Study of the operation and performance of the Hamdallaye electrical substation in Conakry, Guinea

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***Abstract* -** The Guinean electricity grid is constantly overloaded due to the rapidly evolving energy needs of households and businesses. This study, which contributes to grid security, focuses on the operation and performance of the Hamdallaye electrical substation in Conakry. Its overall objective is to monitor the substation's operation to optimize its efficiency (reducing the voltage from 60 kV to 20 kV and improving distribution). The substation's operating parameters (frequency, incoming and outgoing voltages, current, active and reactive power) were monitored for one year (2022), as well as the electrical power supplied to the neighborhoods.Taouyah, Crusher, Commandanyah and Hafia.It appears that: the frequency changes from (50.043 Hz) innovemberhas (50.382 Hz) in February, with an annual average of (50.248 Hz);the incoming voltage varied by (58.638 kV) in April at (60.672 kV) in August, with an annual average of (59.523 kV); the starting voltage varied from (20.228 kV) in August to (22.011 kV) in April with an annual average of (20.971 kV); The current has varied from (130.901 A) in August at (204.251 A) in April, with an annual average of (172.16 A);the active power varied from (12.329 MW) in August at (26.604 MW) in April, with an annual average of 17.005 MW; thereactive power varied from (4.577 MVAr) inOctoberhas(7.630 MVAr) in April with an annual average of 6.072 MVAr. The average annual electrical power distributed per district is: Taouyah (65.881 MW), Crusher (65.656 MW), Commandanyah (40.132 MW), and Hafia (26.294 MW). During 2022, the average peak consumption of the four districts was 20.088 MW in April, with an annual average of 16.497 MW. Taking into account the development of offenders and population growth, we suggest thatthe power transformer (25 MW) of the substation is one of (35 to 50 MW).

Keywords : *Electrical substation, transmission network, power transformer*

I. INTRODUCTION

Guinea has significant energy potential, particularly hydroelectric power [1]. The difficulties in transporting and distributing energy produced in Guinea are characterized by the aging of electrical equipment (cables, poles, transformers, busbars, circuit breakers, disconnectors, surge protectors, electrical cells, cabinets, protection relays, capacitor banks and insulation monitors), which leads to significant electricity losses, approximately 25% to 30% [2, 3]. These energy losses (25% to 35%) of the electricity produced lead to the overheating of cables and substation equipment, causing numerous fires recorded on the network [4, 5]. Due to these multiple electrical accidents, it is important to first conduct a study on the substations (Tombo, Matoto, Kipé, Sonfonia, Maneah and Hamdallaye) on behalf of Conakry [6, 7].

The Hamdallaye substation, located in the Ratoma district of Conakry, plays a strategic role in: voltage transformation (HV/MV or MV/LV depending on its configuration); supplying several high-density districts; distribution and allocation of electrical energy and the stability of the local network. With the accelerated urbanization of Conakry and the constant increase in loads (housing, businesses, industries, administrations), the performance and reliability of this substation become a major issue for: the continuity of the public electricity service; the reduction of technical losses ; the improvement of energy quality and the safety of equipment and users.

Despite efforts to improve Guinea's electricity grid, service interruptions, overloads, and technical malfunctions persist in certain areas of Conakry. The Hamdallaye substation, as a key component of the distribution network, is subject to: a gradual increase in demand; significant load variations; technical constraints related to equipment; and risks of faults (short circuits, overvoltages, overheating).

Electrical substations are key components of the electrical grid, serving both the transmission and distribution of electricity. They allow the voltage to be increased for transmission and then reduced for consumption by users (residential or industrial). Electrical substations are therefore located at the ends of transmission or distribution lines; they are generally referred to as substations [8, 9].

It is therefore necessary to analyze the technical operation, performance level and current limitations of the Hamdallaye substation in order to propose improvement solutions adapted to the Guinean context.

II. PRESENTATION OF THE STUDY FRAMEWORK

The Hamdallaye electrical substation is located in the Ratoma district and is one of six substations (Tombo, Hamdallaye, Matoto, Kipe, Sonfonia, and Maneah) serving Conakry. It covers an area of 872.3 square meters and is operated by the China International Water and Electric Corp (CWE) Guinea company. It is connected to the Matoto substation and the Kaloum thermal power plant via 60kV lines. It operates at two voltage levels (60kV/20kV) with a single busbar and a 25 MVA power transformer. This electrical distribution substation handles 10% of the load on the Guinean grid. It transfers power from a high voltage level (60kV) to a lower voltage level (20kV). It has two incoming lines from the Matoto substation and the Kaloum thermal power plant. It is characterized by 6 feeders for the 20kV voltage level, including 2 spares for a possible extension. The other four (4) serve the districts of: Hafia, Concasseur, Taouyah and Commadanyah. Single-line diagram of the Hamdallaye substation (Figure 1).

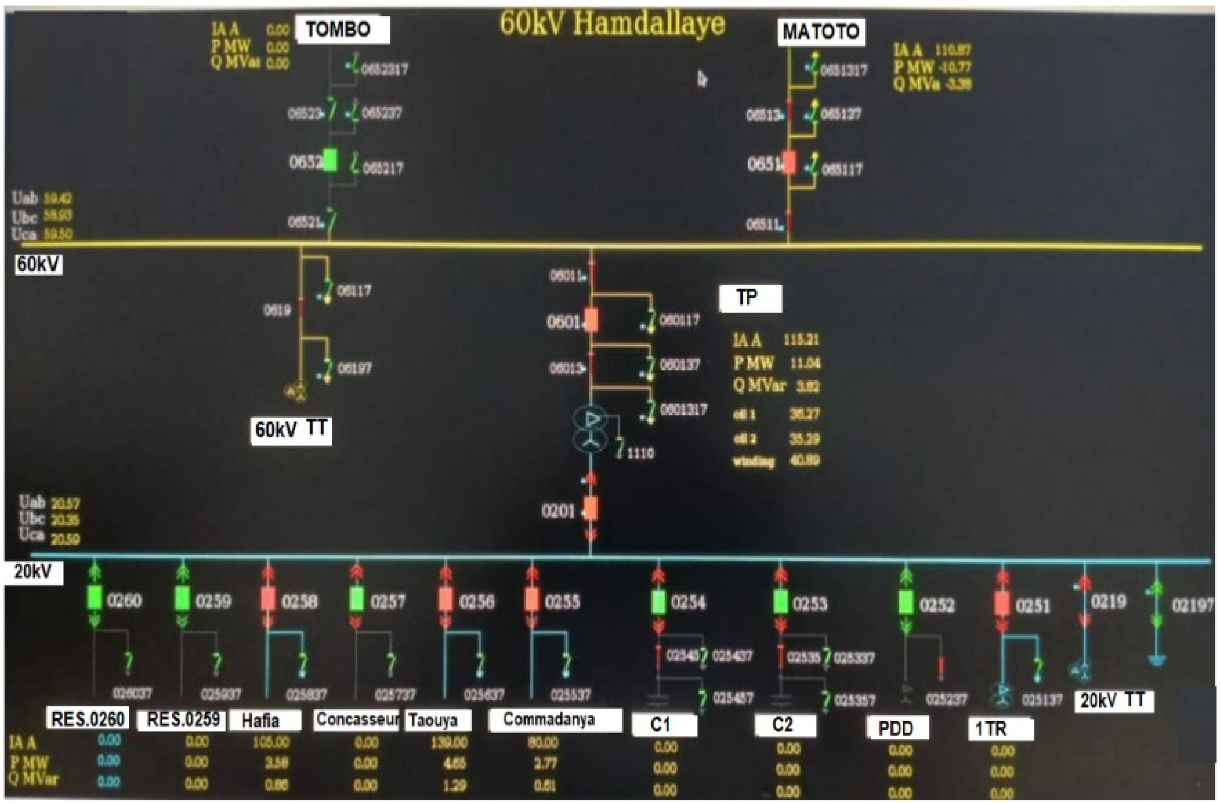

Fig. 1. Single-line diagram of the Hamdallaye substation

The main equipment in the substation is: themain transformer, thewithdrawal transformerthe current transformer, the gamesof bars, the circuit breaker, the grounding switch, thesurge protectors, electrical cells, the voltage transformer cabinet, the protection relays, thecapacitor bank andthe insulation monitor.

Any electrical system (cable, line, transformer, motor, lighting, etc.) using alternating current involves two forms of energy: active energy and reactive energy.

For a single-phase circuit, the active power P(kW), reactive power (kVAr) and S(kVA) are also defined by relations 1, 2 and 3 [10].

$$P = S.cos\varphi \qquad (1)$$

$$Q = I.sin\varphi \quad \text{or } Q = P.tg\varphi \qquad (2)$$

$$S = \sqrt{P^2 + Q^2} \qquad (3)$$

The transformermainfrom the substationtype SFZ11-25000/60, with a powerof 2.5 MVA.The drawdown transformer is of type SC11-100/21, its nominal capacity is 100 kVA, its nominal voltage is 21kV/380V.

III. METHODOLOGY

The methodology for managing and monitoring the substation's operation focuses on: monitoring operating parameters; inspecting or controlling equipment; and handling and managing electrical faults in the system. The substation's operating parameters are displayed and recorded on a computer screen programmed for this purpose (Figure II.4). These main parameters are: frequency [F(Hz)]; input voltage [U(kV)]; output voltage [U(kV)]; current [I(A)]; active power [P(MW)]; and reactive power [Q(MVAr)]. The desired qualities of the electrical substation are: safety, flexibility, maintainability and simplicity.

IV. RESULTS AND INTERPRETATIONS

The main results obtained relate to the monitoring of the substation's operating parameters for the year 2022, namely: frequency [F(Hz)], incoming voltage [U(60kV)], outgoing voltage [U(20kV)], delivered current [I(A)], active power [P(MW)], reactive power [MVAr] (Table 1) and the electrical power supplied to the four districts (Commandanyah, Taouyah, Crusher and Hafia) (Table 2).

TABLE I. FREQUENCY, INPUT AND OUTPUT VOLTAGE, CURRENT, ACTIVE AND REACTIVE POWER

Month	F(Hz)	U(60kV)	U(20kV)	I(A)	P(MW)	Q(MVAr)
January	50.363	59.201	20.785	194.920	18.486	7.107
FEBRUARY	50.382	59.230	20.807	195.515	18.583	6.983
March	50.347	59.068	20.790	193.985	18.666	6.526
April	50.230	58.638	22.011	204.251	26.604	7.630
May	50.234	59.359	20.228	178.167	16.883	6.276
June	50.240	60.194	21.178	160.955	15.154	6.444
July	50.255	60.248	21.270	140.659	13.180	5.789
August	50.244	60.672	21.222	130.901	12.329	5.373
September	50.186	59.542	20.852	142.918	13.730	4.769
October	50.101	59.380	20.817	161.715	15.613	4.577
November	50.043	59.672	20.899	167.988	16.167	4.863
December	50.347	59.068	20.790	193.985	18.666	6.526
Average	50.248	59.523	20.971	172.163	17.005	6.072

TABLE II. AVERAGE MONTHLY EXPENSESIN (MW)THE COMMANDANYA AND TAOUYAH DISTRICTS, CRUSHER AND HAFIA

Month	Commandanyah	Taouyah	Crusher	Hafia
January	3.480	5.766	5.864	3.409
February	3.510	5.777	5.879	3.444
March	3.480	5.635	5.979	3.588
April	3.508	5.765	6.108	4.708
May	3.306	5.443	5.455	2.689
June	3.346	5.624	5.341	0.894
July	3.072	4.851	4.581	0.744
August	2.854	4.649	4.366	0.674
September	3.107	5.076	4.785	0.772
October	3.447	5.769	5.500	0.882
November	3.543	5.892	5.819	0.901
December	3.480	5.635	5.979	3,588
Total	40.132	65.881	65.656	26.294

A. Frequency

The average monthly variations in the substation frequency for the year 2022 are illustrated by the curve of the figure 4.

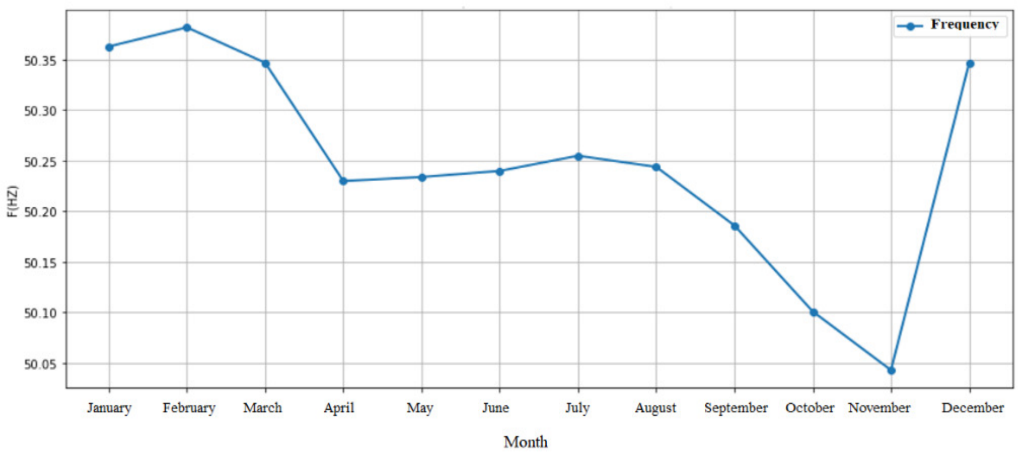

Fig. 4. Average monthly variations in frequency

The frequency of an electrical system is an indicator that shows the balance between electricity supply and demand in a given area. It is a balancing act, with the equilibrium point at 50 Hz (European standard value). The curve in Fig. 4 shows that the average frequency varies from (50.043 Hz) innovemberhas (50.382 Hz) in February, with an annual average of 50.248 Hz. This value remains within the frequency variation range recommended by the IEC [11]. This result shows that the network is quite balanced when compared to the standard (50 Hz).

B. Incoming Voltage 60 kV and Outgoing Voltage 20 kV

The average monthly variations in the incoming (60 kV) and outgoing (20 kV) voltage of the substation are illustrated by the curves of the figure 3.

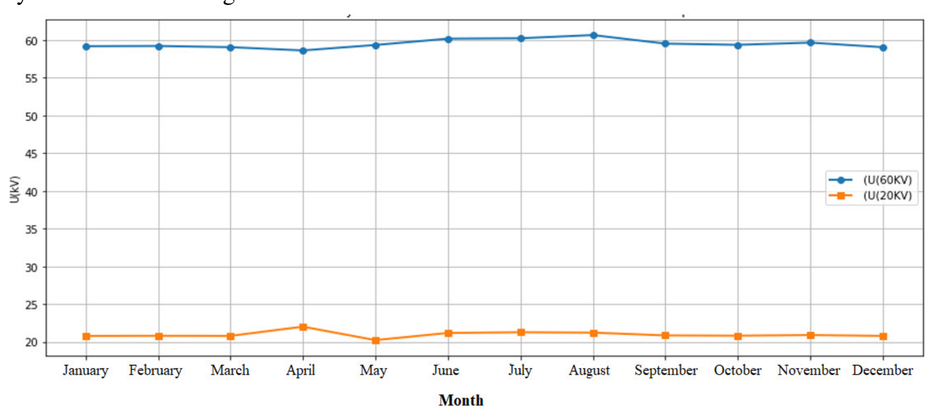

Fig. 3. Average monthly variations in incoming and outgoing voltage

The curves of the figure 3, shows that the incoming voltage has varied by (58.638 kV) in April at (60.672kV) in April, with an annual average of (59.523 kV) ; the supply voltage varied from 20.228 kV in August to 22.011 kV in April, with an annual average of 20.971 kV. The results show that the supply and incoming voltages are fairly stable.

C. Substation Current

The average monthly variations in the current are illustrated by the curve in Figure 4.

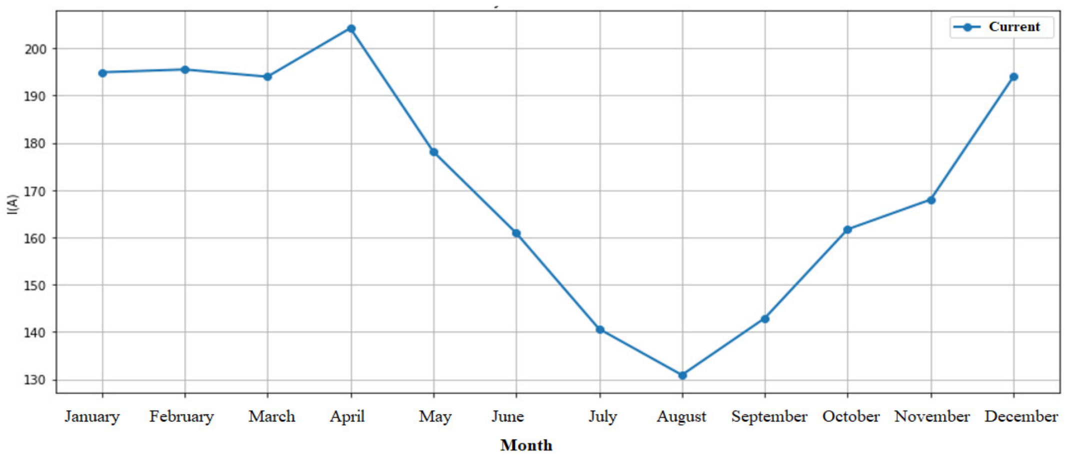

Fig. 4. Average monthly variations in current

The curve of average annual variations of the current (figure 4), shows that the current has varied by (130.901 A) in August at (204.251 A) in April, with an annual average of (172.16 A). Thus, during the months of January to April, the current intensity is high and relatively constant. This intensity is a function of the demand for electrical energy. Therefore, the demand for electrical energy is almost constant from January to April. It decreases from April to August and resumes its growth until December.

D. Active and Reactive Power

The average monthly variations in the active and reactive power of the substation are illustrated by the curves of the figure 5.

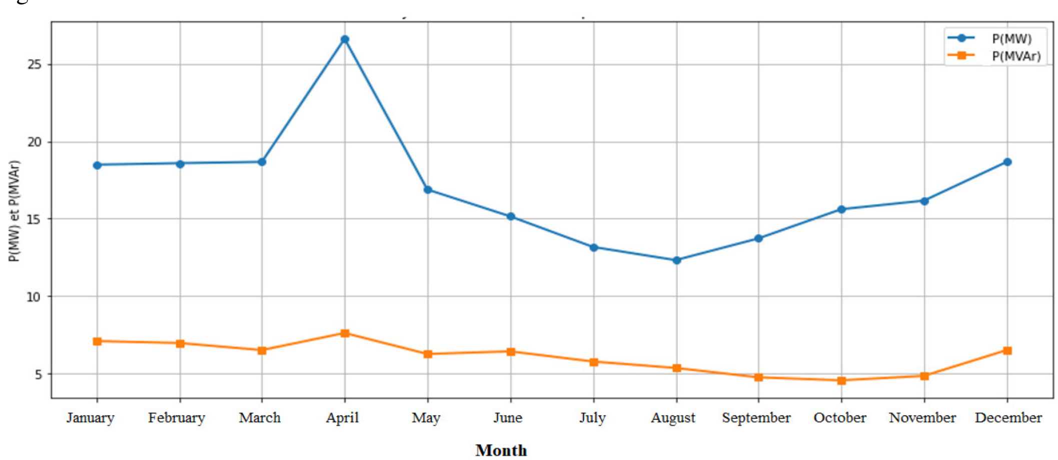

Fig. 5. Average monthly variations in active and reactive power

Active power is the actual usable power ; reactive power is the power that is not used to perform tasks but is required for the operation of inductive loads (motors, fluorescent lamps, etc.) and capacitive loads (capacitors) ; and apparent power is the total power in the network [12]. Similarly, the current intensity, the reactive power curve (figure 5) is stable from January to April and decreases until August.

E. Active Power, Reactive Power and Current

The average monthly variations in active and reactive power as a function of current are illustrated by the curves of the figure 6.

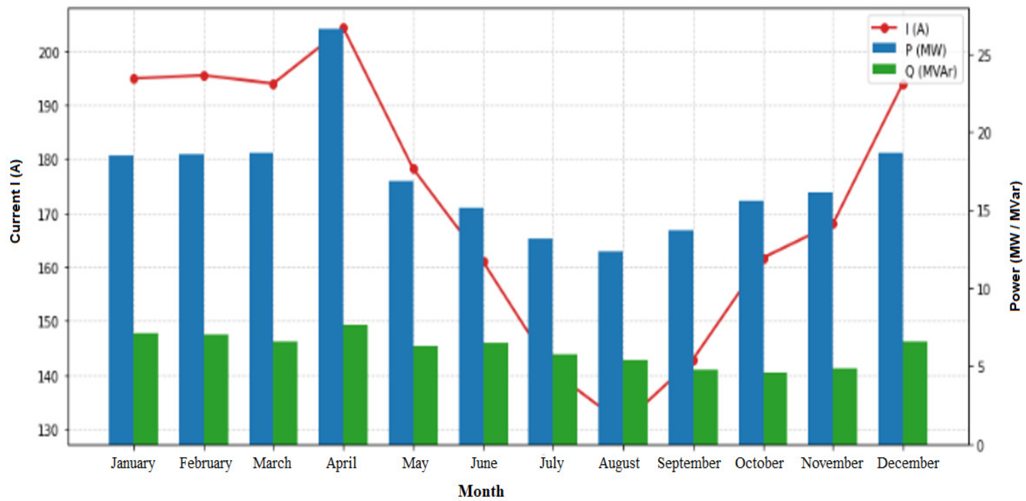

Fig. 6. Average monthly variations in active and reactive power as a function of current

Figure 6 shows that the active power la variation in current intensity.

F. Average monthly charges in (MW) for the Commandanyah, Taouyah, Concasseur and Hafia districts

The average monthly variations in charges per district are illustrated by the curves in Figure 7.

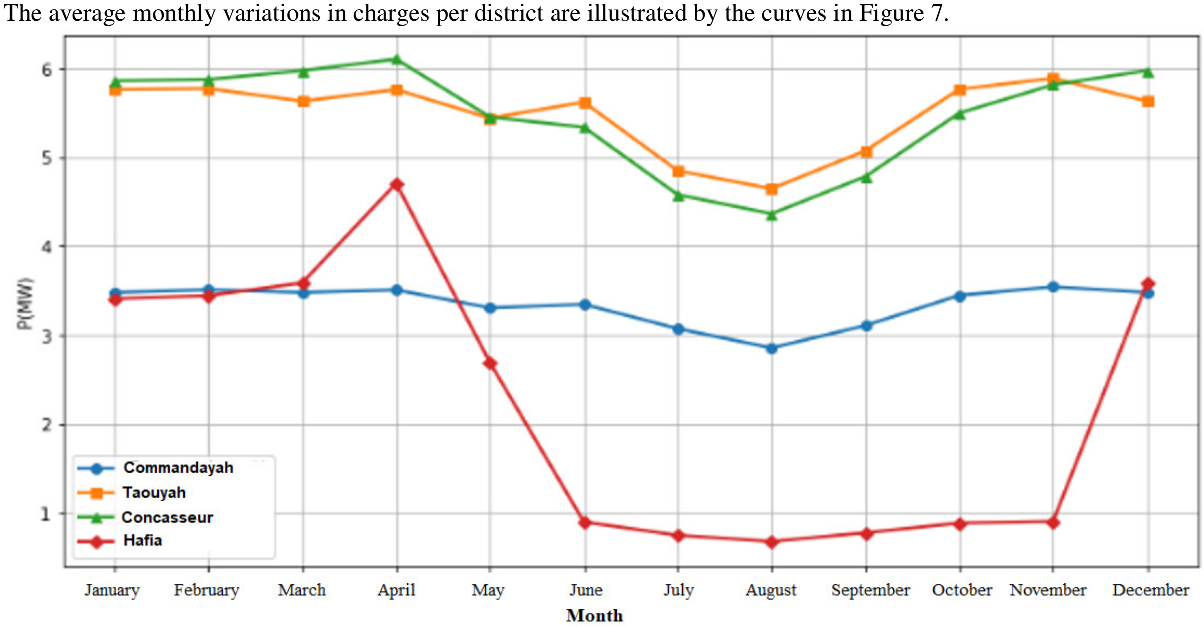

Fig. 7. Average monthly variations in charges per district

G. Total Annual Power per District in (MW)

The total annual power per district is illustrated by the curves in Figure 8.

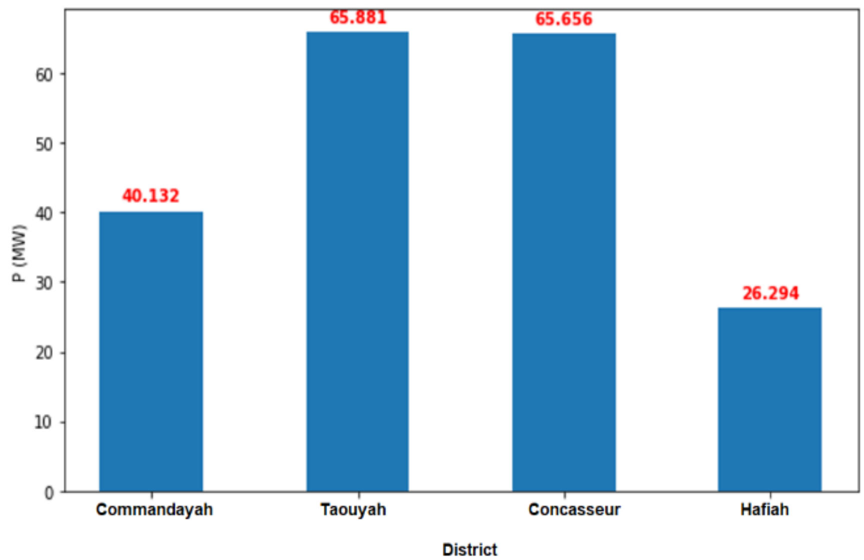

Fig. 8. Total annual power per district

The curves of the Figure 8 shows that the Taouyah and Concasseur districts have higher and more stable electricity consumption. Consumption in the Commandanyah district is fairly stable throughout the year.

V. CONCLUSION

In Guinea, despite electrification efforts and the commissioning of hydroelectric dams, the country still faces significant energy losses, frequent power outages, and poor electricity distribution. These problems are largely due to the inadequacy, obsolescence, or undersized electrical substations, key components of the national power grid. Their current state prevents the efficient management of electricity flows between generation, transmission, and distribution, especially in urban areas with high demand or in developing rural areas.

Given the average electrical power consumed by the four districts (20.088 MW) in April, with an annual average of 16.497 MW in 2022, it is desirable to replace thethe power transformer (25MW) of the substation by another of (35 to 50 MW) and to carry out the same study for all the other substations in the Conakry area.

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