DISTURBANCES OF THE 90 KV ELECTRICAL NETWORK AND THE 380/220 V DISTRIBUTION SYSTEM IN THE DOUALA-CAMEROON AREA

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ABSTRACT

Douala being the economic capital of Cameroon has many industries located within the Bassa and Bonaberi areas. In this paper, the power quality and disturbances are analysed on the Douala 90 kV electrical network and the 380/220 V distribution system. Network disturbance statistics are given over the past few years. Different back-up levels within the Douala area are investigated too.

INTRODUCTION

Applications of electric energy more and more use of power electronic interfaces at the grid connection point, which are more sensitive to network disturbances increasing the importance of power quality issues. Electric power systems are often subjected to a variety of incidents that, to a greater or lesser extend, may adversely affect the delivery of electric energy to consumers. Some of these network disturbances include:

- failure of electric system components;
- difficulties associated with the normal operation of large and complex real-time systems;
- transients;
- extreme weather conditions and earthquakes;
- voltage variations;
- harmonic distortions.

Figure 1 show the existing national electricity generation and transmission system in Cameroon under the Cameroonian national electricity company (AES-SONEL). It is in fact separated in to three independent subsystems; the northern interconnected grid (NIG) supplies the three northern provinces (Ngaoundere, Garoua, and Maroua); the eastern system supplies the eastern province, Bertoua, Abong-Mbang and Batouri; whilst the southern interconnected grid (SIG) covers the southwest region, Yaoundé, Douala, Bafoussam and Bamenda [9,13].

AES Sonel is the sole electric power generation, transmission
and distribution company in Cameroon with 933 MW of installed capacity, of which 77 % is hydro given 721 MW and 23 % is thermal (diesel/fuel oil) given 212 MW of hydroelectric power.

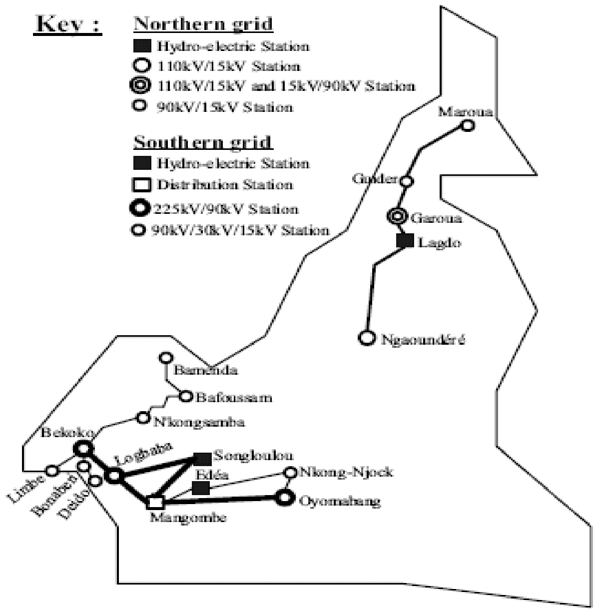

Fig.1: Electric power system of Cameroon

The transmission system is over 1,800 km of high voltage and 12,000 km of medium voltage lines with a distribution system of 528,000 customers, 1,200 medium voltage customers and five large users [9].

Comparing the number of customers (528,000) to the total population of almost 16.5 million, then it is clear most of the population do not have access to electricity. Currently, the southern interconnected system is unable to meet demands especially in the dry seasons due to:

- low water levels in the reservoirs;
- lightning strikes on the overhead lines;
- short circuits and human errors;
- inrush current during the switching of large electrical loads and energisation of large power transformers;
- switching of large capacitor banks;

- insufficient investment in transmission and distribution capacities, thermal generation and insufficient redundancy in all areas of the electric systems;
- rapid demand growth over the last five years;
- carrying out emergency stop operations [1].

Electricity in the southern interconnected system is mainly supplied from the old hydro power stations at Edea and Song-Loulou, both on the Sanaga River. Since building new transmission lines is very difficult and expensive, the following methods can help reduce network disturbances:

- reinforcement and/or optimization of protection systems;
- reducing human error;
- careful design of power systems and installations;
- installing good back up systems;
- using consumer's equipment with good immunity against network disturbances [12].

Considering the fact that electricity from the northern system of Cameroon is used to supply part of Chad Republic, this work will also be beneficial to Chad.

In this paper, network disturbances, possible causes, solutions and back-up systems are explained and discussed.

Network Reliability of the Douala Area

The southern interconnected system has two main hydro-energy production plants which are at Edea and Song-Loulou and benefits from the huge reservoirs with total capacity of 7.5 billion cubic meters of water. Song-Loulou produces 384 MW while Edea 264 MW of electric power and are connected to the Edea and Song-Loulou networks [10].
The 225 kV line transports electrical energy from the Song-Loulou hydro-electric station to a distribution station located at Mangombe and to the 225/90 kV station at Logbaba while the 90 kV line transport energy from Edea hydro-electric station to a second distribution station located at Logbaba. Fig 3 illustrates the interconnected systems within this area [13].

The 90 kV is the main supply in this area. In case of power failure of one of the sources, there is an automatic switch over to the alternative source which is used mostly to supply the Cameroon aluminium company (ALUCAM) being the highest consumer of electrical energy in Cameroon. The only back up facility being the 15 MW thermal plant located in Bassa is used to serve few others critical loads and safety equipment.

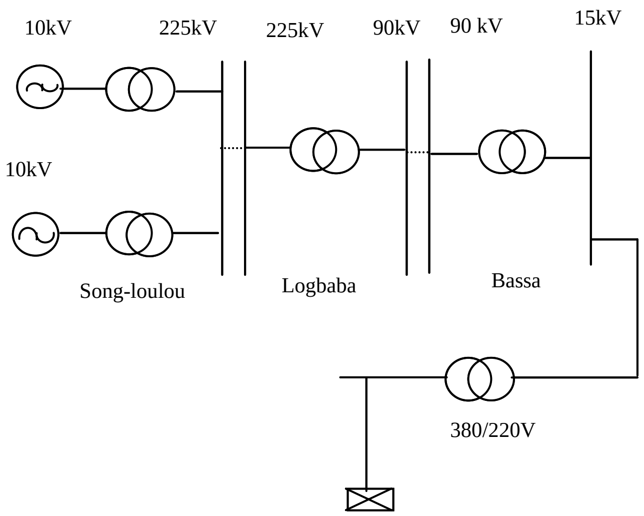

Fig.2: High and very high voltages

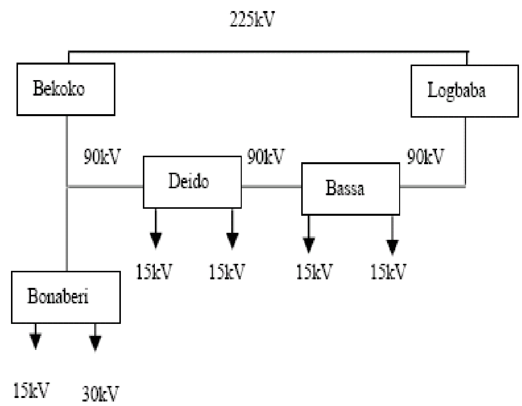

Fig.3: Interconnection within the Douala Area

Power Insufficiency

The power insufficiency is as a result of:

- Increase in energy demand due to economic and demographic growth. An estimated additional 595 MW is needed to supply industries and to cover domestic needs. The local electricity demand has grown by 6 % annually over the past few years.

- Network disturbances, droughts and sedimentations reducing the water retaining area in the reservoirs.

- Inefficient electrical energy usage at many state offices resulting to additional energy demand during peak hours.

Many companies may vie for bids as gas exploitation is attractive to investors under the country's petroleum laws.

However, as a result of changing climatic conditions and obsolete equipment, Cameroon's sole electricity supply company, AES-SONEL is unable to meet this need.
Serious shortages and the necessity to activate load shedding forced the government to approve the building of two hydro-power plants, a thermal and a gas turbine power station projects in the short term [10].

A natural gas turbine thermal station project is underway in Kribi, the southern part Of Cameroon, to increase power generation levels in the country. Upon completion, the gas station will supply 150 MW to the country's southern interconnected network. Experts say they can extend the capacity to 200 MW by adding one more unit.

The natural gas that has been found off-shore in the Atlantic Ocean will be drilled and channelled through pipes onto shore. This is the first part of the project, which has already started. The government has given the gas drilling and transportation to the onshore plant to a private company—an independent power producer (IPP). Most of the projects will be completed by companies licensed for concessions within the perimeters of the AES-SONEL under a regime known as "build, operate and transfer" (BOT). This falls within the law governing the electricity sector, which authorizes the production and sale of energy to third parties granted to operators upon request.

The second part of the project is the generation of electricity through gas turbines. The plant will be located in Kribi, in the South Province. The electricity will be transported through high-voltage overhead lines over a distance of about 100 km to a network control centre for electricity management and distribution in Mangombe. The use of existing high-voltage overhead lines is aimed at reducing the environmental impact the project may cause. It also reduces costs and acts as a security measure.

The Nachtigal hydro power plant will be built by ALCAN**;** a Canadian aluminium smelting multinational company that now owns ALUCAM after privatisation. ALCAN will construct, operate and use the 300 MW electrical power produced by the plant.

The Lom Pangar hydro power plant to be constructed on the Lom River in the Eastern province will generate an estimated 105 MW to 216 MW of power which would assist the southern interconnected grid's capacity and as a hydro power generation at Lom Pangar for the Eastern grid. The Lom River is about 13 km upstream from the Sanaga River with a dam height of 50 m and reservoir size of 610 km^2.

Although the construction work has not yet started at the Kribi, Nachtigal dam and Lom Pangar plants, once the projects are approved it will move forward quickly since detailed studies have been carried out, the structure would be ready for use in two years time (2008/2009). As per the detailed studies, these projects can be started and completed in the near future and once completed the electricity sector will receive a boost for over years [12].

Statistics and Network Disturbances

In order to monitor the power quality and network disturbances AES-SONEL has equipped transient recorders and other measurement devices, recording both current and voltage variations above certain trigger levels. They measure high voltages in the range of kV (for 90 kV, 30 kV, 15 kV networks) and are used in a central data analysis, while other (simpler) types measure low voltages (for 220/380V systems) with a plug in 220V socket. As per past data, the majority of variations/disturbances have the same nature and mostly occur during the dry seasons. It is often difficult to have disturbances recorded at all times at different voltage levels due to the data communication problems of the transient recorder and low-voltage measurement devices.

Fig 4 shows the network disturbance frequency of occurrence percentages per month and it has been noticed that the disturbances vary from one month to the other depending on the volume of water in the reservoirs. From the diagram, power outages and rolling blackouts are most common during the dry seasons (January to June) and less frequent during the rainy seasons (July to December) of each year with the peak periods in February and March [9, 12].

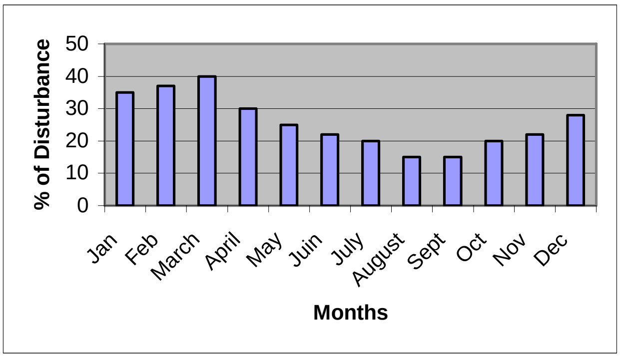

Fig 4: Disturbances in function of percentages and months

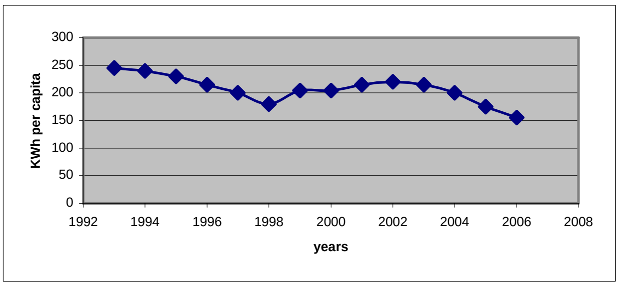

Fig.5: Energy consumption per capita

Even as the demand need grows; the stagnating or even decreasing energy consumption over the passed years in Cameroon is due to:

- Insufficient use of water in reservoirs i.e. exceptionally dry years thus limiting the availability of water to generate electricity.
- Poor maintenance of existing electric equipment resulting in not being able to transport electric energy to consumers. Up to about 30% of transmission losses are possible during this process.
- Lack of investment in new capacity to supply the demand growth.

Since the privatisation of the electric power sector in 2001, the quality of electricity supply has deteriorated significantly given rise to long blackouts and brownouts. Firms have incurred important losses and citizens have demonstrated their anger in the streets [10].

The Canadian aluminium smelting multinational plant in Edea (ALUCAM) making use of many arc furnaces consumes about 45% of the total electrical energy produced in the country annually and is also the major source of network perturbation within the Douala area due to the unstable nature of the arc.

Rolling and daily blackouts of up to 8 hours and more is even possible within the capital and major cities (Douala, Limbe) while rural areas receive power for as little as an hour a day or not even at all especially during dry seasons. This can be attributed to insufficient resources available to meet prevailing demand for electricity, aging electricity generation infrastructure, faults in the power station, thunder-storms, damage to power lines or other part of the distribution system, short circuits, overloading of electricity mains, high temperatures during the dry seasons, causing a surge in demand due to heavy use of air conditioning and among others high incidence of power theft.

A critical disturbance resulting from the use of arc furnaces by ALUCAM is the flicker in low voltage networks. The random flicker cannot be calculated easily with the standard Pst=1 curve and usually varies from cycle to cycle depending on the quality and quantity of scrap used and quantity of oxygen injected into the system. The fluctuation is usually high during the start-up phase lasting between 3-5 minutes due to rather low temperature of the scrap, long distance between the electrode and the scarp and perturbed surroundings of the electrodes. It is also very difficult predicting the flicker value for it depends on the system reactance, arc stability and quality of scrap. [7, 8]

Fig 6 shows the random and non-periodic nature of the current resulting from the unstable nature of the arc, thus introducing perturbations in the grid. Increases in voltage R.M.S value of more than 15 % of the rated voltage (voltage swells/over voltages) due to power-line switching, energising large capacitor banks, large load variation, harmonic resonance and ferro-resonance phenomena are common.

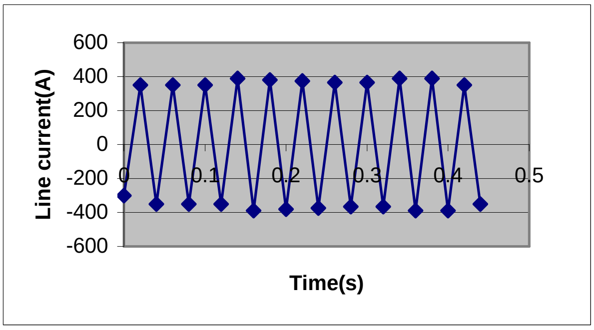

Fig.6: Time variation of current absorbed by arc furnaces.

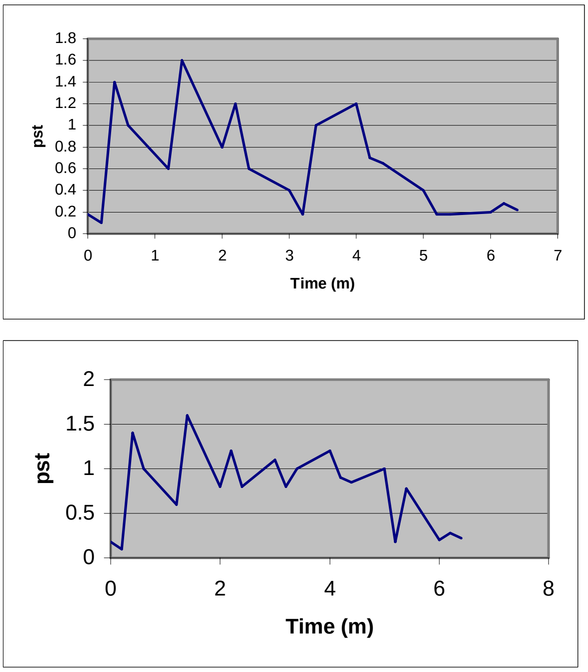

Fig.7: Flicker Evolution with time at Different Cycles

Decreases in voltage value amounting to more than 15 % of the nominal voltage (voltage sag/dip) are common and are generally caused by large inrush current generated by short circuits on the system or on customer installations, by starting of motors and thunderstorms.

Additionally, the non-linearity of the arc, use of non-linear loads such as electronic power converters for motor drives, office computers produces harmonic currents whose frequencies are integer multiple of the fundamental frequency 50 Hz. This harmonic current which is injected into the supply network causes harmonic voltages for all other consumers. This leads to overheating and malfunctioning of electronics components, motors and transformers.

Thunderstorms and lightning are common within this area resulting in sudden and significant deviations from the rated 220 V voltage level leading to a unidirectional impulse and a dampened oscillating wave. The switching of system lines and equipment, switching-on of capacitor banks resulting in a damped oscillation superimposed on to the fundamental wave and switching of inductive loads produces fast transients. Their duration is usually very short, lasting typically less than one half-cycle but causes failure of electronic components, halt of industrial processes and insulation.

It is also common to notice non-symmetrical voltage supply to customers coming from non-symmetrical voltage drops at the network impedances. The causes of such voltage unbalance are blown fuses on partially failed three-phase loads, asymmetries of line impedance and uneven distribution of single phase loads/ single-phasing conditions.

In such cases there is overheating of motors, transformers, and electronics components thus the system becomes less stable and incurs a lot of losses. Furthermore, vibrating torques in induction motors at double supply frequency may cause large mechanical stresses in the drives [2, 3, 5].

Conclusions

Network disturbances on the transmission and distribution systems within the Douala Cameroon area has been analysed and it is found out that most of these disturbances result from the operation of arc furnaces by ALUCAM**,** thus ALUCAM being the main operator of arc furnaces should make use of latest compensator generation (STATCOM and SVC-light) using GTO's or IGBT's instead of thyristors, since their control speed is much higher with the result that they reach higher flicker improvement factors.

There is a constant increase of power demand and AES-SONEL relies on hydro-power and few aged diesel power stations (15 MW) as the only back-up facilities. It is recommended that the government of Cameroon should create a national energy action plan which should be able to present all energy options for development and be able to know the energy needs of the Cameroon people and that of the industries.

In order to meet this growing demand of electric power more back-up supply levels be made available for general services, critical loads and safety equipment thus AES-SONEL in conjunction with the government of Cameroon should increase and provide funds for the earmark projects and above all integration of innovative technologies such as the use of distributed generation equipment needed for rapid electrification. Sufficient transmission capacity, possibly linking Cameroon with neighbouring countries may improve the situation too.

Since most transient events results from lightning striking on overhead systems, inrush current which are normally out of our control, tolerance levels for users equipment are given with a further recommendation of harmonisation of equipment standards, regular maintenance and respecting of engineering specifications.

Considering technological trends such as more network automation, a high degree of communication and improved interconnection between networks or countries, it is of utmost importance that AES SONEL should improve the power flow by making use of the newest development such smart metering, wide area measurement, modern protection systems and support higher levels of education and regulation.

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