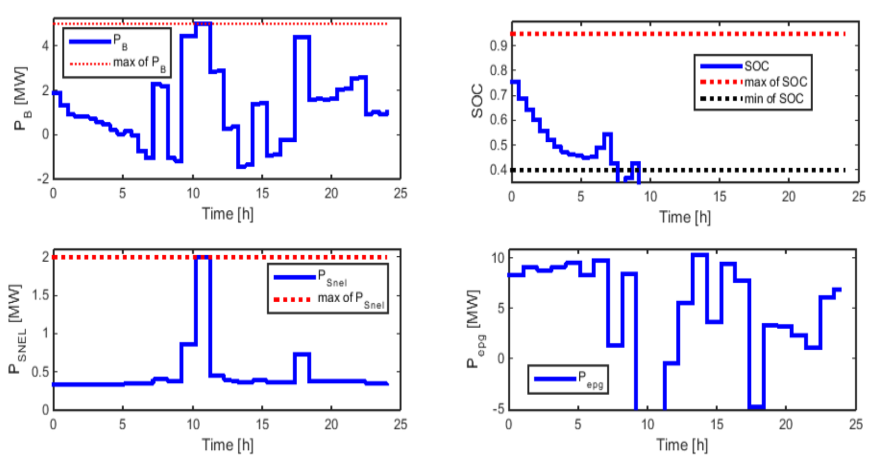

Figure 8: The variations of (**a**) output power from Batteries, output power from (**b**) SNEL Grid system, (**c**) SOC(k) and (**d**) Reserve of Power (WTG).

certain hours of the day, as can be seen on the $P_{SNEL}(k)$ graph, the source of SNEL is automatically disconnected.

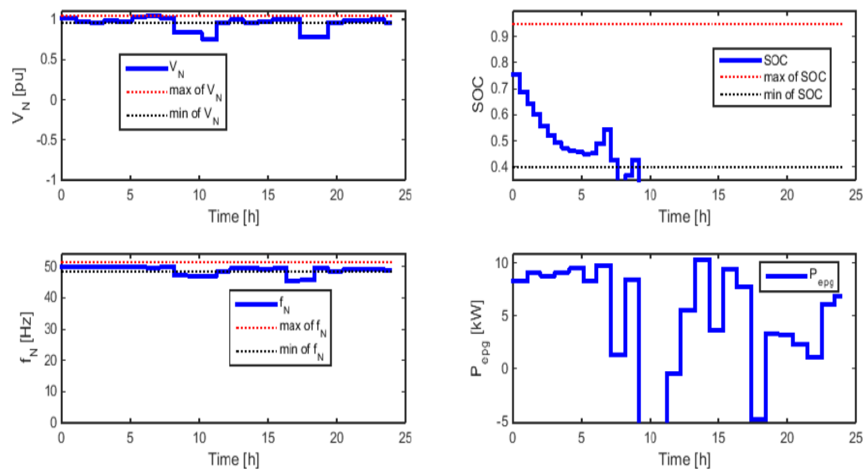

Figure 9: The variations of (**a**) Network Voltage (**b**) Network Frequency, (**c**) SOC(k) of Batteries and (**d**) Excess Power (Pepg).

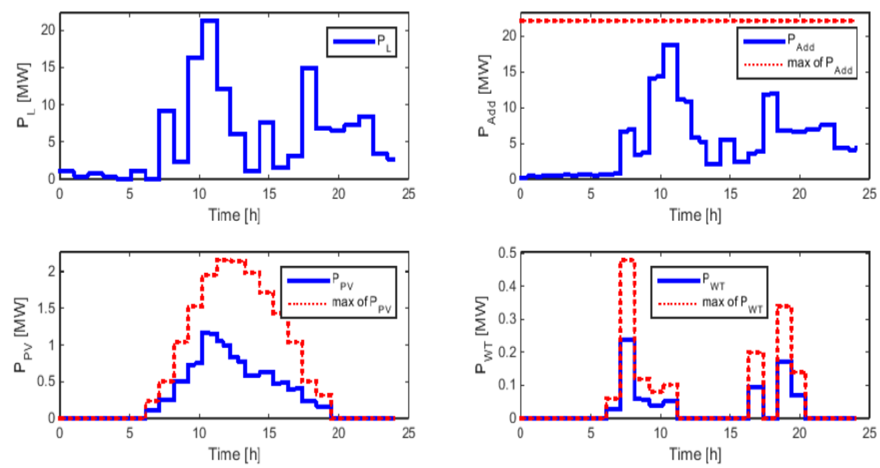

Figure 10: The variations of (**a**) daily load profile, output power from (**b**) PV system, (**c**) Additional Power from GBS and (**d**) Wind Turbine Generator (WTG).

Figures **11** to **12** illustrate the results obtained from the hybrid system. The SNEL power system is automatically disconnected due to GBS power compensation and the results of variations in energy resources such as GBS. Renewable energy sources are used for their greater delivery capacity. Electricity from SNEL cannot be considered for this period due to its lower delivery capacity.

CONCLUSION

SNEL is the largest electricity company in the DR Congo. Provision of power for unforeseen and future loads is mandatory with the aim of promoting industrial and mining investment opportunities that can create more jobs for local and international experts as well as suppliers. The key problem to be solved in the mining areas of this country is to ensure that new mines will always need to be supplied with efficient energy at low cost instead of running their operations with DGs which are very expensive due to the cost of fuel, and which are very polluting. After this study, the conclusion is that the SNEL network must be designed as a complete hybrid system and must be controlled appropriately to retain major customers such as mining and industrial companies. Priority should be given primarily to GBS technology and secondarily to RES. GBS technology can easily solve the problems of frequency and voltage fluctuations in the SNEL MG system to avoid the reduction of productivity in the industrial sector. With the current state of SNEL, when there is no additional power source to augment the existing supply, the consequence is the shedding of some loads to avoid the unbalancing aspect of the MG system. The consequence of operating the SNEL network without an additional power supply from the GBS technology is the presence of an undervoltage and under frequency problem in the MG. A good way to solve an unbalanced situation is to make the SNEL system intelligent so that in the event of a disturbance

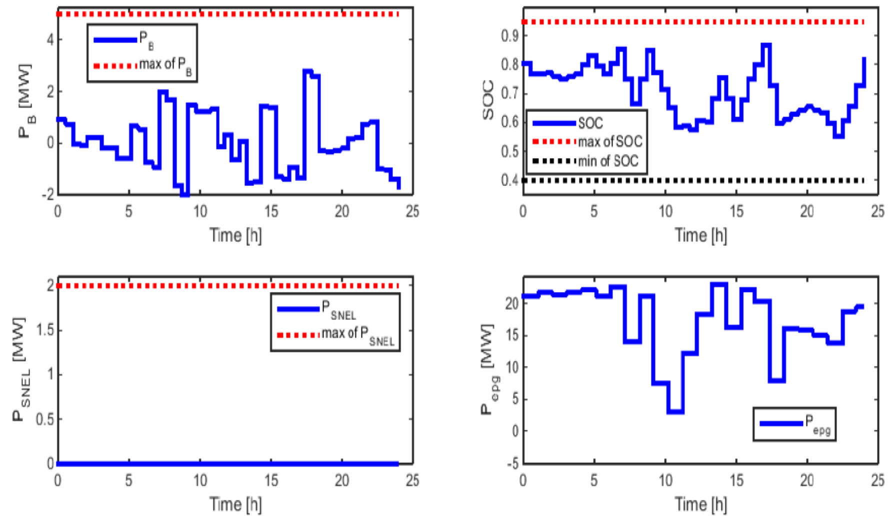

Figure 11: The variations of (**a**) output power from Batteries, output power from (**b**) SNEL Grid system, (**c**) SOC(k) and (**d**) Reserve of Power (Pepg).

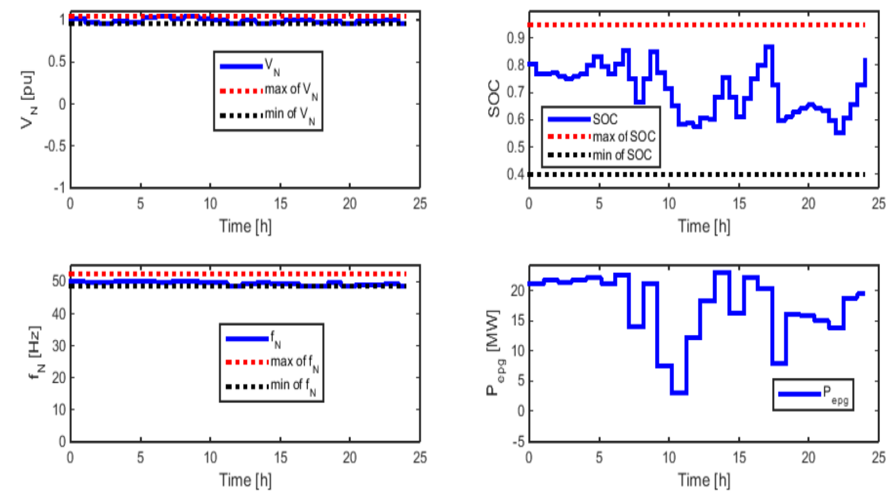

Figure 12: The variations of (**a**) Network Voltage, (**b**) Network Frequency, (**c**) SOC(k) of Batteries and (**d**) Excess Power (Pepg).

in the supply capacity on the production side, renewable energy will be present permanently as a backup to maintain voltage and frequency of the SNEL MG system stable.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest regarding this research paper.

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