Preliminary Design for the Sizing of An Emergency Thermal Power Plant (Ge) for the Continuity of Service of a Production Chain Case of the Kakula Concentrator

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ABSTRACT

This work concerns the preliminary project for the sizing of a thermal power station with emergency generators capable of supplying electrical energy to the Kamoa concentrator located in kakula. The Kakula concentrator, beneficiary of this preliminery project is a plant that concentrates the ore coming from the Kakula mine and having a grade of 5%. After treatement, a copper concentrate of about 55% is obtained and transported for sale.

For the choice of generators, the most important element was the determination of the power to be supplied. To do this, we based ourselves on some principales of general electricity. The results enabled us to choose thirteen (13) generators of 4500 kVA of the brand SDMO that we coupled in parallel to obtain a power of 58500 kVA. Then, we chose a 50 MVA transformer to raise the 11 kV voltage produced by generators to a voltage of 33 kV which must be available on the main busbar of the plant. In the end, we proposed a general scheme of the plant with an automatic start system for the generators using an inverter.

Keywords : Generator, Inverter, Thermal power station, Electric, Concentrator

GENERAL INTRODUCTION

Electrical energy has become the most consumed product worldwide. It is an important factor in the development process of any nation because industries and other consumers need it for their consumption. It is produced in hydroelectric, wind, thermal, photoelectric, etc. power stations. In the DRC, this energy is marketed by the National Electricity Company (SNEL). For several years, SNEL has encountered difficulties in satisfying its customers. The ever-increasing need for electrical energy is one of the reasons for the unavailability of satisfactory electrical energy.

After a visit to the Kakula concentrator specialized in the production of copper concentrates, we noticed that the instability of the electrical energy marketed by SNEL is observed and has a great negative impact on the production chain of the factory. It is with this in mind that we have chosen our theme entitled "Preliminary design for the sizing of an emergency thermal power plant (GE) for the continuity of service of a production chain. Case of the Kakula concentrator". It will be question in this work to carry out calculations necessary for the choice of various equipment which one uses in a thermal power station, and to propose the possibility of an interconnection to help the factory of Kakula in the event of unavailability of the network. SNEL.

This document is structured around three chapters apart from the general introduction and the general conclusion. The first presents on the one hand the Kamoa Copper company, and on the other hand it traces the production chain of its Kakula concentrator. The second gives some general information on the elements to be used in the plant. The third deals with the criteria for choosing a generator, the coupling of several groups, the choice of the transformer, the sections of the cables, as well as the proposal for the plant diagram with the backup system.

I. PRESENTATION OF THE KAMOA COPPER COMPANY AND ITS KAKULA CONCENTRATOR

In this first chapter, we will describe our work site, give some details on the equipment installed in the Kakula concentrator plant and give its general electrical diagram. Kamoa Copper is a joint venture between Ivanhoé Mines, Zijin Mining Group and the Government of the Democratic Republic of Congo (DRC) with the objective of producing high-grade copper in the Kolwezi region, which is located in the province of Lualaba, DRC. With copper production started in July 2021.

I.1 GEOGRAPHICAL SITUATION AND HEAD OFFICE OF THE COMPANY

The Kamoa Copper project concession is located more or less 60 km from Kolwezi, in the region straddling two groups governed by two chiefs, Musokantanda and Mwilu, in the locality (sector) of Lufupa in the territory of Mutshatsha, The project is centered at approximately 10º46'S latitude and 25º15'E longitude. Its head office is located at number 1148-6 avenue de la libération, in the Golf les Battants district in the municipality of Lubumbashi. The figure below gives a geographical location of the Kakula concentrator.

Figure I.1 Geolocation of the Kamoa company

I.2 THE KAMOA-KAKULA CONCENTRATOR

Copper concentrates are produced at the concentrator. For this ore concentration, the following components are installed at the Kakula site:

- A two-stage crushing circuit feeds the primary stockpile intended to supply the crushing infrastructure;
- Primary and secondary ball mills operated in closed circuit with hydrocyclones;

- The flotation infrastructure that separates the useful mineral from the gangue;
- Concentrate and rejects decanters;
- Larox filters that remove water from concentrates coming from settling;
- A dedicated storage facility for transport and marketing purposes

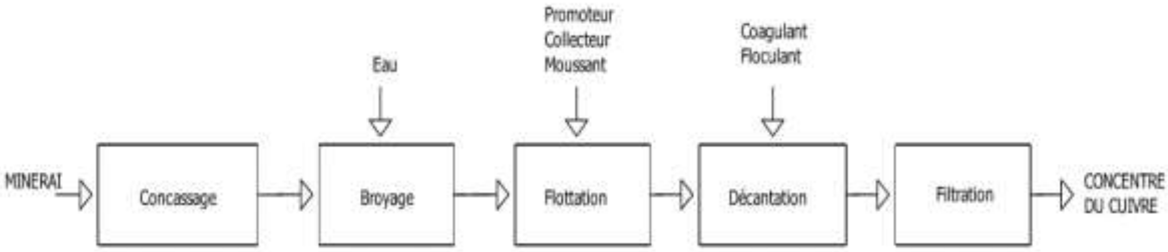

Figure I.10 Flowsheet of the copper production chain

I.9 SIMPLIFIED PLANT DIAGRAM

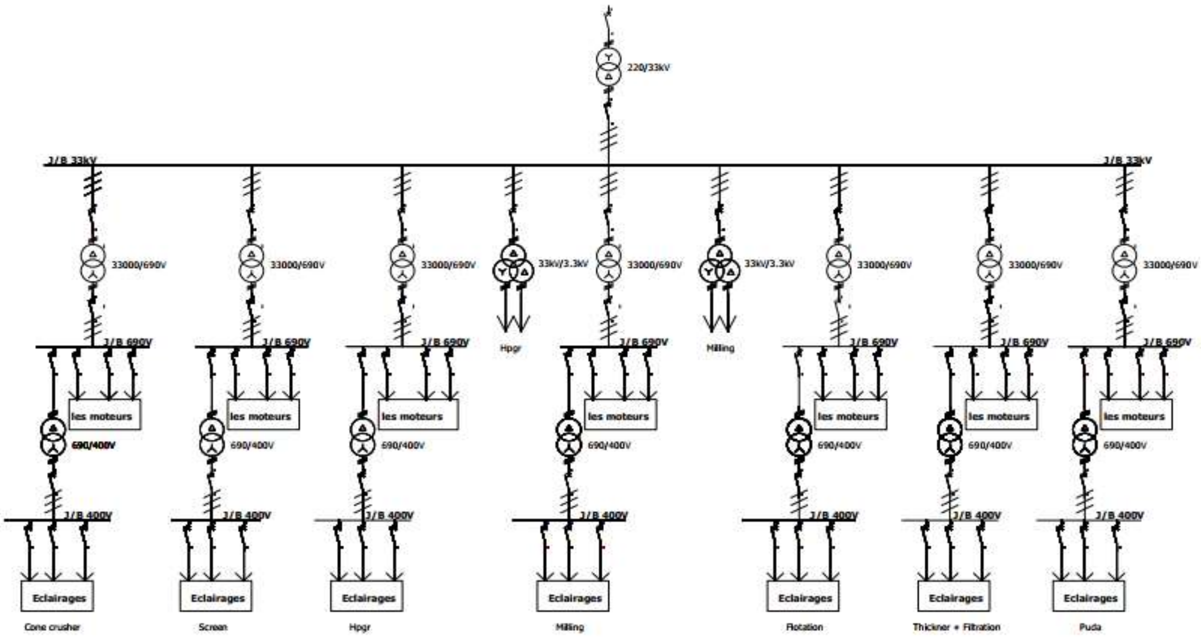

Figure I.19 Plant electrical installation

II. GENERAL INFORMATION ON THE COMPONENT ELEMENTS OF THE PLANT

The purpose of this chapter is to study the elements that will constitute our power plant. Thus, we will define and give some brief details about the generator set, the transformer, the electric cables and the elements of their protection.

II.1 GENERATING SETS

Etymologically, all generating sets are designed on the basis of the same principle: the difference is made in terms of their size and their power because they are in the range.

II.1.1 DEFINITION OF A GENERATING SET

A generator set is an autonomous system capable of producing electrical energy from mechanical energy via a diesel engine.

II.1.2 SYNOPTIC OF THE ENERGY CONVERSION PROCESS BY A GENERATING SET

Most groups consist of a heat engine which drives an alternator. Their size and weight can vary from a few kilograms to several tens of tons.

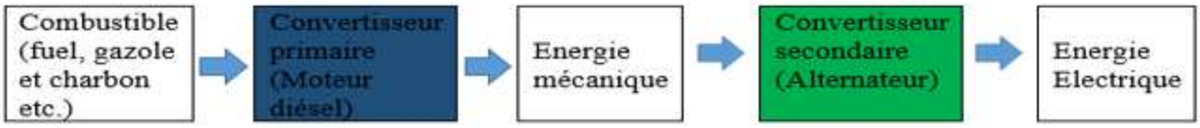

Figure II. 1 Block diagram of a generating set

It therefore consists of three parts which are:

- The electrical part (Alternator);
- The mechanical part (thermal engine);
- The command part (Control and command panel);

II.2 THE POWER TRANSFORMER

The power transformer is the most important equipment in an electrical network, its cost is extremely high and its downtime in the event of an incident is always very long. Its role is to raise or lower the voltage from one level to another while allowing the transit of very high powers.

II.3 HIGH VOLTAGE CIRCUIT BREAKERS

High voltage circuit breakers are mechanical switching devices capable of making, carrying or breaking a current below its rated voltage under normal conditions and under abnormal (short circuit) conditions. The circuit breaker is the only device that can break a short-circuit current, so it is the main protection element of any high-voltage network.

II.4 THE BUSBAR

In electrical distribution, a busbar refers to a copper or aluminum conductor that conducts electricity in an electrical panel, inside electrical equipment or in an electrical substation. It is therefore a low impedance conductor to which several electrical circuits can be connected at separate points. The figure below shows an MV busbar.

II.5 ELECTRIC CABLES

A high-voltage electric cable is a cable used for the transmission of electricity. It must withstand the constraints imposed both by the transport of significant electrical power, but also by physical and environmental conditions. The figure below shows an HV electrical cable.

III. DIMENSIONING STUDY OF THE THERMAL POWER PLANT (GE)

We will approach in this third chapter the main criteria which determine the choice of the elements of the thermal power plant with generators.

III.1 CALCULATION OF THE POWER OF THE KAKULA CONCENTRATOR BACKUP GENERATING SETS

III.1.1 Determination of installed power

To determine the installed power of the plant, we must determine the nominal power of each device and then calculate the total nominal power by applying Boucherot's theorem, on this, we must make a power balance.

Table III. 4 Power balance of the load to be supplied

RECEPTEURS	Description	Nombre	Tension triphasé (Volt)	Courant (Ampère)	Cos φ	Puissance Active par appareil (kW)	Puissance active totale (kW)	Puissance réactive (kVAR)
Concasseurs	à cônes	3	690	919,1	0,86	315	945	559,3
	HPGR	2	3300	488,2	0,86	1200	2400	1420,4
Tamis	Primaire	2	690	108,2	0,85	55	110	67,9
	Secondaire	1	690	45,9	0,82	45	45	31,2
Broyeurs	Primaire	1	3300	1360,7	0,90	7000	7000	3384,9
	Secondaire	1	3300	1360,7	0,90	7000	7000	3384,9
	Finisseur	1	690	345,4	0,86	355	355	210,1
Cyclones	Primaire	3	690	1568,8	0,80	500	1500	1123,1
	Secondaire	7	690	2417,8	0,86	355	2485	1470,9
Compresseur	à air	2	690	1045,9	0,80	500	1000	748,7
	Filtre à air 16 bars	1	690	109,5	0,84	110	110	70,8
	Filtre à air 10 bars	1	690	384,7	0,87	400	400	226,3
Cellules de Flottation	Dégrossisseur	8	690	1732,5	0,85	220	1760	1088
	Epuiseuse	6	690	1299,4	0,85	220	1320	816
	Lavage	4	690	288,5	0,87	75	300	169,7
	Relavage	5	690	270,7	0,85	55	275	169,4
	Lavage d'épuisseuse	9	690	1639	0,85	185	1665	1029,2

	Rélavage d'épuisseuse	4	690	216,5	0,85	55	220	135,9
Traitement de l'eau	Eau potable	1	690	5,2	0,87	5,5	5,5	3,06
Epaississeur	Concentrés	1	690	11	0,83	11	11	7,3
	Rejets	1	690	18,8	0,82	18,5	18,5	12,8
Bâches	décharge prim	1	690	698,9	0,85	710	710	438,9
	décharge sec	1	690	875,6	0,86	900	900	532,6
	Rejets	4	690	930,2	0,90	250	1000	483,8
	conditionnel	1	690	216,5	0,85	220	220	135,9
souffleurs	Cellules de flottation	5	690	1923,5	0,87	5,5	5,5	3,06
Filtres	Concentrés	2	690	37,7	0,82	18,5	37	25,7
Eclairage	Section broyage		400	230,9	1	160	160	0
	Section HPGR		400	230,9	1	160	160	0
	Section tamis		400	230,9	1	160	160	0
	Section flottation		400	230,9	1	160	160	0
	Concasseurs à cônes		400	230,9	1	160	160	0
	Décantation et filtration		400	230,9	1	160	160	0
	Section puda		400	230,9	1	160	160	0

Total active power of the installation

Pi=945+2400+110+45+7000+7000+355+1500+2485+1000+110+400+1760+1320+300+275+1665+220+5,5+11+18,5+710+900+1000+220+5,5+37+160+160+160+160+160+160+160=**34 912 kW**

Total reactive power of the installation:

Qi=559,3+1420,4+67,9+31,2+3384,9+3384,9+210,1+1123,1+1470,9+748,7+70,8+226,3+1088+816+169,7+169,4+1029,2+135,9+3,06+7,3+12,8+438,9+532,6+483,8+135,9+3,06+25,7=**18 879,28 kVAR**

Apparent power of the installation

Si= $\sqrt{Pi^2 + Qi^2}$

Si= $\sqrt{(34912)^2 + (18879{,}28)^2}$

Si= $\sqrt{1218847744 + 356424192{,}65}$

Si= $\sqrt{1575271936{,}6}$

Si= 39689,6 kVA

Si= 39,6 MVA ≅ 40 MVA

III.1.2 DETERMINATION OF THE OVERALL POWER FACTOR

Cos φ = $\frac{Pi}{Si}$

Cos φ = $\frac{34912}{39689{,}6}$

Soit **Cos φ = 0,87**

III.1.3 DETERMINATION OF THE POWER CONSUMED BY THE INSTALLATION

Electric motors :

The efficiency of the electric motors being 80%, the power absorbed by them will be given by:

Pam = $\frac{Pm}{\eta}$

Pam = $\frac{33\,792}{0{,}8}$

Soit, Pam = 42 240 kW

Lighting :

Pae = 1120 kW

The total absorbed power will be the sum of the power absorbed by the motors and that absorbed by the lighting circuit.

Pa = Pam + Pae

Pa = 42240 + 1120

That is, Pa = 43,360 kW

III.1.4 DETERMINATION OF THE POWER OF USE

Motors and other powerful devices:

Ku= 0.75

Ks= 1

Hence Pum = 1 X 0.75 X 42240 kW

Let Pum= 31680 kW

Lighting :

Ku= 1

Ks= 1

Hence Pue = 1 X 1 X 1120 kW

Let Pue = 1120 kW

The total power utilization is therefore: Pu = Pum + Pue= 31,680+1120

Pu= 32,800 kW

III.1.5 DETERMINATION OF THE APPARENT POWER OF THE ALTERNATOR

We need a three-phase generator, so CL = 1.05

Which implies :

P = 1.05 X 32,800kW

Let P = 34,440 kW

Knowing that :
P = S X Cos φ
So, S = P/(Cos φ)
Considering the overall power factor of the installation as well as the active power of the alternator, the apparent power of the alternator will be given by:
S = (34,440)/0.87
Let S = 39,586 kVA Or S = 39.5 MVA ≅ 40 MVA

III.1.6 FINAL DETERMINATION OF THE APPARENT POWER OF THE GENERATING SET

The selected extension coefficient being equal to 1.25; the apparent power of the generating set will be equal to:

$$SG = \frac{Ce \times P}{Cos\ \varphi}$$

$$SG = \frac{1{,}25 \times 34440}{0{,}87}$$

Soit SG = 49482,7 kVA ou SG = 49,4 MVA ≅ 50 MVA

SG = 50 MVA

II.1.7 CHOICE OF GENERATING SET

The value of the apparent power of the generating set calculated previously leads us to the choice of a generating set with a nominal value of 50 MVA. However, we cannot find a generating set of such power on the market, which leads us to opt for 13 generating sets with a nominal apparent power of 4.5 MVA each, an output voltage of 11 kV which we will couple in parallel to achieve the desired power. The choice is made in the catalog of Köhler SDMO brand industrial generating sets.

III.2 CALCULATION OF TRANSFORMER CURRENTS 11/33 KV, 50 MVA

The power of the transformer being Sn = 50 MVA, we will calculate the primary and secondary current using the formula:
Sn = √3 x In x Un
With :
Sn: Nominal apparent power of the transformer
In: Nominal transformer current
We will note: (I1n = primary nominal current, I2n = secondary nominal current)
Un: Nominal transformer voltage
We will note: (U1n=Primary rated voltage, U1n =Secondary rated voltage)

Calculation of the primary current

By drawing In in the previous formula, the primary current will be given by the formula:

$$I1n = \frac{Sn}{U1n \times \sqrt{3}} \qquad (3.1)$$

$$I1n = \frac{50 \times 10^6}{1{,}73 \times 11 \times 10^3}$$

Soit **I1n = 2627,4 A**

b) Calculation of the secondary current

$$I2n = \frac{Sn}{U2n \times \sqrt{3}}$$

$$I2n = \frac{50 \times 10^6}{1{,}73 \times 33 \times 10^3}$$

Soit **I1n = 875,8 A**

The transformation ratio is given by the formula:

m = U2/U1=N2/N1=I1/I2

With :

- U1, U2: Primary and secondary voltage
- I1, I2: Primary and secondary current
- N1, N1: Number of primary and secondary turns of the transformer

We have chosen a transformer whose primary is connected in star and the secondary in delta. The transformer ratio of a star-delta transformer is given by:

$m = \frac{U2}{\sqrt{3}\,U1}$

$m = \frac{33}{\sqrt{3}\,x\,11} = \frac{33}{1{,}73\,x\,11} = 1{,}7$

After performing the calculations, the transformer needed for our central must have the following characteristics:

Table III. 7 Characteristic of the selected Transformer

Caractéristique	Grandeur électrique
Puissance apparente S	50 MVA
Tension primaire U1	11 kV
Tension secondaire U2	33 kV
Courant primaire I1	2627,4 A
Courant secondaire I2	875,8 A
Rapport de transformation m	1,7

III.3 DETERMINATION OF CONDUCTOR SECTIONS

III.3.1 TRANSFORMER → PLANT MAIN BUSBAR

a) Operating current

The apparent power absorbed by the installation being 48 MVA, under a phase-to-phase voltage of 33 kV, the operational current will be struck by:

$Ie = \frac{48\,x\,10^6}{1{,}73\,x\,33\,x10^3}$

Ie = 840,7 A

b) Fictitious current

To determine the fictitious current, it is necessary to have the correction factor K; Selection letter F

- K1 = 1
- K2 = 0.82 (Single layer on cable ladders)
- K3 = 0.93 (floor temperature at 30° C, PR cable)

K = K1 x K2 x K3 = 1 x 0.82 x 0.93 = 0.76

If = 840.7/0.76

Let If = 1106.1 A

The table gives for PR2, copper:

Iz = 1254 A

Section : **630 mm^2** ou 3 câbles de 240 mm^2 pour une phase.

c) Verification of voltage drop

L = 70 m ; S = 630 mm^2 ; Ie = 840,7 A ; U= 33 $x10^3$V ; ρ=22,5Ωmm^2/Km

ΔU (%) = $\sqrt{3}$ x Ie x (R cos φ + X sin φ) x $\frac{100}{Un}$

ΔU = $\sqrt{3}$ x 840,7 x (22,5x$\frac{0,07}{630}$ x 0,87 + 0,08 x 0,07 x 0,49)

ΔU = 7,14 V

ΔU (%) = 7,14 x $\frac{100}{33000}$

ΔU (%) = 0,021 less than 8%

III.3.2 11 GENERATING SET BUSBARS → TRANSFORMER

a) Operating current

The apparent power absorbed by the transformer being 50 MVA, under a phase-to-phase voltage of 11 kV, the operational current will be struck by:

Ie = $\frac{50 \ x \ 10^6}{1,73 \ x \ 11 \ x10^3}$

Ie = 2627,4 A

b) Fictitious current

The installation conditions of the pipe are the same, on this:

K = K1 x K2 x K3 = 1 x 0, 82 x 0, 93 = 0, 76

If = $\frac{2627,4}{0,76}$

Soit **If = 3457,1 A**

The table gives for PR2, copper:

Iz = 3762 A

3 cables of 630 mm^2 are suitable for one phase or 5 cables of 240 mm^2

Checking voltage drop

We have L = 5 m ; S = 3 x 630 mm^2 ; Ie = 2627,4 A ; U= 11 $x10^3$V ; ρ=22,5Ωmm^2/Km

ΔU (%) = $\sqrt{3}$ x Ie x (R cos φ + X sin φ) x $\frac{100}{Un}$

ΔU = $\sqrt{3}$ x 2627,4 x (22,5x$\frac{0,005}{3 \ x \ 630}$ x 0,8 + 0,08 x 0,005 x 0,59)

ΔU = 1,28 V

ΔU (%) = 1,28 x $\frac{100}{11000}$

ΔU (%) = 0,011 inférieur à 8

III.3.3 GENERATING SETS → GENERATING SET BUSBARS

a) Operating current

The apparent power per group being 4500 kVA, with a phase-to-phase voltage of 11 kV, the operational current will be struck by:

Ie = $\frac{2627,4}{13}$

Soit **Ie = 202,1 A**

b) Fictitious current

The installation conditions of the pipe are the same, on this:

K = K1 x K2 x K3 = 1 x 0, 82 x 0, 93 = 0, 76

If = $\frac{202,1}{0,76}$

Soit **If = 266 A**

c) Verification of voltage drop

Nous avons L = 10 m ; S = 70 mm^2 ; Ie = 236,4 A ; U= 11 $x10^3$V ; ρ=22,5Ωmm^2/Km

$\Delta U (\%) = \sqrt{3} \text{ x Ie x } (R \cos \varphi + X \sin \varphi) \text{ x } \frac{100}{Un}$

$\Delta U = \sqrt{3} \text{ x } 202{,}1 \text{ x } (22{,}5\text{x}\frac{0{,}01}{70} \text{ x } 0{,}8 + 0{,}08 \text{ x } 0{,}01 \text{ x } 0{,}59)$

$\Delta U = 1{,}06$ V

$\Delta U (\%) = 1{,}06 \text{ x } \frac{100}{11000}$

$\Delta U (\%) = 0{,}009$ inférieur à 8%

III.4 DETAILED BACKUP DIAGRAM

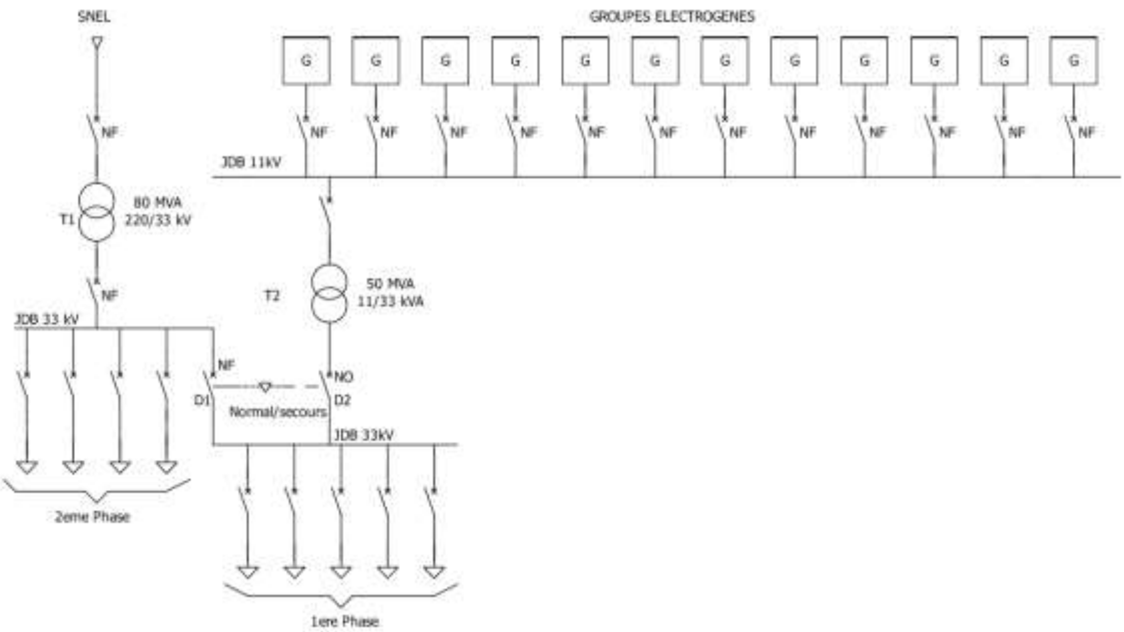

Figure III. 5 Diagram of the installation with the emergency system

Functioning

In normal operation, D1 is closed and D2 is open. The plant is powered by transformer T1. In the event of failure of the normal source, the following steps are carried out:

1. Operation of the normal/emergency device, opening of D1;
2. Automatic start of generator sets;
3. Load shedding that the generators will not be able to supply.
4. Closing of circuit breaker D2 when the generating sets will be able to supply the load and the residual voltage on the busbar is less than 30%

GENERAL CONCLUSION

At the end of our work, we were able to determine all the essential parameters to consider when choosing the elements to be used in our plant. We have determined the power of generators; the characteristics of the transformer as well as the sections of the cables to be used.

The choice of industrial generators requires several steps, namely, knowledge of the balance of the loads to be supplied, the type of fuel that the groups will have to use, knowledge of the installation that exists to know if we are going to use a single-phase generator or three-phase. Emergency generators are essential nowadays, given the permanent unavailability of the electrical energy supplied by SNEL, because without electrical energy, there is no activity.

The development of a maintenance point would be essential to ensure the proper functioning of the plant.

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