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Study of dynamic stability of MV (middle voltage) Network of Douala within the meaning of Lyapunov

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Abstract - *The studies undertaken have used the method of Lyapunov of the system theory to evaluate the stability of the electric network starting from the power function depending on the dephasing between voltage and current in time. To carry out these studies, a look into the dynamic stability of the electrical network, and the stability within the meaning of Lyapunov was effected. Then a modelling of our network with application under MATLAB/Simulink was carried out as well as the tests of simulations without disturbances, and another test with disturbances was made. This reveals that the Douala network suffered falls in voltage, increasing instability depending on the critical disturbances, with the network eliminating the faults slowly.*

Résumé - *Les travaux menés utilisent la méthode de Lyapunov de la théorie des systèmes pour évaluer la stabilité des réseaux électriques à partir de la fonction puissance en fonction du déphasage courant-tension dans le temps. Pour réaliser ces travaux, une étude de la stabilité dynamique des réseaux électriques, ainsi que de la stabilité au sens de Lyapunov ont été menées. Puis une modélisation de notre réseau d'application sous MATLAB/Simulink a été réalisée et des tests de simulations sans des perturbations, puis avec ces dernières ont été simulés. Il en ressort que le réseau de Douala présente des baisses de tension, une instabilité grandissante selon la criticité des perturbations et élimine lentement des défauts.*

Keywords: Stability - Disturbances.

1. INTRODUCTION

Several works define the stability of the electrical systems like the capacity of this systems to keep their points of operation under the normal operating conditions, and to return to the state of normal functioning after the usual disturbance of exploitation.

This functional state is balanced or synchronous (a term indicating the synchronous movement of the generators constituting the electrical system) because it represents a balance of exchange of electrical energy between the various elements of the electrical system.

In system theory, the analysis of the stability of dynamic systems is related to the analysis of the energy evolution in these systems.

This type of stability, called stability within the meaning of Lyapunov, relates to the stability of the balanced points, and will be detailed in a later part of this article.

Then, we will apply this theory to MV network of Douala town and will simulate this network with some critical cases of disturbances.

2. DYNAMIC STABILITY OF ELECTRICAL NETWORK

The stability of an electric power system is defined as the capacity of the system to maintain a state of balance during and after possible disturbances and to recover a new state of balance which may be different from the one at start.

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Stability is a problem based on the following factors:

- the natural physics of instability;
- the severity of the disturbance which appears in the system;
- the devices, processes and the scale of time to hold in (take to) account;
- the suitable methods of calculation and prediction of the stability concerned.

2.1 The types of stability on the electrical network

In an electrical network, there exist two principal classes of stability: angular stability and tension stability. These two standards of stability are more or less connected and are defined in extreme situations:

- a) a synchronous generator connected to the network infinity via intermediary transport lines which are used for the studies of the stability of the angles;

- b) a load connected to the network infinity via intermediary transport lines, which is used for the studies of voltage stability of.

Figure 1 shows a classification of the various standard of stability [1].

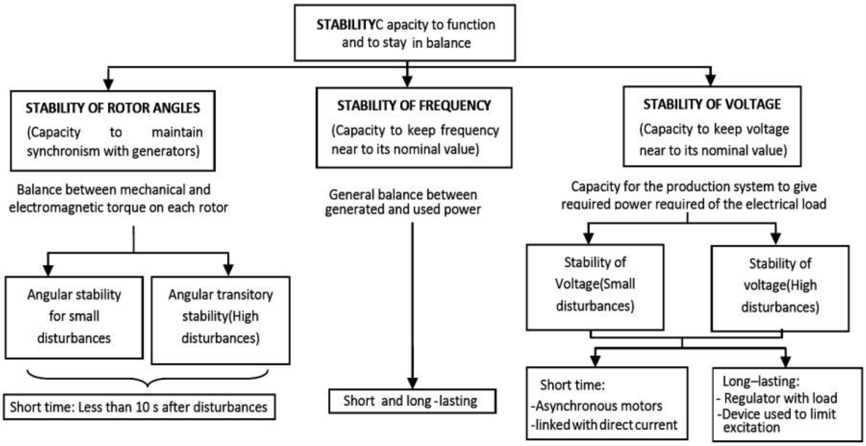

Fig. 1: Overall picture of the stability of the electrical systems [01]

The types of stabilities can also be classified depending on the various constants times in the dynamics of the different means of the system and of the various types of time-constants of study [2]. Among these various types of stability, the stability of voltage, and angular transitory stability will be evaluated in course of our paper.

2.2 The study of the dynamic stability

The studies of dynamic stability consist of [03]:

- considering the principal critical scenarios such as short-circuit, mechanical loss of energy, loss of electrical source, radial force, constraints of process;

- predicting the behavior of the network with these disturbances;

- forecasting the measures to be taken in exploitation, such as type of protection, of adjustment of relay, unballastings, of configurations… to avoid the undesirable modes of functioning.

These studiest husallow the mastery of the behaviour of the network under consideration, whe theritis public or private, HV or LV, and requires everal methods.

3. STUDY OF STABILITY WITHIN THE MEANING OF LYAPUNOV

Interpretation will be done by truly evaluating the stability of our system.

Let us remember that the second method or direct method of Lyapuno visstated as follows:

The point of equilibrium X_0 balance is stable if there exists in a certain vicinity v of this point, a function of Lyapunov, i.e. a scalar function $V(X)$ such as:

1. $V(X^0) = 0$
2. $V(X) > 0$ to represent any X in v
3. $dV(X) \leq 0$ in v (v : chosen interval of time).

In this paper, we will use the instantaneous power function like function of Lyapunov. We know that single-phase current has one tension to a form: $v(t) = V\sqrt{2}\cos(\omega t)$ and a current such that: $i(t) = V\sqrt{2}\cos(\omega t - \phi)$.

The instantaneous power will be:

$$p(t) = P(1 + \cos 2\omega t) + Q\sin 2\omega t \quad (1)$$

With, $\begin{cases} P = UI\cos\varphi = RI^2 & (\text{in} W) \\ Q = UI\sin\varphi = \pm XI^2 & (\text{in} Var) \end{cases}$

For a tri-phase system,

$$p(t) = v_1 i_1 + v_2 i_2 + v_3 i_3 \quad (2)$$

Given that our loads are balanced, let us consider: for $n \in \{0, 1, 3\}$

$$V_{n+1}(t) = V\sqrt{2}\cos\left(\omega t - (2\pi n / 3\right) \quad (3)$$

$$I_{n+1}(t) = I\sqrt{2}\cos\left(\omega t - (2\pi n / 3\right) \quad (4)$$

Then,

$$p(t) = 3VI\cos\varphi + VI[\cos 2\omega t - \varphi) + \cos(2\omega t - 4\pi/3 - \phi) + \cos(2\omega t - 8\pi/3 - \varphi) \quad (5)$$

The term between hooks is the sum of three cosine angles of equal parts on the trigonometric circle, they are thus worthless. The active power consumed by the load is constant (if there is balance between the phases). Unlike the average power in single-phase current, no term of fluctuating power appears in the expression**:**

$$p(t) = P = 3VI\cos\varphi \quad (6)$$

In sum, we will use the function active power in time, and the function dephasing in time, in order to interpret the curve of the power according to dephasing.

4. MODELLING AND SIMULATION OF NETWORK

4.1 Modelling of HTA of the Douala town

We build our network between Log baba and Bonabéri substation since the arrival of Song Lulu. The tensions go from 225 kV to 15 kV near the loads of the users and are gathered around the various source stations of the city.

The characteristics of the principal equipment of stations HTB/HTA of which the lines are parameterized on the tools of the library Simpower Systems of Simulink [4]. The data are real and come from the documents of the operation department of AES SONEL (2010). Below is the current network of the city:

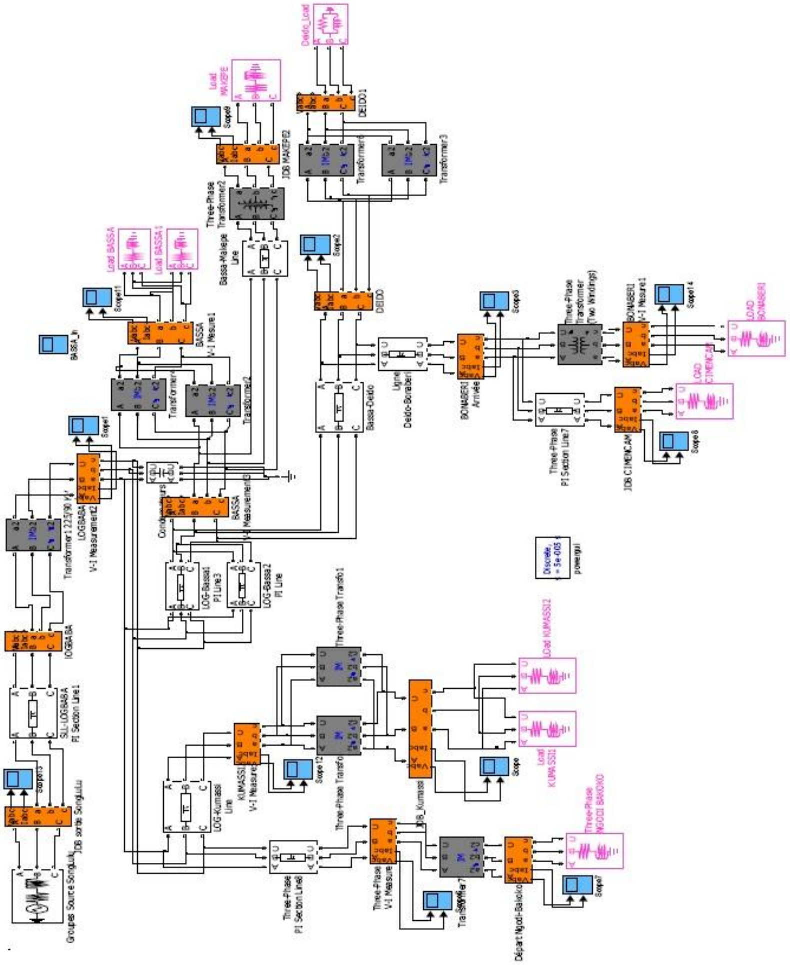

Fig. 2: MV network of Douala in Simulink

Key of colours:
Orange: Bar games; *Gray*: Transformers of the source stations; *Pink*: Three-phase load; *Blue*: Multi-meter (Simple Three-phase voltage and Three-phase current).

4.2 Results of simulation in HTA network

a- Tests and results of simulation without disturbances

After a simulation during 2s, the electrical values wanted and obtained are:

During analyzing, we can view a good frequency. About voltage, some substations have low voltage more than 10 %, like:

- Bonabéri: 16 % ;
- Koumassi 1 and 2: 11.44 % ;
- Bassa 1 and 2: 11.28 %.

Table 1: Voltages and current on the MV Douala network

Substation	**Power Installed (MVA)**	**Wanted power (MW)**	**Available power (MW)**	**Cos (phi)**	**Wanted voltage**		**Simple real voltage**		**Current in the loads (A)**
					Arrival (kV)	Departure (V)	Arrival (kV)	Departure (V)	
Songlulu	456	-	-	-	-	129.9		138.9	654.9
Logbaba		-	-	-	129.9	51.96	12.7	4.461	1623
Koumassi1 Dep. 15kV	50	27.45	42.5	0.85	51.96	8.660	44.1	7669	407.8
Koumassi2 Dep. 15kV	50	27.47	42.5	0.85	51.96	8.660	44.1	7669	407.8
Bassa Dep. 15kV	50	33.67	42.5	0.85	51.96	8.660	44.392	7683	2705
Bassa Dep. 15kV	50	33.67		0.85	51.96	8.660	44.392	7683	2705
Ngodi Bakoko Dep. 15kV	50	29.17	36	0.90	51.96	8.660	44.29	7838	1129
Deido Dep. 15kV	20	15.00	17	0.85	51.96	8.660	43.47	7761	608.7
Makepe Dep. 15kV	36	27.79	32.4	0.90	51.96	8.660	43.75	7618	1045
Bonabéri Dep. 15kV	36	40.29	30.6	0.85	51.96	8.660	43.24	7229	1521
Bonabéri Cimencam		10.69	-	0.85	51.96	8.660	43.24	43.23	67.12

b- Tests and results of simulation with disturbances

● Falling of voltage

We simulated the network by adding an overload to the Bonabéri substation, and retract this after 0.5s. We obtain-

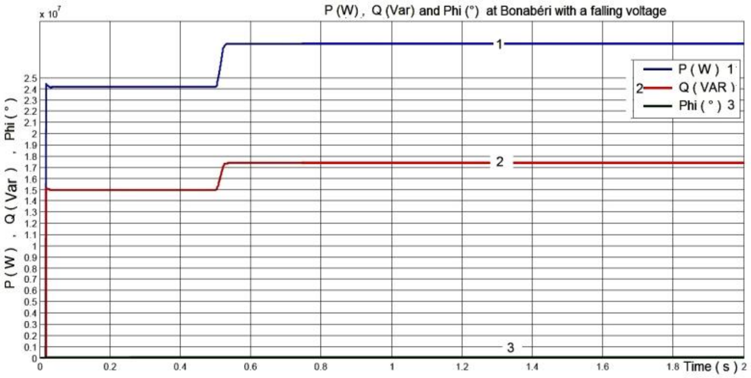

Fig. 3: Powers P and Q and dephasing Phi
with decreasing voltage and then without this falling of voltage

The disturbance has created a voltage drop of 13 % of more in Deido. Thus According to the voltage plan there is a nominal fall of 21.8 %. and in all the networks the output voltages of the stations toward the loads have a fall of nominal voltage more than 10 %. This dip in voltage was thus propagated every where in HTA [05].

In the figure 3, we can't appreciate the variation of the dephasing. After a zoom, we obtain-

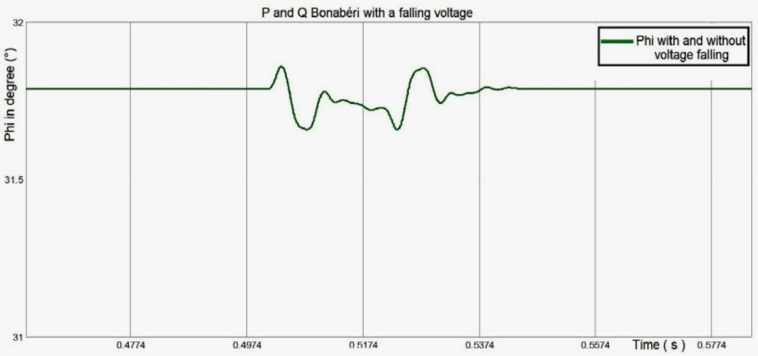

Fig. 4: Zoom on dephasing (Phi) during a change of voltage level

Let us note that the angular variations persist for only 2 periods.

- **Generated harmonic**

We connect a generator of harmonics having a tension of 380V, with one THD= 21.27 % on the Bonabéri loads in HTA, and 0.5 with 0.6s (let it be 5 periods).

We will notice that the harmonics are not spreade normously because the THD of Bonabéri totals 0.07 %.

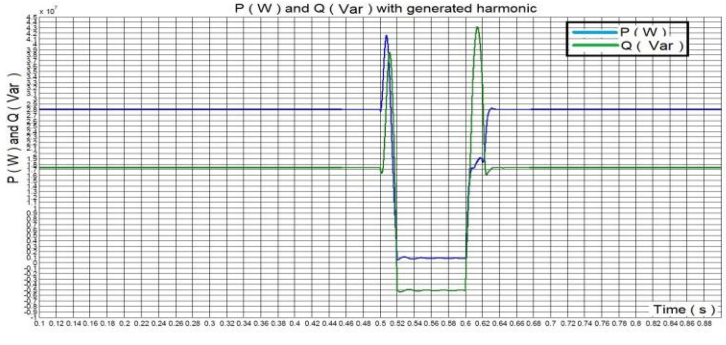

Fig. 5: Powers P and Q on the substation of Bonabéri

We will quickly notice that after 3, to see 4 periods the active power becomes constant again depending on to the level of voltage present. For the dephasing, it appears to exceed 270° from where the reactive power becomes negative and the active power stays positive.

5. INTERPRETATION OF RESULTS

The active power consumed by the load is constant. Unlike the average power in single-phase current, no term of fluctuating power appears in the expression-

$$p(t) = P(\varphi) = 3VI\cos\varphi$$

5.1 Network without disturbances

$p(t)$ is positive and a constant for all $t > 0$, and with $t = 0$, $P = 0W$. The curve φ (t) is also a constant in time. Let us look at also $P(\varphi)$:

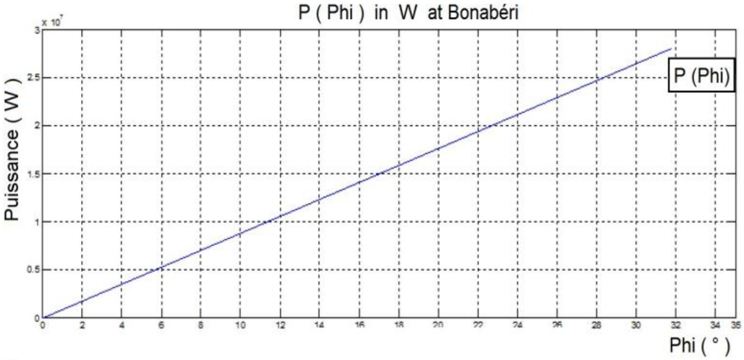

Fig. 6: Active power in function of dephasing at Bonabéri

Thus-

1. $P(\varphi^0) = 0$
2. $P(\varphi^0) > 0$ for all φ in ν (one period)
3. $dP(\varphi)/dt = 0$ in ν.

It acts therefore as a stable system and it is asymptotically.

5.2 Network with disturbances

a- Decline in tension or falling voltage

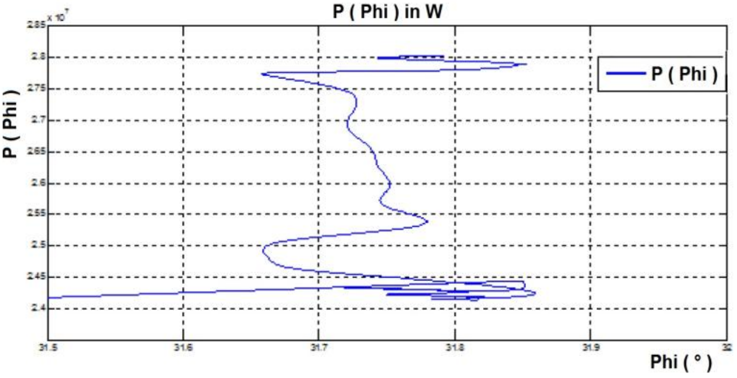

Fig. 7: Active power in function of dephasing Bonabéri (with decline in voltage)

Thus-

1. $P(\varphi^0) = 0$
2. $P(\varphi^0) > 0$ for all φ in ν (one period)
3. $dP(\varphi)/dt = 0$ in ν.

It acts therefore as a stable system.

b- Harmonics

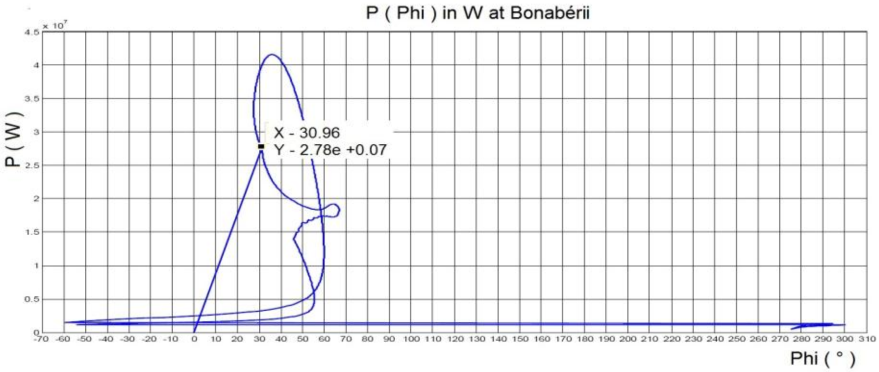

Fig. 8: Active power in function of dephasing with harmonics at Bonabéri

Thus-

1. $P(\varphi^0) = 0$
2. $P(\varphi^0) > 0$ for all φ in ν (one period)
3. $dP(\varphi)/dt > 0$ in ν

It acts in a system which is not stable around the φ^0, but this instability does not exceed 3 cycles.

Around $t = 0.5s$, rather we have: $P(\varphi) \approx 0$; $P(\varphi) > 0$.

$$\frac{dP(\varphi)}{d\varphi} < 0 \text{ and } \frac{d\varphi(t)}{d\varphi} < 0$$

In order words, we have- $\dfrac{dP(\varphi)}{d\varphi} = \dfrac{dP(\varphi)}{d\varphi} \times \dfrac{d\varphi}{dt}$

Then- $\dfrac{dP(\varphi)}{dt} > 0$

So, with the inlet of the harmonics, the system becomes instable.

6. CONCLUSION

In this article wetackled the question of the dynamic stability of electrical network of distribution, with an application to Douala city.

The study undertaken has materialized the modelling of the lines, and stations of HTA network, and a simulation of this network was carried out with critical cases of disturbances. Concerning the stability of angular-transistor and on the plan of the tension, this reveals that this network comprises a fall in tension and that is very vulnerable to the disturbances and the harmonics propagate his self enormously.

The time of elimination of defects also increases with the overloads caused by the increase in load of the users. This network shows the need for the principal supplier AES SONEL to install parallel generators and help create either for small or for medium size industries users to install decentralized productions.

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