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Hydro-Atmospheric Modeling Of Losses by Joule Effect on the Bukavu-Bujumbura High-Voltage Line ofthe Societe Nationale D'electricite (SNEL-RDC).

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Abstract:
As part of the Doctoral Research of the Head of work Muyisa Teddy with all his Supervisory Team on the Adequate Modeling to Approach, Prevent and Operate Early Alerts of Electrical Energy Losses on High Voltage Electric Transmission Lines BUKAVU-BUJIMBURA Axis , the Researcher is responsible for solving a Fundamental Question, namely how to design and identify two Mathematical models, among others, the Least Squares and the Lagrange Quadratic model: which best approaches the in situ Energy Data of the Joule losses on the SNEL Line .
According to the review of the literature on Loads and Losses on High Voltage Power Transmission Lines, the Lagrange quadratic model modeling would be the best fit. This was taken as a hypothesis from our article.
To perform this hydro-atmospheric modeling, we used the hydro-atmospheric data of the turbine flow D of the RUZIZI River and the temperatures θ_{BUK} of BUKAVU and θ_{BUJ} of BUJUMBURA which constitute our independent variables in the models and the data of the losses by effect. Joule from 1990 until 2017 was the dependent variable of the models.
We have therefore generated 12 equations which correspond to 12 months by the least square model of the form: $P_{Ji}=a\theta_{1i}+b\theta_{2i}+cD_i+k+\varepsilon_I$ where a, b and c are coefficients to be determined as well as the constant k. ε represents the error on the model in MWh.
We also generated 12 equations that correspond to 12 months by the least square model of the form: $P_{ji}=a\theta_{1i}^2+b\theta_{2i}^2+cD_i^2+d\theta_{1i}+e\theta_{2i}+fD_i+k+\varepsilon_i$ where a, b, c, d, e, f are coefficients to be determined as well as the constant k. ε represents the error on the model in MWh.
The equation plots showed us that the least square model was closer to the in situ data than the Lagrange quadratic model.
To validate the model, we then placed the in situ flow and temperature data for 2018 in the different equations generated by the two models.
Finally, we noted on our graph that the line of the least squared model practically rhymes with the line of the in situ data while that of the quadratic Lagrange model is out of phase with that of the lesser squared model.
Thus we have drawn as a conclusion that the least square model is better suited for this modeling than the quadratic model of Lagrange. So the hypothesis is rejected.
Keywords: *model, lesser square, Lagrange quadratic model.*

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I. Introduction

01. Problem

Electric current is a useful product because it contributes to the development of countries. This is why it is necessary to carry out research on the problems of its operation and even its transport and to propose possible solutions. It is produced to be marketed as electrical energy which must be well controlled. Electrical energy can indeed be secured by limiting losses in high voltage overhead lines.

Speaking of SNEL's BUKAVU-BUJUMBURA interconnected high voltage network, we asked ourselves this question:

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Which between the least square model and the quadratic model of Lagrange is appropriate for carrying out the hydro-atmospheric modeling of the losses by Joule effect on the high-voltage line BUKAVU-BUJUMBURA of SNEL?

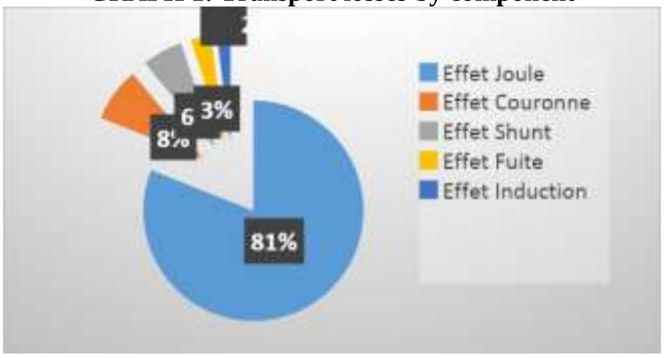
02. Hypothesis

In the context of our article we formulated the following hypothesis:

The model which would be best suited to carry out the hydro-atmospheric modeling of the losses by Joule effect on the BUKAVU-BUJUMBURA high-voltage line of SNEL is the quadratic model of Lagrange because in the article entitled “Shared energy” RSEIPC of January 2007 the author modeled the technical losses on the electrical distribution network by the quadratic method of Lagrange of the form: $P_T=aP^2+bP+c$ where P_T represents the technical losses on the network and P represents the power injected into the electrical distribution network.

Joule losses constitute the main component of transmission losses as shown in the figure below.

GRAPH 1: Transport losses by component



Source: [Anonymous, 2000, p 9].

These losses are caused by the current flowing through transformers and lines and the resistance of the elements. All elements of the network offer resistance to the transport of the load. The resistance depends on the size and number of conductors per phase, the length of the circuits and the resistivity of the conductive material. The current is related to the quantity of transmitted power, the voltage level and the number of elements in service.

The load, configuration and mode of operation of the network influence these variables and the resulting losses. Maintaining the supply-demand balance constantly changes the power transmitted. These fluctuations act on the network voltage and the current flowing through it. Regarding the resistivity of the network, there is little room for maneuver with the equipment already installed. [Anonymous, 2000, p 4]

-The transport of energy from source to consumption amounts to the delivery of power: $P = VI\cos\varphi$

-The power lost in resistor R is written: $P_J=RI^2$ or $P_J=R\frac{P^2}{V^2\cos^2\varphi}$ (Lasne, 2008, p 20).

-The losses by Joule effect are equal to RI^2, where R is the linear resistance of the core in alternating current, at the operating temperature of the cable, taking into account the effects of skin and proximity:

$R=R_{20}[1+\alpha_{20}(\theta-20)][1+Y_S+Y_P]$

With: -R20 [Ωkm^{-1}] maximum linear resistance in direct current at 20°C.

-Y_P: Proximity effect factor.

-Y_S: Skin effect factor

-α_{20} [K^{-1}]: Coefficient of variation at 20°C of the electrical resistance.

-θ [°C]: Service temperature of the core.[Michel Pays, pp 22 and 23]

03. Objectives

Objective is:

- to carry out the hydro-atmospheric modeling of the losses by Joule effect on the BUKAVU-BUJUMBURA high voltage line of SNEL

04. Choice and Interest

The choice and interest of this research is prompted by the concern to seek solutions to the problems of losses by Joule effect on the BUKAVU-BUJUMBURA high voltage line of SNEL.

05 Delimitation of the subject

We conducted this study over a period from January 1990 to December 2017 excluding the year 1996 when the area was infested by wars.

II. Methodology

We started by taking the energies produced monthly at the RUZIZI I Plant. Then we took the energies received monthly at the REGIDESO of BUJUMBURA and finally we took the difference between the source and received energies to have the overall monthly electrical energy losses on the BUKAVU-BUJUMBURA high-voltage line of SNEL.

The overall losses were obtained by measurement while the losses by the Joule effect were obtained analytically.

As we have seen from the intro chart, Joule losses account for 81% of overall losses. In this article we will model the losses by Joule effect as a function of the hydro-atmospheric variables given that this BUKAVU-BUJUMBURA high-voltage line from SNEL is subject to climatic hazards.

The hydro-atmospheric variables here are: turbine flow and temperature.

Turbine flow being a hydraulic variable is found as an independent variable in the modeling of losses by Joule effect. This can be explained by the following mathematical proof:

$dW = Pdt$

$\Leftrightarrow dW = pdV$

We also know that: $P=\frac{dW}{dt}$

$\Leftrightarrow P=\frac{pdV}{dt}$

$\Leftrightarrow P=\frac{FdV}{Sdt}$

$\Leftrightarrow P=\frac{F}{S}D$

$\Leftrightarrow P=p*D$

Where $p=p_0+\rho gz+\frac{1}{2}\rho v^2$

Hence $P= (p_0+\rho gz+\frac{1}{2}\rho v^2)*D$

With P: Nominal power of the alternator

D: Turbine flow

P_0: Atmospheric pressure

ρ: Density of water

g: Acceleration of gravity

z: Height difference

v = Rω; R: Radius of the turbine and ω: Angular speed

W: Electric energy

t: time

p: Pressure

V: Volume of water.

F: Water force

S: Pallet surface

From the last relation found we can say that the power of the turbine is a function of the flow, the electrical energy is a function of the power of the turbine, the losses by Joule effect depend on the electrical energy therefore the losses by effect Joule depend on the turbined flow.

Referring to the introduction, the Joule losses depend on the flow and temperature.

II.1. Least squared modeling of Joule effect losses on SNEL's BUKAVU-BUJUMBURA high-voltage line.

The losses by Joule effect PJ depend on the turbinate flow D of the RUZIZI River, the temperature θ_1 of the BUKAVU region and the temperature θ2 of the BUJUMBURA region.

Indeed: $P_{Ji}=a\,\theta_{1i}+b\,\theta_{2i}+cD_i+k+\varepsilon_i$ where a, b and c are coefficients to be determined as well as the constant k. ε represents the error on the model in MWh.

$\varepsilon_i= P_{Ji}-a\,\theta_{1i}-b\,\theta_{2i}-cD_i-k$

$\Leftrightarrow \varepsilon_i^2=(P_{Ji}-a\,\theta_{1i}-b\,\theta_{2i}-cD_i-k)^2$

$\Leftrightarrow \Psi=(P_{Ji}-a\,\theta_{1i}-b\,\theta_{2i}-cD_i-k)^2$

With $\Psi=\varepsilon_i^2$ is the variance
As a result we will have:

$$\frac{\partial\Psi}{\partial a}=\frac{\partial\Psi}{\partial b}=\frac{\partial\Psi}{\partial c}=\frac{\partial\Psi}{\partial k}=0$$

Finally we will have a system of 4 equations with 4 unknowns to solve to have the coefficients a in MWh⁄(° C), b in MWh⁄(° C) and c in $MWhs/m^3$ as well as the constant k in MWh.

$$a\sum_{i=1}^{27}\theta_{1i}^2+b\sum_{i=1}^{27}\theta_{1i}\theta_{2i}+c\sum_{i=1}^{27}\theta_{1i}D_i+k\sum_{i=1}^{27}\theta_{1i}=\sum_{i=0}^{27}\theta_{1i}P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}\theta_{2i}+b\sum_{i=1}^{27}\theta_{2i}^2+c\sum_{i=1}^{27}\theta_{2i}D_i+k\sum_{i=1}^{27}\theta_{2i}=\sum_{i=1}^{27}\theta_{2i}P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}D_i+b\sum_{i=1}^{27}\theta_{2i}D_i+c\sum_{i=1}^{27}D_i^2+k\sum_{i=1}^{27}D_i=\sum_{i=1}^{27}D_iP_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}+b\sum_{i=1}^{27}\theta_{2i}+c\sum_{i=1}^{27}D_i+kn=\sum_{i=1}^{27}P_{Ji}$$

II.2. Modeling by the quadratic method of Lagrange of the losses by Joule effect on the high-voltage line BUKAVU-BUJUMBURA of SNEL

The losses by Joule effect PJ depend on the turbinate flow D of the RUZIZI River, the temperature θ1 of the BUKAVU region and the temperature θ2 of the BUJUMBURA region.
Indeed: $P_{ji}=a\theta_{1i}^2+b\theta_{2i}^2+cD_i^2+d\theta_{1i}+e\theta_{2i}+fD_i+k+\varepsilon_i$ where a, b, c, d, e, f are coefficients to be determined as well as the constant k. ε represents the error on the model in MWh.

$\varepsilon_i=P_{ji}-a\theta_{1i}^2-b\theta_{2i}^2-cD_i^2-d\theta_{1i}-e\theta_{2i}-fD_i-k$
$\Leftrightarrow \varepsilon_i^2=(P_{ji}-a\theta_{1i}^2-b\theta_{2i}^2-cD_i^2-d\theta_{1i}-e\theta_{2i}-fD_i-k)^2$
$\Leftrightarrow \Psi=(P_{ji}-a\theta_{1i}^2-b\theta_{2i}^2-cD_i^2-d\theta_{1i}-e\theta_{2i}-fD_i-k)^2$
With $\Psi=\varepsilon_i^2$ is the variance
As a result we will have:

$$\frac{\partial\Psi}{\partial a}=\frac{\partial\Psi}{\partial b}=\frac{\partial\Psi}{\partial c}=\frac{\partial\Psi}{\partial d}=\frac{\partial\Psi}{\partial e}=\frac{\partial\Psi}{\partial f}=\frac{\partial\Psi}{\partial k}=0$$

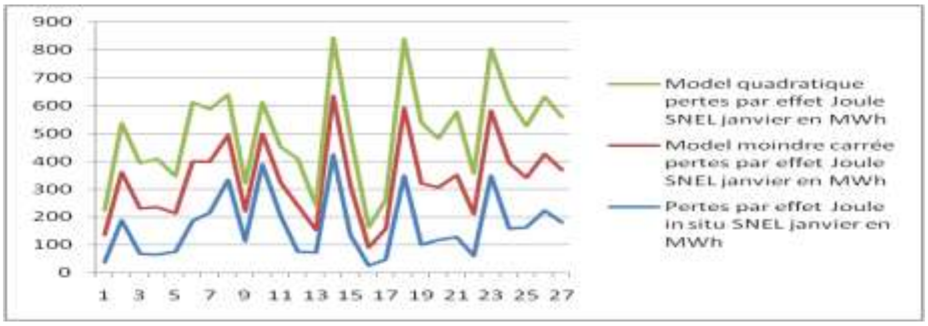
Finally we will have a system of 7 equations with 7 unknowns to solve to have the coefficients a in MWh⁄(° C)², b in MWh⁄(° C)², c in $MWhs^2/m^6$, d in MWh⁄(° C), e in MWh⁄(° C), f in $MWhs/m^3$ as well as the constant k in MWh.

$$a\sum_{i=1}^{27}\theta_{1i}^4+b\sum_{i=1}^{27}\theta_{1i}^2\theta_{2i}^2+c\sum_{i=1}^{27}\theta_{1i}^2D_i^2+d\sum_{i=1}^{27}\theta_{1i}^3+e\sum_{i=1}^{27}\theta_{1i}^2\theta_{2i}+f\sum_{i=1}^{27}\theta_{1i}^2D_i+k\sum_{i=1}^{27}\theta_{1i}^2=\sum_{i=1}^{27}\theta_{1i}^2P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^2\theta_{2i}^2+b\sum_{i=1}^{27}\theta_{2i}^4+c\sum_{i=1}^{27}\theta_{2i}^2D_i^2+d\sum_{i=1}^{27}\theta_{2i}^2\theta_{1i}+e\sum_{i=1}^{27}\theta_{2i}^3+f\sum_{i=1}^{27}\theta_2^2D_i+k\sum_{i=1}^{27}\theta_{2i}^2=\sum_{i=1}^{27}\theta_{2i}^2P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^2D_i^2+b\sum_{i=1}^{27}\theta_{2i}^2D_i^2+c\sum_{i=1}^{27}D_i^4+d\sum_{i=1}^{27}\theta_{1i}D_i^2+e\sum_{i=1}^{27}\theta_{2i}D_i^2+f\sum_{i=1}^{27}D_i^3+k\sum_{i=1}^{27}D_i^2=\sum_{i=1}^{27}D_i^2P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^3+b\sum_{i=1}^{27}\theta_{2i}^2\theta_{1i}+c\sum_{i=1}^{27}\theta_{1i}D_i^2+d\sum_{i=1}^{27}\theta_{1i}^2+e\sum_{i=1}^{27}\theta_{1i}\theta_{2i}+f\sum_{i=1}^{27}\theta_{1i}D_i+k\sum_{i=1}^{27}\theta_{1i}=\sum_{i=1}^{27}\theta_{1i}P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^2\theta_{2i}+b\sum_{i=1}^{27}\theta_{2i}^3+c\sum_{i=1}^{27}\theta_{2i}D_i^2+d\sum_{i=1}^{27}\theta_{1i}\theta_{2i}+e\sum_{i=1}^{27}\theta_{2i}^2+f\sum_{i=1}^{27}\theta_{2i}D_i+k\sum_{i=1}^{27}\theta_{2i}=\sum_{i=1}^{27}\theta_{2i}P_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^2D_i+b\sum_{i=1}^{27}\theta_{2i}^2D_i+c\sum_{i=1}^{27}D_i^3+d\sum_{i=1}^{27}\theta_{1i}D_i+e\sum_{i=1}^{27}\theta_{2i}D_i+f\sum_{i=1}^{27}D_i^2+k\sum_{i=1}^{27}D_i=\sum_{i=1}^{27}D_iP_{Ji}$$
$$a\sum_{i=1}^{27}\theta_{1i}^2+b\sum_{i=1}^{27}\theta_{2i}^2+c\sum_{i=1}^{27}D_i^2+d\sum_{i=1}^{27}\theta_{1i}+e\sum_{i=1}^{27}\theta_{2i}+f\sum_{i=1}^{27}D_i+kn=\sum_{i=1}^{27}P_{Ji}$$

III. Presentation And Discusion Of The Results

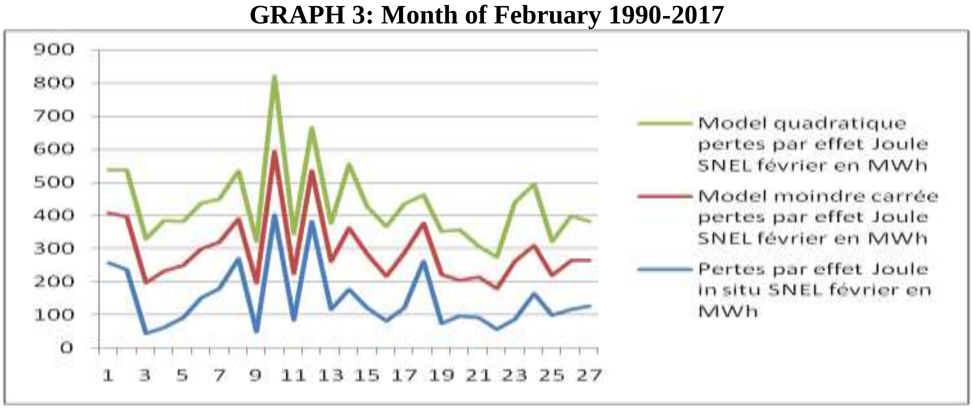
The following results are presented by month over a period going from 1990 until 2017. Unfortunately the year 1996 was not taken into account because it did not have availability of data for most of the months due to the war that was rampant in the region at that time. This makes the number of years of study 27 instead of 28.

GRAPH 2: Month of January 1990-2017



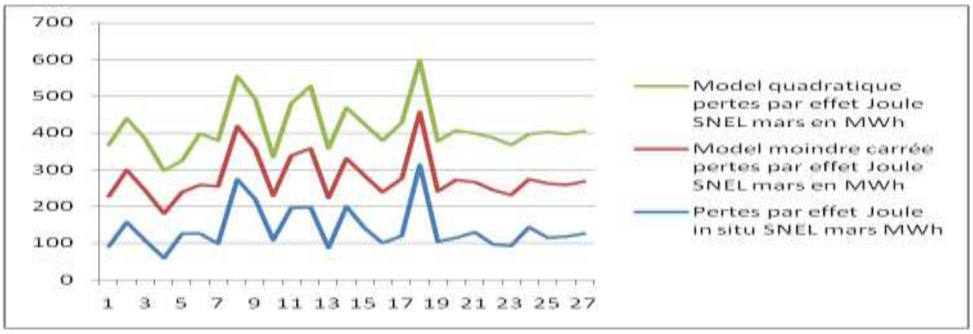
$P_{J\ NEL}=-109.292*\theta_{BUK}+26.976*\theta_{BUJ}+4.685*D+1240.482$ (Least square model)
$P_{J\ NEL}=2.08*10^{-5}*\theta_{BUK}^2-12.649*\theta_{BUJ}^2-2.014*10^{-8}*D^2-102.898*\theta_{BUK}+618.913*\theta_{BUJ}+4.766*D-5808.82$ (Quadratic model)

GRAPH 3: Month of February 1990-2017



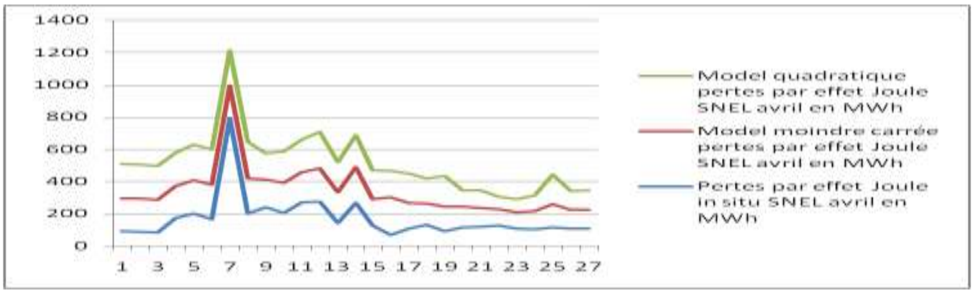
$P_{J\ NEL}=-5.13*\theta_{BUK}-38.656*\theta_{BUJ}-1.618*D+1291.663$ (Least square model)
$P_{J\ NEL}=1.596*10^{-5}*\theta_{BUK}^2+61.677*\theta_{BUJ}^2+0.022*D^2-11.929*\theta_{BUK}-2936.883*\theta_{BUJ}-5.691*D+35631.714$ (Quadratic model)

GRAPH 4: Month of March 1990-2017



$P_{J\ NEL}=13.157*\theta_{BUK}+18.872*\theta_{BUJ}+0.254*D-576.952$ (Least square model)
$P_{J\ NEL}=5.83*\theta_{BUK}^2-24.225*\theta_{BUJ}^2+0.007*D^2-218.645*\theta_{BUK}+1143.471*\theta_{BUJ}-1.278*D-11246.264$ (Quadratic model)

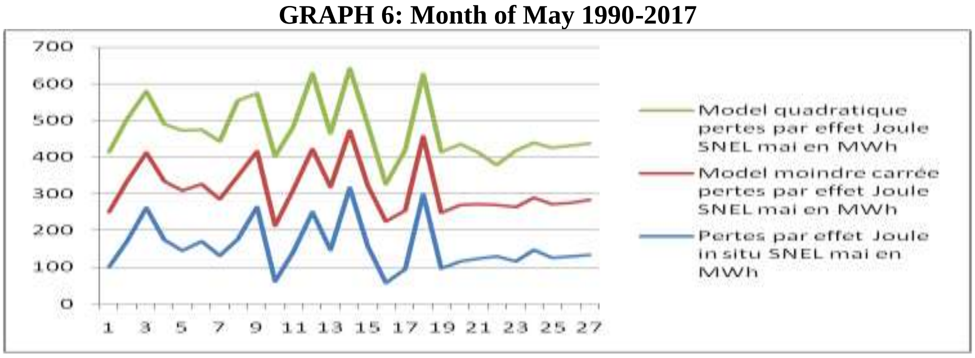
GRAPH 5: Month of April 1990-2017



P_{JNEL}=-33.475*θ_{BUK}+13.401*θ_{BUJ}-2.412*D+711.276 (Least square model)

P_{JNEL}=-66.675*θ_{BUK}^2 -8.928*θ_{BUJ}^2 -
0.136*D^2+2536.755* θ_{BUK}+433.027*θ_{BUJ}+21.878*D-30030.118(Quadratic model)

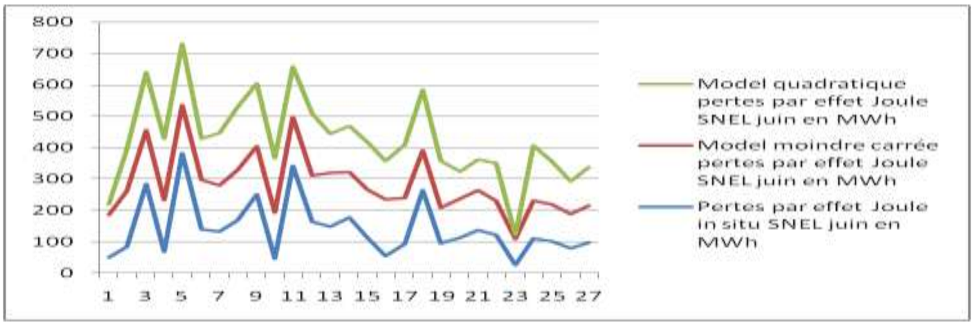
GRAPH 6: Month of May 1990-2017



P_{JNEL}=13.079*θ_{BUK}+11.336*θ_{BUJ}-0.758*D-295.182 (Least square model)

P_{JNEL}=-17.851*θ_{BUK}^2 +33.402*θ_{BUJ}^2 -0.108*D^2+691.077* θ_{BUK}-
1543.54*θ_{BUJ}+18.393*D+ 10527.329 (Quadratic model)

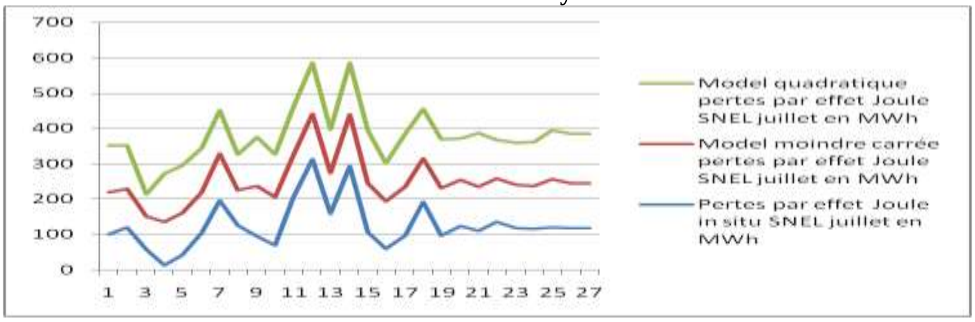
GRAPH 7: Month of June 1990-2017



P_{JNEL}=9.174*θ_{BUK}+16.489*θ_{BUJ}-1.585*D-255.389 (Least square model)

P_{JNEL}=-172.44*θ_{BUK}^2 -48.437*θ_{BUJ}^2 -
0.113*D^2+6480.608* θ_{BUK}+2114.644*θ_{BUJ}+17.832*D-84449.947 (Quadratic model)

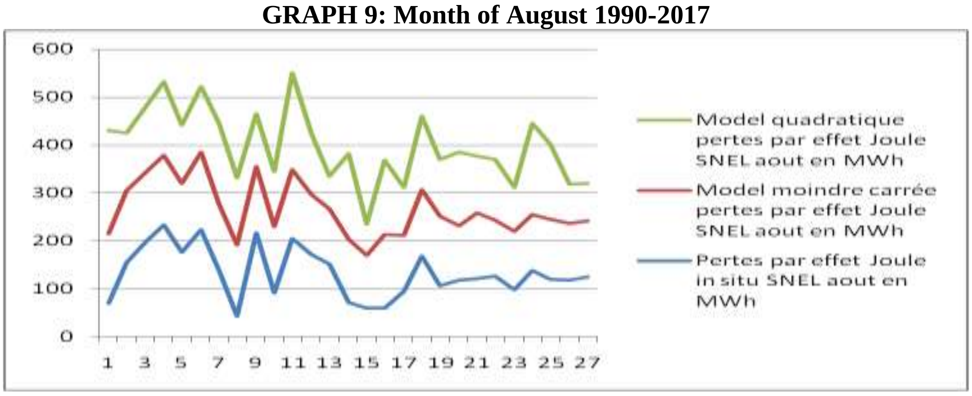
GRAPH 8: Month of July 1990-2017



$P_{J\,NEL}=-24.316*\theta_{BUK}+2.751*\theta_{BUJ}-0.217*D-553.441$ (Least square model)

$P_{J\,NEL}=0.001*\theta_{BUK}^2+50.133*\theta_{BUJ}^2+8.79*10^{-6}*D^2-38.669*\theta_{BUK}-2054.428*\theta_{BUJ}+0.004*D+21872.306$ (Quadratic model)

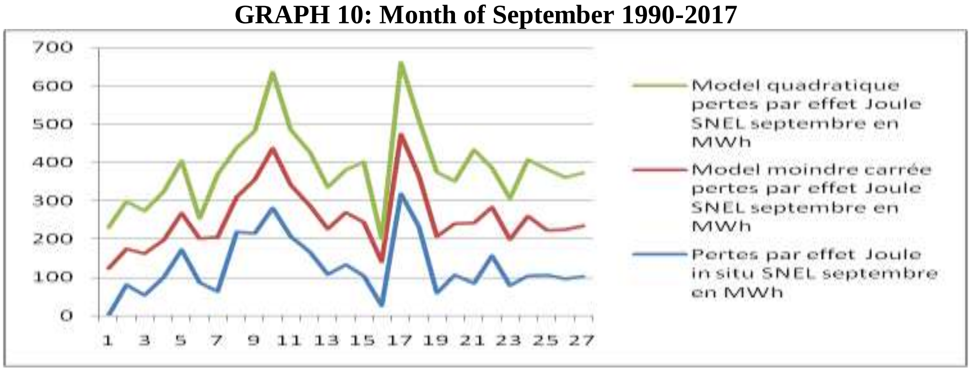
GRAPH 9: Month of August 1990-2017



$P_{J\,NEL}=15.116*\theta_{BUK}+10.862*\theta_{BUJ}-0.065*D-398.803$ (Least square model)

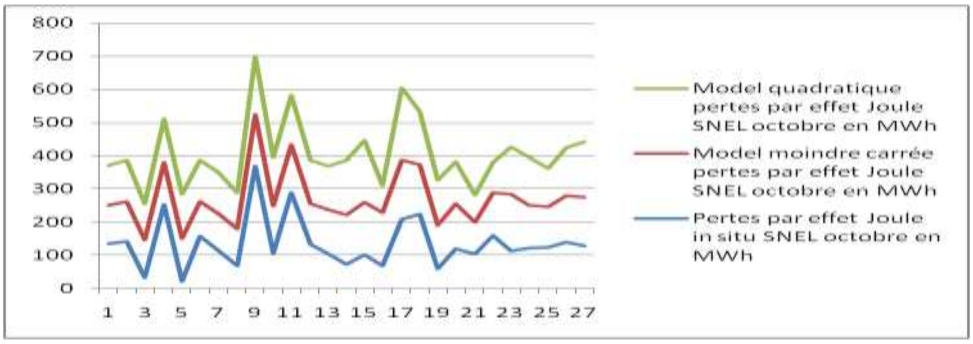
$P_{JNEL}=-8.251*\theta_{BUK}^2-11.784*\theta_{BUJ}^2-0.064*D^2+332.44*\theta_{BUK}+511.081*\theta_{BUJ}+10.371*D-9157.281$ (Quadratic model)

GRAPH 10: Month of September 1990-2017



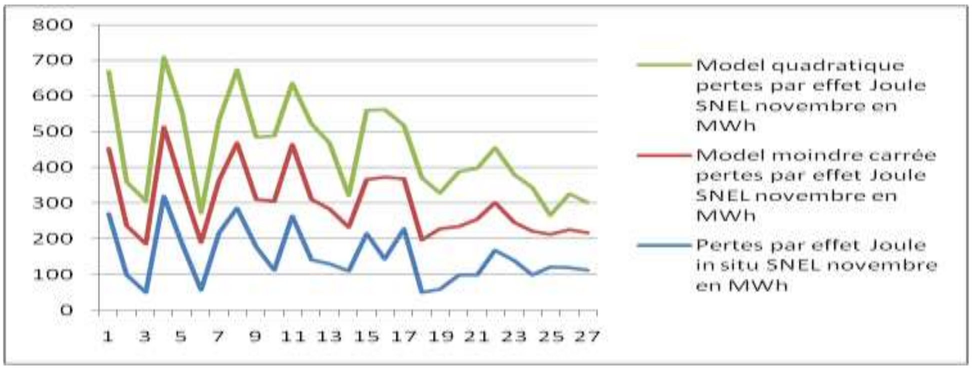
$P_{J\,NEL}=12.463*\theta_{BUK}+19.31*\theta_{BUJ}-0.363*D-576.889$ (Least square model)
$P_{J\,NEL}=-31.465*\theta_{BUK}^2+21.989*\theta_{BUJ}^2-0.097*D^2+1245.925*\theta_{BUK}-976.713*\theta_{BUJ}+16.099*D-2004.983$ (Quadratic model)

GRAPH 11: Month of October 1990-2017



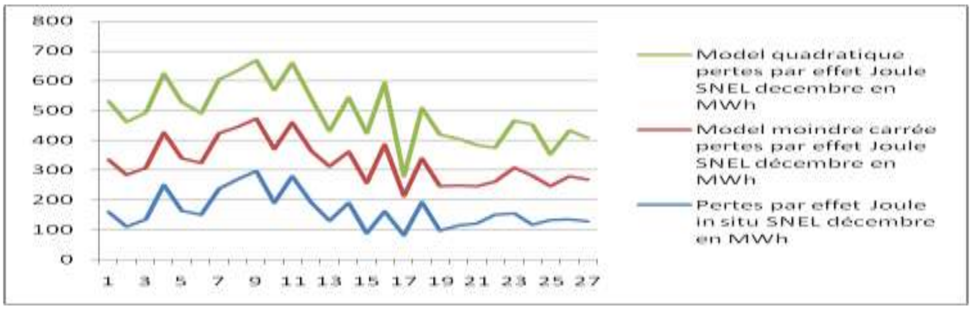
$P_{J\,NEL}=42.746*\theta_{BUK}+8.736*\theta_{BUJ}-0.26*D-868.625$ (Least square model)
$P_{J\,NEL}=40.08*\theta_{BUK}^2-12.165*\theta_{BUJ}^2-0.142*D^2-1486.403*\theta_{BUK}+572.397*\theta_{BUJ}+23.83*D-6182.094$) (Quadratic model)

GRAPH 12: Month of November 1990-2017



$P_{J\,NEL}=-15.256*_{BUK}+40.888*_{BUJ}-1.592*D-363.114$ (Least square model)
$P_{J\,NEL}=0.0005*BUK2-101.982*BUJ2-4.172*D^2-14.121*\theta_{BUK}+4724.683*_{BUJ}-1.915*D-54094.89$ (Quadratic model)

GRAPH 13: Month of December 1990-2017



$P_{J\,NEL}$=1.431*θ_{BUK}+4.648*θ_{BUJ}-3.289*D+320.004 (Least square model)
$P_{J\,NEL}$=-41.657*θ_{BUK}^2 -9.945*θ_{BUJ}^2 -0.11*D^2-1548.44* θ_{BUK}+471.583*θ_{BUJ}+16.583*D-20391.566(Quadratic model)

By observing all twelve graphs, we find that the least squared model is better than the quadratic Lagrange model. The curve of the least squared model is closer to that of the in situ data over the 27 years while that of the quadratic Lagrange model, although following the same course, moves further away from it.

IV. Discussion Of The Results

In this point we will seek to validate the model that would be most suitable for modeling losses by Corona effect on the BUKAVU-BUJUMBURA high-voltage line of SNEL. Here we will have to replace the hydro-atmospheric data of 2018 in our equations and thus have the data modeled 2018 for the losses by Joule effect.

Table I: Hydro-atmospheric data for 2018

Month	2018 flow in m^3/s	θ_{BUK} 2018 en °C	θ_{BUJ} 2018 en °C
JAN	100.1	19	22.3
FEV	97.55	18.9	23.4
MAR	97.62	19.2	23.4
AVR	101.99	18.8	22.8
MAI	94.55	18.7	23.7
JUI	94.96	18.5	22
JUIL	95.34	18.4	21.3
AOU	89.17	20	22.7
SEP	90.56	19.8	21.2
OCT	93.27	19.3	22.1
NOV	90.38	18.5	23.7
DEC	93.92	17.2	23.7

Source: RUZIZI I SUD-KIVU power station

Table II: Overall losses and losses by Joule effect 2018

Month	ES NEL 2018	ER NEL 2018	P_{GOBAL} NEL 2018	P_{Joule} NEL 2018
JAN	3126	2853	273	221.13
FEB	2617	2442	175	141.75
MAR	2615	2451	164	132.84
APR	3262	3089	173	140.13
MAY	3424	3250	174	140.94
JUNE	3009	2842	167	135.27
JULY	3506	3343	163	132.03
AUG	3555	3377	178	144.18
SEP	2680	2539	141	114.21
OCT	2404	2249	155	125.55
NOV	2814	2604	210	170.1
DEC	3144	2955	189	153.09

Source: RUZIZI I plant monthly technical report (RTM)

IV.1. 2018 MODELED JOULE LOSS PER LESSER SQUARE
January
$P_{J\,NEL}$=-109.292*θ_{BUK}+26.976*θ_{BUJ}+4.685*D+1240.482
=-109.292*19+26.976*22.3+4.685*100.1+1240.482
=234.467 MWh

February

$P_{J\ NEL}$=-5.13*θ_{BUK}-38.656*θ_{BUJ}-1.618*D+1291.663
=-5.13*18.9-38.656*23.4-1.618*97.55+1291.663
=132.319 MWh

March

$P_{J\ NEL}$=13.157*θ_{BUK}+18.872*θ_{BUJ}+0.254*D-576.952
=13.157*19.2+18.872*23.4+0.254*97.62-576.952
=142.062 MWh

April

$P_{J\ NEL}$=-33.475*θ_{BUK}+13.401*θ_{BUJ}-2.412*D+711.276
=-33.475*18.5+13.401*22.8-2.412*101.99+711.276
=141.488 MWh

May

$P_{J\ NEL}$=13.079*θ_{BUK}+11.336*θ_{BUJ}-0.758*D-295.182
=13.079*18.7+11.336*23.7-0.758*94.55-295.182
=146.389 MWh

June

$P_{J\ NEL}$=9.174*θ_{BUK}+16.489*θ_{BUJ}-1.585*D-255.389
=9.174*18.5+16.489*22-1.585*94.96-255.389
=126.576 MWh

July

$P_{J\ NEL}$=-24.316*θ_{BUK}+2.751*$\theta\theta_{BUJ}$-0.217*D-553.441
=-24.316*18.4+2.751*21.3-0.217*95.34-553.441
=143.934 MWh

August

$P_{J\ NEL}$=15.116*θ_{BUK}+10.862*θ_{BUJ}-0.065*D-398.803
=15.116*20+10.862*22.7-0.065*89.17-398.803
=144.288 MWh

September

$P_{J\ NEL}$=12.463*θ_{BUK}+19.31*θ_{BUJ}-0.363*D-576.889
=12.463*19.8+19.31*21.2-0.363*90.56-576.889
=112.250 MWh

October

$P_{J\ NEL}$=42.746*θ_{BUK}+8.736*θ_{BUJ}-0.26*D-868.625
=42.746*19.3+8.736*22.1-0.26*93.27-868.625
=125.188 MWh

November

$P_{J\ NEL}$=-15.256*θ_{BUK}+40.888*θ_{BUJ}-1.592*D-363.114
=-15.256*18.5+40.888*23.7-1.592*90.38-363.114
=179.810 MWh

December

$P_{J\ NEL}$=1.431*θ_{BUK}+4.648*θ_{BUJ}-3.289*D+320.004
=1.431*17.2+4.648*23.7-3.289*93.92+320.004
=145.871 MWh

IV.2 LOSSES BY JOULE EFFECT MODEL 2018 BY THE LAGRANGE QUADRATIC METHOD

January

$P_{J\ NEL}$=2.08*10^{-5}*θ_{BUK}^2 -12.649*θ_{BUJ}^2 -2.014*10^{-8}*D^2-102.898* θ_{BUK}+618.913*θ_{BUJ} +4.766*D-5808.82=2.08*10^{-5}*$(19)^2$-12.649*$(22.3)^2$-2.014*10^{-8}*$(100.1)^2$-102.898*(19) +618.913*(22.3)+4.766*(100.1)-5808.82=224.740 MWh

February

$P_{J\ NEL}$=1.596*10^{-5}*θ_{BUK}^2 +61.677*θ_{BUJ}^2 +0.022*D^2-11.929* θ_{BUK}-2936.883*θ_{BUJ}-5.691*D+35631.714=1.596*10^{-5}*$(18.9)^2$+61.677*$(23.4)^2$+0.022*$(97.55)^2$ -11.929*(18.9)-2936.883*(23.4)-5.691*(97.55) +35631.714 =109.250 MWh

March

$P_{J\ NEL}$=5.83*θ_{BUK}^2 -24.225*θ_{BUJ}^2 +0.007*D^2-218.645* θ_{BUK}+1143.471*θ_{BUJ}-1.278*D-11246.264=5.83*$(19.2)^2$-24.225*$(23.4)^2$+0.007*$(97.62)^2$-218.645*(19.2) +1143.471*(23.4)-1.278*(97.62)-11246.264 =139.452 MWh

April

$P_{J\,NEL}$=-66.675*θ_{BUK}^2 -8.928*θ_{BUJ}^2 -0.136*D²+2536.755* θ_{BUK}+433.027*θ_{BUJ} +21.878*D-30030.118=-66.675*(18.8)²-8.928*(22.8)²-0.136*(101.99)²+ 2536.755*(18.8) +433.027*(22.8)+21.878*(101.99)-30030.118 =143.818 MWh

May

$P_{J\,NEL}$=-17.851*θ_{BUK}^2 +33.402*θ_{BUJ}^2 -0.108*D²+691.077* θ_{BUK} 1543.54*θ_{BUJ}+ 18.393*D+ 10527.329 =-17.851*(18.7)²+33.402*(23.7)²-0.108*(94.55)² +691.077*(18.7)-1543.54*(23.7) +18.393*(94.55) +10527.329 =174.192 MWh

June

$P_{J\,NEL}$=-172.44*θ_{BUK}^2 -48.437*θ_{BUJ}^2 -0.113*D²+6480.608* θ_{BUK}+2114.644*θ_{BUJ} +17.832*D -84449.947 =-172.44*(18.5)²-48.437*(22)²-0.113*(94.96)²+ 6480.608*(18.5) +2114.644*(22) +17.832*(94.96)-84449.947=176.731 MWh

July

$P_{J\,NEL}$=0.001*θ_{BUK}^2 +50.133*θ_{BUJ}^2 +8.79*10^{-6}*D²-38.669* θ_{BUK}-2054.428*θ_{BUJ}+ 0.004*D + 21872.306 =0.001*(18.4)²+50.133*(21.3)²+8.79*10^{-6}*(95.34)²-38.669*(18.4)-2054.428*(21.3) +0.004*(95.34)+21872.306 =147.112 MWh

August

$P_{J\,NEL}$=-8.251*θ_{BUK}^2 -11.784*θ_{BUJ}^2 -0.064*D²+332.44* θ_{BUK}+511.081*θ_{BUJ}+10.371*D-9157.281=-8.251*(20)²-11.784*(22.7)²-0.064*(89.17)²+332.44*(20) +511.081*(22.7) +10.371*(89.17)-9157.281=136.380 MWh

September

$P_{J\,NEL}$=-31.465*θ_{BUK}^2 +21.989*θ_{BUJ}^2 -0.097*D²+1245.925* θ_{BUK}-976.713*θ_{BUJ}+16.099*D-2004.983 =167.631 MWh

October

$P_{J\,NEL}$=40.08*θ_{BUK}^2 -12.165*θ_{BUJ}^2 -0.142*D²1486.403* θ_{BUK}+572.397*θ_{BUJ}+23.83*D- 6182.094 =40.08*(19.3)²-12.165*(22.1)²-0.142*(93.27)² 1486.403*(19.3) + 572.397*(22.1)² + 23.83*(93.27)-6182.09 =119.706 MWh

November

$P_{J\,NEL}$=0.0005*θ_{BUK}^2 -101.982*θ_{BUJ}^2 -4.172*D²-14.121* θ_{BUK}+4724.683*θ_{BUJ}-1.915*D-54094.89 =0.0005*(18.5)²-101.982*(23.7)²-4.172*(90.38)²-14.121*(18.5)+4724.683*(23.7)² -1.915*(90.38)-54094.89=163.679 MWh

December

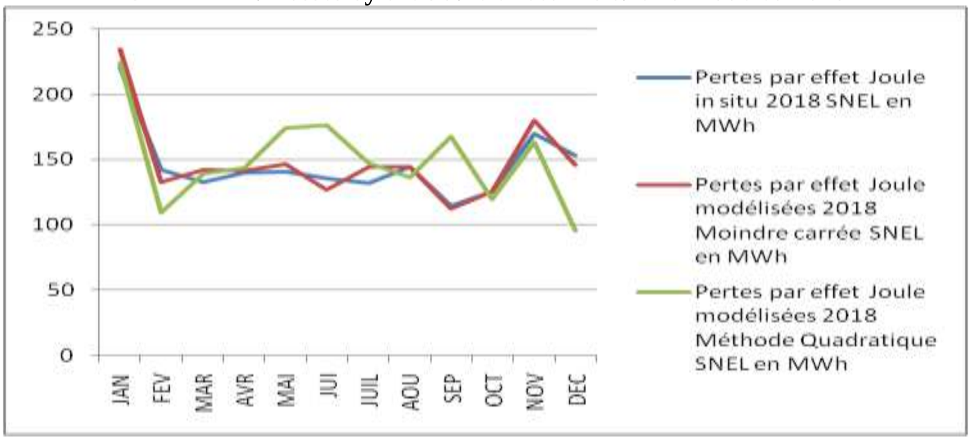
P_{JNEL}=-41.657*θ_{BUK}^2 -9.945*θ_{BUJ}^2 -0.11*D²-1548.44* θ_{BUK}+471.583*θ_{BUJ} +16.583*D-20391.566=-41.657*(17.2)²-9.945*(23.7)²-0.11*(93.92)²-1548.44*(17.2) +471.583*(23.7) +16.583*(93.92)-20391.566 =95.474 MWh

Table III: In situ and modeled losses by Joule effect 2018

Month	P_{Joule} NEL 2018	P_{Joule} NEL 2018 Least square	P_{Joule} NEL 2018 Quadratic method
JAN	221.13	234.467	224.740
FEB	141.75	132.319	109.250
MAR	132.84	142.062	139.452
APR	140.13	141.488	143.818
MAY	140.94	146.389	174.192
JUNE	135.27	126.576	176.731
JULY	132.03	143.934	147.112
AUGUST	144.18	144.288	136.380
SEP	114.21	112.250	167.631
OCT	125.55	125.188	119.706
NOV	170.1	179.810	163.679
DEC	153.09	145.871	95.474
TOTALS	**1751.22**	**1774.642**	**1798.165**

Source: RTM Centrale RUZIZI I and Modeling

GRAPH 14: Losses by the Joule effect in situ and modeled 2018



Source: EXCEL software

As we observed in the previous point, the least square model is best suited for hydro-atmospheric modeling of Joule losses of SNEL.

The graph presents a situation where the red line of the least square model practically rhymes with the blue line of the in situ data over the 27 years while the green line of the quadratic Lagrange model is a little out of phase.

V. Conclusion

Here we are at the end of our work devoted to the modeling of the losses by Joule effect in electrical energy on the BUKAVU-BUJUMBURA high-voltage line of SNEL. In the presentation point of the results the twelve graphs, clearly shows us that the least squared model is better than the quadratic model of Lagrange.

The curve of the least squared model is closer to that of the in situ data over the 27 years while that of the quadratic Lagrange model, although following the same course, moves further away from it.

The graph presents a situation where the red line of the least square model practically rhymes with the blue line of the in situ data over the 27 years while the green line of the quadratic Lagrange model is a little out of phase with the other two.

Consequently our initial hypothesis is rejected because we find that to carry out a hydro-atmospheric modeling of the losses by Joule effect for our case, it is necessary to apply the model of least squares.

VI. Suggestions

To keep the line in good condition we make the following suggestions:

To the governments of the DRC:

To become actively involved in finding solutions to the problems that SNEL is experiencing on the BUKAVU-BUJUMBURA high-voltage line;

To support SNEL's efforts to combat online losses caused by the Joule effect;

To seek both national and international partners to improve SNEL's work system on the BUKAVU-BUJUMBURA high-voltage line;

To create relationships with researchers to master the problem of online losses due to the Joule effect.

At SNEL:

To make regular descents on the ground for possible maintenance and especially to fight against pollution caused by vegetation around the line;

To gradually replace the cables of the SNEL line which have become increasingly obsolete with an age of about 61 years.

Raise the voltage from 70kV to 110KV because the greater the voltage, the less there are line losses due to the Joule effect.

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