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Lack of Power and Public Improvement Strategies in Senegalese Electric System: An Economic and Managerial Perspective

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Abstract: **This article uses two models of optimization of the SENELEC (Senegalese Electricity Society) generators and other sources of electricity layout. It shows that the implementation of an optimization strategy in the use of the sources of electricity can enable quantifiable savings on costs as a good way for slacks reduction in SENELEC. JEL: D2, Q4.**

Keywords: **Electric system, Optimization, Multi-Agent System, Slacks.**

I. INTRODUCTION

Senegalese government has recently renewed the crucial importance of its energy policy in order to reach the objective of an economic growth rate of about 8%. The electricity sector crisis caused the loss of 2% economic growth per year from 2006 to 2010 according to the IMF statistics. To face this problem, Senegalese government took many measures to solve financial and power deficits of SENELEC (The public monopoly for electricity transport and distribution). The new development policy of the electricity sector initiated in 2011 is based on the diversification of the sources of production of electricity, the adaptation of infrastructures and the improvement of energy efficiency. The economic pertinence of these choices of investments and their financial model is based on the capacity of SENELEC to ensure its self-financing through the minimization of the costs that can be made possible by the optimization of the production mechanisms and distribution.

In this article we use two models previously tested by Mbodj, Ndiaye, al, (2014a) and Mbodj, Ndiaye, al, (2014b), respectively. We propose a reflection on the basis of a definitive financial equilibrium to SENELEC, through a considerable reduction of its slacks (that are markups in the input and insufficiencies in the output) that is symptomatic of the existence of an Averch-Johnson effect (over capitalization due to the low productivity of the capital). For that purpose, the adoption of a cost modeling method can offer a way to optimize the use of the electricity sources.

II. METHODOLOGY

We first proceed by making simulations of the slacks costs for the period before the adoption of new power strategies. From 2012, new power capacities have been installed by the government, with a better, but not sufficient, part of renewal sources. Our analysis relies on two models used in two contributions appeared in 2014. These two models propose the optimization of sources used in order to minimize the costs.

In the first model (see Mbodj A., Ndiaye E. M., Ndiaye M. L. 2014), each source agent has at his disposal a priority parameter which is determinant in the choice of the sources of production that contribute to satisfying the demand. It is a function of the criterion of optimization, the availability of the source, the cost of production of the source and the quantity of the greenhouse gas.

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In the second model (Mbodj A., Ndiaye M. L, Ndiaye E. M., Ndiaye P. A. 2014), the electric system studied consists of a photovoltaic generator, an aero generator, storage batteries and alternative current (AC) and direct current (DC) consumption sources. The general idea is to minimize the cost of production, but also the power deviation between the production of renewable sources and the consumption by modifying the charge profiles through their different local entities. The following model has been tested in this latest work.

$$Deviation(t) = P_{PV}(t) + P_{Aer}(t) + P_{Bat}(t) - P_{SC}^{DC}(t) - (\frac{1}{\eta_{Inv}})P_{SC}^{AC}(t) + P_{Gen}(t)$$

Where $P_{PV}(t)$ is the amount of power supplied by the photovoltaic generator, $P_{Aer}(t)$ the amount produced by the aero generator, $P_{Bat}(t)$ the amount produced or consumed by the battery. $P_{Bat}(t)$ is negative if the battery is a receiving one, $P_{SC}^{DC}(t)$ is the power called by the DC loads and $P_{SC}^{AC}(t)$ is the power called by the AC loads, $P_{Gen}(t)$ the volume produced by the fossil generator, and η_{Inv} is the inverter efficiency.

In both model the authors opted for the use of the platform devoted to the Multi-Agent Systems (MAS). MAS applied to the distributed control of electrical systems present a major issue for the management of the control complexity and flexibility. The technical specifications used are based on an environment of development and agents-oriented programming, and on the services to offer. The choice was about MADKIT (Multi Agent Development Kit) an organizational and generic model (or platform) of conception and execution of the MAS. MADKIT (that can be downloaded for free at http://www.madkit.org) is an environment of Java programming aimed at the creation of the MAS in order to develop applications based on an organization-oriented paradigm.

With these tools, the authors undertook a static evaluation of the slacks without use of the optimization model. Now, for dynamic models, the appropriate method of calculation of the slacks is Data Envelopment Analysis Program (DEA) (see Chaffai 1997, and Coelli 1998, among others).

In the case of SENELEC, we pose W as the average wage per employee, Dg as the global demand in electricity, Pf as the production charged for, Cp as the cost to the electricity producer, Ta use as the tariff to target consumer and Tn as the reality of prices.

Table 1. Possible Slacks

Input Slacks	**Output slacks**
Excess staffs (ES) : $W \times ES$ Excess remunerations Abnormal consulting charges Lack of financial calculation	Technical losses of power (Tl): $Tl \times Cp$ Costs of Piracy (Py) : $Py \times Cp$ Losses of turnover (Lto) : $(Dg - Pf - Tl)Ta$. Non optimal tariff effects (Sf) : $Pf(Tn - Ta)$
Hypothesis : SENELEC applies abnormally low social tariff	

Table 2 : Production and consumption

Production	**Available Power**	**Sales**	**Technical losses**	**Non technical losses**
	2489GWh	1928,91GWh	497,8GWh	62,29GWh
Consumption	**State and small users**	**Industrials**	**Commercials**	**Technical losses**
	50%	10%	20%	20%

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Table 3: Purchasing cost and electricity sale price by SENELEC[1]

Production costs (Cp)		**Final Tariff (Ta)**	
Dam of Manantalli	15 F CFA/KWh	Low Power	121,3F CFA/KWh
GTI (IPP)	60 F CFA/KWh	Medium Power	116,9 F CFA/KWh
Kounoune Central Power (IPP)	10 F CFA/KWh	Hight Power	82,8F CFA/KWh
Average	**50 F CFA/KWh***	**Average**	**117,8 F CFA/KWh**

IPP: Independent Power Producer-

For the cost of power, we retain 50 FCFA per KWh because the cost for SENELEC is about 115 FCFA per Kwh. To get an idea of the scale of the slacks, we estimate the technical and non technical losses (piracy for example).

With, 1GWh=10^6Kwh, we get:

- Technical losses: $Tl \times Cp = (497.8)10^6 \times 50$ = 25,000,000,000 FCFA.
- Other losses: $Py \times Cp = (62.29)10^6 \times 50$ = 3,110,000,000 FCFA.

III. ELECTRICITY SUPPLY AND SLACKS CONSEQUENCES IN SENEGALESE ELECTRIC SYSTEM

The useful power of the electricity generating fleet went from 562,5 MW in 2005 to 684,5 MW in 2009, meaning a relative increase of around 22% (AFD, 2012). But the non provided energy resulting from the deficiencies of the system was 91 GWh in 2007, 104.3 GWh in 2008 and 89.0 GWh in 2009.

Table 4: Power available and sales

	2005	2006	2007	2008	2009	2010	2011
Available Power (en Gwh)	2171	2192	2306	2400	2489	2618	2559
SENELEC	67%	66%	69%	64%	76%	69%	53%
Bought Power	33%	34%	31%	36%	24%	31%	47%
Part of Dames Power	12%	11%	8%	10%	10%	10%	10%
Sales	79%	79%	77%	78%	79%	79%	80%
Losses	21%	21%	23%	22%	21%	21%	20%

Source : NDIAYE, 2016 [page 110]

Electricity consumed in low voltage represents the greatest part of the global consumption, with 64 % in 2013. The consumptions in average and high voltage represent 29.3 % and 6.7 %, respectively, for the same year.

Table 5 : SENELEC's financial results in billions XOF

	2005	2006	2007	2008	2009	2010	2011
Tariff compensations	26	33	37	60	40	28	103
Exploitation Results	-7	-23	-3	-1	13	-52	4
Final results (after taxes)	-4	-34	-6	-7	6	-55	-13

Source: Statistics from the IMF (Fmi, 2010) and Agence Française de Developpement (AFD, 2012).

Because of the crisis in the enegalese power sector, several subsidies have been put in Senelec since 2000: 158 billion FCFA mobilized in 2003, operating subsidies worth 337 billion FCFA from 2005 to 2011, recapitalization of 109 billion in 2008. The expense of fuel has been the main argument for the justification of power cuts and the recent falls in oil prices seem to have a small positive effect related to the phase-out of tariff compensations from the year 2012 (see

[1] Franc CFA (F CFA) is senegalese currency.

Ndiaye, 2016, page 109). In 2015, the Head Manager of the society revealed that about 30 billion FCFA are lost annually, as it results from our slacks calculation.

IV. NEW POWER AND CAPACITIES ESTIMATION FOR 2020

From 2006, the Senegalese government implemented a new strategy of capacities enforcement in order to face an increasing demand (10% per year). The following equation allows estimating the demand for a given year.

$$(Demand)_N = (Demand)_{N_0} \times (1+0.1)^{N-N_0}$$

$\mathbf{N_0}$ is the current year and **N** is the year when the energy demand was estimated. This equation allows following the evolution of the energy demand. It is reasonable to retain at least a 10% rate in the evolution of the demand in electricity in order to take into account the new actions in favor of local production initiated within the context of the PSE (Plan Sénégal Emergent or Senegal Emergence Plan). Finally, the demand, estimated to around 500MW in 2010, is expected to reach 1426 MW in 2020.

From the year 2012, investments in production capacities were accelerated within the context of an energy mix engendering rural electrification that aims at reaching a 60% rate of 2017 for an investment of 99 billion FCFA as it is drawn in the PSE.

Table 6. Forseen non renewal Powers

Location	Type and Power	Availability
Boutoute (South)	10 MW (thermic)	2012
Dakar	126 MW (iso dual fuel)	2012
Sendou	250 MW (Coal)	2017
Kayar	350 MW (Coal)	2017
Taïba Ndiaye (Center area)	90 MW (Fuel and Gaz))	2016
Importation from Mauritania	330 MW (Gaz)	Between 2015 and 2018.

Table 7. Forseen renewal power

Type	Operators and Power	Contractuals aspects
Dams on Senegal River	Gouina (Mali): 140 MW Sambagalou (Senegal): 128 MW Kaleta (Guinea) : 240 MW	Public project: 109 MW expected for Senelec.
Solar central in Bokhol (north area)	Project called Synergy 2: 20 MW	Public project: 34 GWh of Power expected from 2016.
Solar Central in Ourossogui (north area)	Production by SENSOL (from Morroco): 15 MW.	22 years of concession. Available in 2016
Solar Central in Méouane (Center area)	Project called Sernergy PV SA: 20 MW	25 years of concession. Available in 2017
Solar central in Mérina Dakhar (Center area)	Senelec project: 20 MW	In building since 2016
Solar central in Malicounda (Center area)	Solaria, Chemtech Group (Italien group) : 22MW	25 years of concession Available in 2016.

Thus, a 5.1% annual average increase in public production is expected and 8.9 % of the photovoltaic solar. From 2013, global electricity production reached more than 3 000 GWh, meaning more than 20 % increase for 4 years, compared to 2009.

Table 8. Current Supply/Demand and projection for 2020

	2014	In 2020
Capacities	828 MW	1924 MW in 2018
Demand	700 MW	1426 in 2020

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V. MODELING RESULTS AND MINIMIZATION OF COSTS: A MANAGEMENT PERSPECTIVE

The problems of a network are not only economic, but also they integrate an even more important technical dimension in the case of SENELEC. The first model shows that the optimization of energy management is critical mostly in a system in which some groups conceived to work alternatively constitute sources of basic production. The sources of production include different types and efficiency that is why the control of their operating conditions will allow drawing up a wise plan, following the lowest cost. Testing this model leads to various scenarios.

The first simulation (figure 1) permits to get a forever lower production cost with the criterion of optimization used. Indeed, without criterion of optimization, the curve obtained is always above (on all the duration of the simulation) the curve that uses the criterion of optimization.

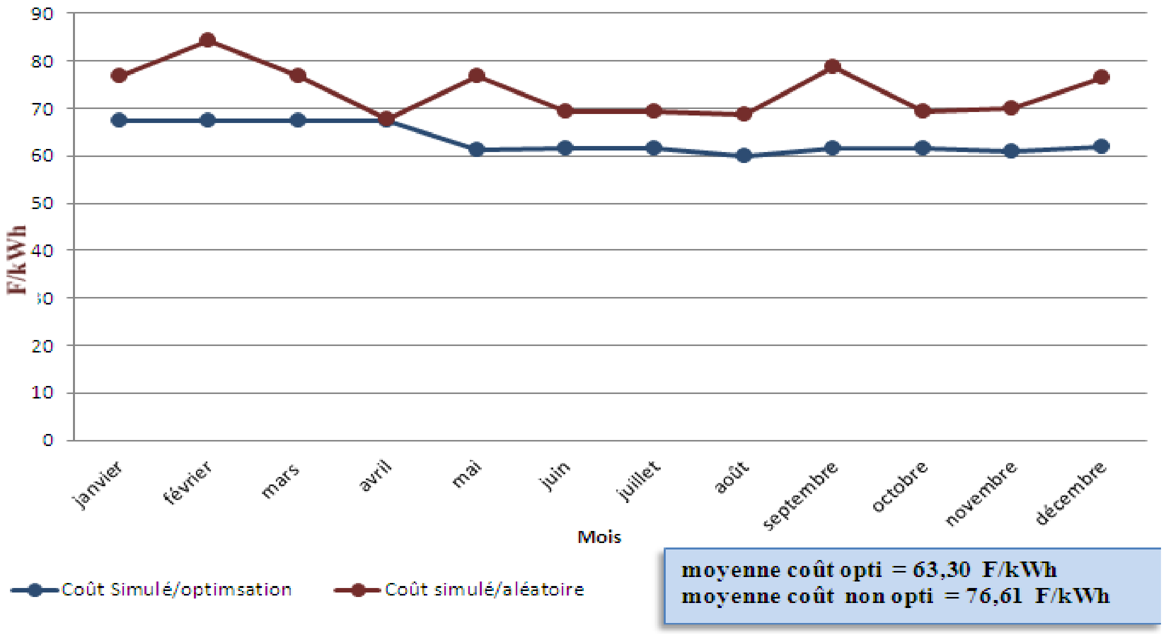

Figure 1. Cost optimization or not (contents in French)

In the second model, the simulations are carried out following two scenarios and two day type. Day type I where the battery is fully charged and day type II where the battery discharge level is at a critical state (around 30%). In the first simulation scenario (S1) the system is managed without production source cost. The second scenario (S2) applies the decentralized control model. The two simulation results are then compared**.** The simulation results show a production cost source when the strategy is applied. The control system applied results in a cost reduction from 25.88 $/kWh to 18.47 $/kWh during the day type I and from 62.07 $/kWh to 33.86 $/kWh for the day type II.

Table 9. Potentials of costs minimization by optimization

Possible Cost economies per Kwh	**Generators layout optimization**	**Sources optimization**
	17%	20%
	Available in 2018	Forseen Sale
Power	1924MW	79% = 1519 MW
Estimated normal costs of production	1924×10^6 x 50 F CFA= 96,200,000,000 FCFA	
Possible economies in generators optimization	16,354,000,000 FCFA	
Possible economies in sources optimization	19,240,000,000 FCFA	

Concluding Remarks :

In Senegal, the electric sources of energy are widely got from combustible. However, the new investments in capacities leave more and more places to renewable energies. Our work shows that it would be interesting to open the system for other production sources conventional networks. The application of the models shows that the adoption of the method of optimization in the SENELEC generators layout and all the other sources of electricity (groups, photovoltaic and hydroelectric) allows saving 37% of the incurred costs. We've seen that slacks of SENELEC reach 28,110,000,000 FCFA.

From 2018, around 35,600,000,000 XOF can be saved out of the 96,200,000,000 XOF required to exploit the 1924 MW of capacities planned. It is about a managerial perspective according to which SENELEC will be able to overcome the slacks and Aversh-Johnson effects that hamper the correct management of the company.

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