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Lost-Phase and Short-Circuit Impacts on Electrical Network Managed by a Dual IPCs 30P15

Bedel Giscard Onana Essama*[1,2,3], Jacquie Therese Ngo Bisse[1] , Joseph Koko Koko[1,3], Jacques Atangana[4], Salome Ndjakomo Essiane[1,3]

1. Laboratory of Electrotechnics, Automatics and Energy, Department of Electrical Engineering, Higher Technical Teachers, Training College (ENSET) of Ebolowa, University of Ebolowa, P.O. Box 886 Ebolowa, Cameroon
2. Higher Institute of Transport, Logistics and Commerce (ESTLC) of Ambam, University of Ebolowa, P.O. Box 22 Ambam, Cameroon
3. Cameroonian Association for Research and Innovation in Environmental and Energetic Technologies (ACRITEE), P.O. Box 59 Ebolowa, Cameroon
4. Higher Teacher Training College (ENS) of Yaounde, University of Yaounde I, P.O. Box 47 Yaounde, Cameroon
E-mail: onanaessama@yahoo.fr (Corresponding author)

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Abstract: This work evaluates the impact of short-circuit and the phase-lost in a particular transmission network located in south division in Cameroon (Central Africa). This network is precisely located between two towns called Songloulou and Logbaba (douala Town). The chosen network is modelled in Matlab Simulink software. Further, the network currents and voltages undergo non periodical distortions when short-circuit and phase lost come into play. Those distortions are deleted when dual controllers' system is introduced and the network is stabilized. It appears that dual IPCs (interphase power controllers) present good results. However, the dual system which is a combination of two IPCs improves the network stability. The investigation of dual IPCs' system uses the phase shift method.

Keywords: Transmission line; High contingencies; FACTS devices; UPFC; Three-leg IPC 30P15; Phase-shifting transformer; Dual system; Modeling.

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1. Introduction

Nowadays, the problems of electrical energy production, transmission and distribution in transmission networks have taken a significant interest during the last years. As all productive sectors, the electrical energy production and the transmission are both influenced the growing market. Moreover, production sources and transmission network are depended on the interconnection development, the deregulation, the fuel fluctuation prices and other economic aspects [1, 2].

The IPC is one of the FACT devices that employ both a fault current limiter and power flow controller for networks [3]. We can observe four families of IPC according to implementations [3]. The first family is the IPC based on passive components. Those passive components are reactor, capacitor, transformers and phase-shifting transformers (PST) [4–9]. The second family stands for the IPC based on active components. Those active components use low frequency switches called thyristors [10–14]. The third family corresponds to the IPC based on parallel converter. Moreover, the DC voltage of each voltage source by a parallel converter [15–17]. The fourth family is the IPC based on series converter where the DC link voltage is controlled by series converter. This category of the IPC uses the static synchronous series compensator (SSSC) [18, 19].

The management of the power produced and transmitted through the network remains a significant problem. In addition, stochastic variations related to nonlinear dynamic loads, devastating effects (overcurrent, overvoltage, loss of a major production unit...etc.) can reduce the stability of the network [20]. Moreover, the improving of the quality and the reduction of operating costs of the network, are considered as major problems of power flow [20]. According to these previous remarkable points, the use of active lines can be considered. Consequently, these active lines can instantaneously reduce contingencies and counteract dangerous situations [20].

In order to solve these problems, several investigations have improved the power transit, FACTS technologies and interphase power regulators. However, FACTS devices exhibit some malfunctions according to certain short circuit peaks. Consequently, it is necessary to create new power flow controllers in order to improve the network stability [21]. Hence, these new devices can be called interphase power controllers (IPCs) [21]. Moreover, the IPC technology improves the network problems both technically and economically [21]. So, it is necessary to study the impact of dual technology (UPFC and IPC or two IPCs) in various contexts of power network operation. In this paper, we evaluate the impact of a dual IPCs' system in order to improve the network stability.

The paper is organized as follows. Section 2 presents the model of the transmission network and the methods of investigation. In section 3, we introduce the fault (short-circuit or phase lost) in the transmission network. The network voltages and currents are presented to evaluate the impact of short-circuit or phase lost. Thereafter, we introduce a dual IPCs' device to delete the distortions introduced by the fault (short-circuit or phase lost). This situation improves the network stability. The other outcomes are summarized in the different tables presented in Section 3. In section 4, we conclude.

2. Model and methods

2.1 Methodology: Phase shift method for IPC

Instead of using decoupled watt-var method [22,23], we introduce phase shift method for IPC. The IPC operating is done in three different ways known as the variation of susceptance, the phase shift variation, and the variation of the transformation ratio. The variations of susceptance and phase shift method control the transit of active power as well as the production or consumption of reactive power on either side of the device. For its part, the variation of the transformation ratio acts above all on the control of the reactive power transit [24]. The phase shift method is the most interesting method. It offers both fine adjustment and space minimum, the possibility of working at higher voltage as well as an investment minimal [25].

2.2 The model

2.2.1 Modeling and control of the IPC 30P15

The interphase power regulator uses a group of three-phase inductors and capacitors each installed in series between two networks or subnetworks [26]. What distinguishes this new class of equipment from other series compensation equipment is the way the series components are connected to the networks [**27**]. For example, the A-phase inductor and capacitor of the first network could be connected to the B and C phases of the network [**28**]. When all the components are energized, the magnitude and phase angle (δ) of the current is set in one of the two buses to which the controller is connected.

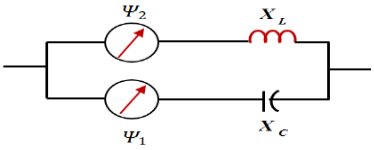

Figure 1: IPC connected between two networks or subnets [26, 29]

The current control thus allows the power carried by the controller to be adjusted, as well as the reactive power absorbed or generated at one of the buses. Inductors and capacitors are always considered perfect without losses. The impedances of the series components are then reduced to their imaginary part. In the context of the controller where the series components are arranged in parallel to each other, the term susceptance is used instead of reactance for practical reasons (B = -l / X) [28]. This is observed in Fig.1.

One of the most fundamental aspects of an IPC is the number of branches. In general, the single-phase circuit of an IPC can have n branches in parallel. In practice, however, this number is kept to a minimum in order to limit the size and cost of the device. It is the angular range of the angle δ_{sr} at the terminals of the device that defines the number of branches [29]. To illustrate this, and at the same time justify the construction constraints that we will use later, the configuration of IPC highlighted in our work is the one with a phase-shifting transformer (PST) in parallel with a capacitor. This kind of controller is called IPC 30P15. This configuration is illustrated in Fig.2.

The IPC is not a fixed configuration device, but rather an innovative and flexible technology for characterizing and configuring "custom" power flow control systems [31]. An IPC is a series-connected device consisting of two parallel branches each with an impedance with a phase-shifting element as shown in Fig. 3.

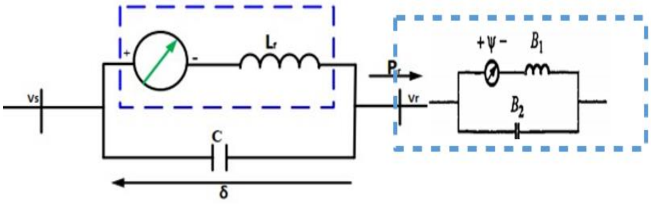

Figure 2: *IPC realized by means of a phase-shifting transformer and a capacitor* [26, 30].

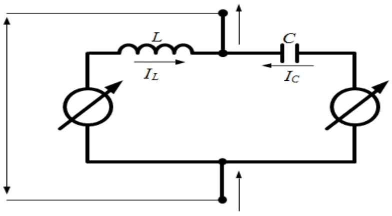

Figure 3: *Generic one-line diagram of the interphase power controller* [32].

The four design parameters (two impedances and two phase shifts) offer a great deal of flexibility and allow for a wide variety of applications. Because of this versatility, each IPC solution has a different name. IPCs can be adapted to the operating conditions. Adaptation is often synonymous with optimization. For example, eliminating the phase shift in one of the two branches of the IPC makes the equipment lighter and optimizes the position of the control characteristic in the angle-power plane. Another proof of the adaptability of IPCs is the different ways to produce internal phase shifts. Traditional phase shifters are the most common solution. However, it is also possible to use conventional transformers with auxiliary windings that produce the desired internal phase shift by injecting series voltages from other phases [33].

The primary objective of our work will be to design an IPC to passively solve fundamental frequency problems. Power electronics can be used when quick action is required to damped oscillations or prevent excessive voltage fluctuations [34].

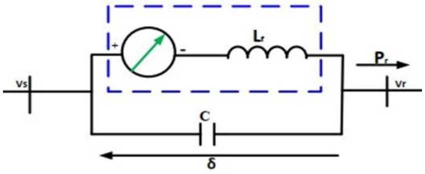

Figure 4: *IPC realized by means of a phase-shifting transformer and a capacitor* [22, 26].

Basic IPC systems incorporate only conventional equipment (capacitors, inductors and phase shifters), so they do not generate any harmonics and have no switching losses. They are particularly robust and their maintenance is much simpler than that of power electronic devices. Therefore, our choice for the achievement of the said objective was the configuration of IPC with a phase-shifting transformer and known under the acronym of IPC 30P15 which is presented in Fig. (4).

When a decoupling link connecting two voltage levels is connected in parallel with conventional transformers, its configuration can be simplified and optimized. It is then called a "fault current limiting transformer" (FCLT) and used to increase the total capacity of a substation without increasing the short-circuit power [23]. The model of our grid-connected IPC can be referred to a π-quadrupole as shown in Fig. (5).

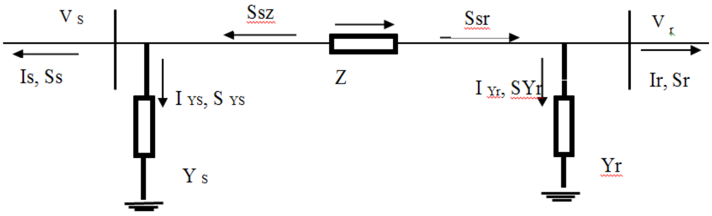

Figure 5: *Quadrupole in π* [26, 35]

The power balance of this circuit leads to the following equations.

2.2.2 Convention of signs of powers

The apparent powers S_S and S_r are defined in the same direction as the currents as given by the following equations [26, 35]:

$$V_s = V_s \exp\,(j\delta_{B_1}) \tag{1}$$

$$V_r = V_r \exp\,(j\delta_{B_2}) \tag{2}$$

$$\begin{cases} \delta_{B1} = \delta - \varphi_1 \\ \delta_{B2} = \delta - \varphi_2 \end{cases}. \tag{3}$$

The powers S_r and S_s of the shunt admittances are given such as:

$$S_s = \frac{V_s V_r \exp\,(j\delta_{B_1})}{Z^\star} - \frac{V_s^2}{Z^\star} \tag{4}$$

$$S_r = \frac{V_s V_r \exp\,(j\delta_{B_2})}{Z^\star} - \frac{V_r^2}{Z^\star}. \tag{5}$$

These power equations are based on the following assumptions. (i) The system is symmetrical, so it is always possible to represent a three-phase element by a single-phase equivalent. (ii) The frequencies of the S and R bars are essentially the same (fs=fr), so that it is possible to use the phasors for the equation. (iii) The series elements are linear (they do not produce harmonics). By positing:

$$Z = R + jX \tag{6}$$

$$\underline{Y_s} = G_s + jB_s \tag{7}$$

$$\underline{Y_r} = G_r + jB_r \tag{8}$$

We can rewrite as follows in trigonometric form

$$S_s = \frac{1}{Z}\left[V_s V_r (Rcos\left(\delta_{B_1}\right) - Xsin\left(\delta_{B_1}\right)) - V_s{}^2 R\right] + \frac{1}{Z}[V_s V_r (Rsin\left(\delta_{B_1}\right) - Xcos\left(\delta_{B_1}\right)) - V_s{}^2 R] \tag{9}$$

$$S_r = \frac{1}{Z}\left[V_s V_r (Rcos\left(\delta_{B_2}\right) - Xsin\left(\delta_{B_2}\right)) - V_r{}^2 R\right] + \frac{1}{Z}[V_s V_r R(sin\left(\delta_{B_2}\right) - Xcos\left(\delta_{B_2}\right)) - V_r{}^2 R] \tag{10}$$

$$\underline{S_s} = V_s{}^2 (G - jB_1) = -P + jQ_s \tag{11}$$

$$\underline{S_r} = V_r{}^2 (G - jB_2) = -P + jQ_r. \tag{12}$$

The active power P is positive when the power flow occurs from the S side to the right side. The reactive power Q_S and Q_r are positive when the IPC generates reactive power since $\delta_{B1} = -\delta_{B2}$. The powers P, Qs and Qr of the series element, formulated in terms of conductance and susceptance, become in matrix form as [36]:

$$\begin{bmatrix} -V_s V_r \sin\,(\delta_{B1}) & -V_s V_r \sin\,(\delta_{B2}) \\ V_s^2 - V_s V_r \cos\,(\delta_{B1}) & V_s^2 - V_s V_r \cos\,(\delta_{B2}) \\ V_r^2 - V_s V_r \cos\,(\delta_{B1}) & V_r^2 - V_s V_r \cos\,(\delta_{B2}) \end{bmatrix} \cdot \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} = \begin{bmatrix} P \\ Q_s \\ Q_r \end{bmatrix} \tag{13}$$

Where the quantities B_1 and B_2 are given as:

$$B_1 = \frac{P(2V_r - V_s\cos(\delta) - \sqrt{3}V_s\sin(\delta)) - Q_r V_r(\sqrt{3}\cos(\delta) - \sin(\delta))}{\sqrt{3}V_s V_r (V_s - 2V_r\cos(\delta))} \tag{14}$$

$$B_2 = \frac{-P(2V_r - V_s\cos(\delta) + \sqrt{3}V_s\sin(\delta)) - Q_r V_r(\sqrt{3}\cos(\delta) - \sin(\delta))}{\sqrt{3}V_s V_r (V_s - 2V_r\cos(\delta))}. \tag{15}$$

Equations (14) and (15) indicate that the reactive powers are coupled to each other by the following simple relationship:

$$Q_s = (B_1 + B_2)(V_s^2 - V_r^2) + Q_r. \tag{16}$$

Fig. 5 shows the three-phase model of our IPC 30P15 on a three-phase network [26, 30]:

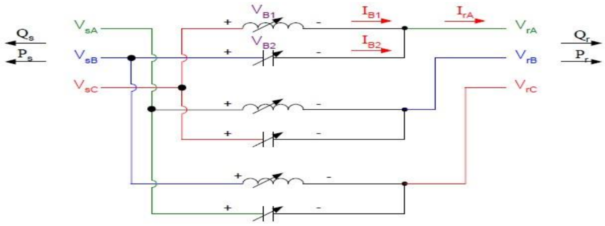

Figure 6: *Three-phase model of IPC 30P15 connecting two regions of a network* **[26, 30].**

3. Numerical simulations

3.1. Network presentation without controller

The chosen network is located in the south division of Cameroon (Central Africa). This transmission network is included in a whole structure called in Cameroon the south interconnected network (SIN). This network is limited by two towns in south region of Cameroon called “Songloulou” and “Logbaba”. The parameters of the line at the beginning of the investigation are given in Tab.1. So, those parameters are known as the voltage V, the frequency F, the inductance L, the resistance R, the reactance X, the active power P, the reactive power Q, the apparent power S and the phase angle δ or the transport angle φ. Some other assumptions are made to perform our investigation. (i) The generator and the phase-shifting transformer are assumed ideal. (ii) The line balanced, the voltage drops across the line represented by the reactance X and the inductance L. The distance related to the network is given L_0. The characteristics of the network are given in Tab. 1.

Table 1: *Characteristics of the chosen network (Songloulou-Logbaba)*

I(kA)	V(kv)	F(Hz)	L_0(km)	R(Ω)	X(Ω)	P(Mw)	Q(Mvar)	S(Mva)	φ(°)
2.8	225	50	93	8.17	38.6	228.8	48.65	234	12

This investigation concerns the damage coming from contingencies as well as the capacity to protect the line with the protection devices. In this work, two types of faults are studied known as phase-lost and short-circuit. Consequently, we begin by showing a model of the transmission network in the Matlab Simulink software as illustrated in the Fig.7.

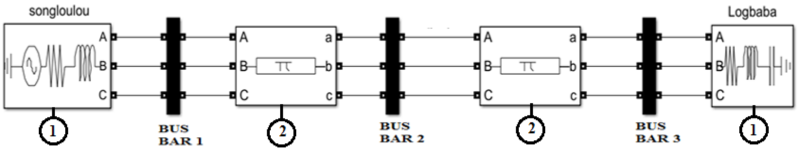

Figure 7: *Network without fault and without controllers*

The network contains the following elements. (1) The generator at the beginning and the receiver at the end of the network. (2) The phase-shifting transformers. This network will be submitted to different tests and at the end of each test a comparative study of the measured quantities will be made. The measured quantities during this work are the network voltages, currents, and powers.

3.1.1 Network voltages and currents without fault and without controllers

During the pre-fault phase, the network is generally in a stable steady state. This step of network operation is characterized by a synchronization of network parameters, such as a harmonization of voltages and currents. So, they are equalized in amplitude and frequency and shifted by 120 degrees as shown in Figs.8 and 9. The observation of Figs.8 and 9 shows that the voltages and the currents exhibit sinusoidal behaviors. This oscillating behavior corresponds to a normal behavior for alternative voltage and alternative current. The three curves on the left part of Figs.8 and 9 are three-phase voltages and currents, respectively. Moreover, the voltages vary between -0.01kV and +0.01kV as seen in Fig.8. In addition, the corresponding currents vary between -50 kA and +50 kA. It appears that the amplitudes of voltages are least important compared to those of the corresponding currents as depicted in Fig.8 and 9.

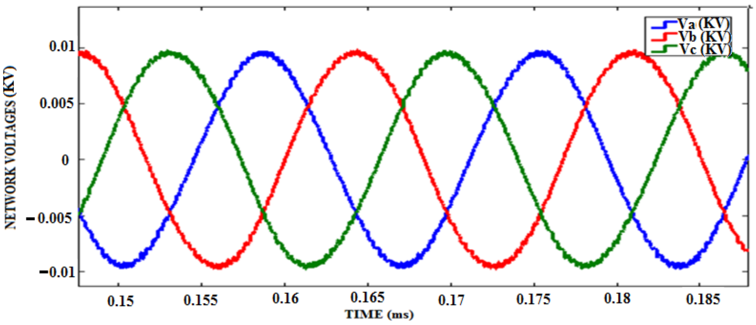

Figure 8: *Network voltages without fault and without controllers*

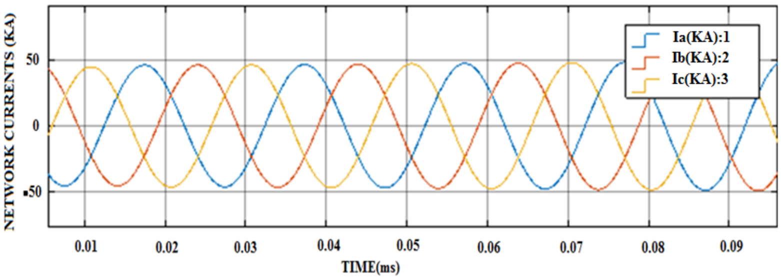

Figure 9: *Network currents without fault and without controllers*

3.2 Network representation with short-circuit without controllers

We now introduce in the network a device able to induce short-circuit as seen in Fig.10. In the next section, we will evaluate the impact of short-circuit in the network parameters.

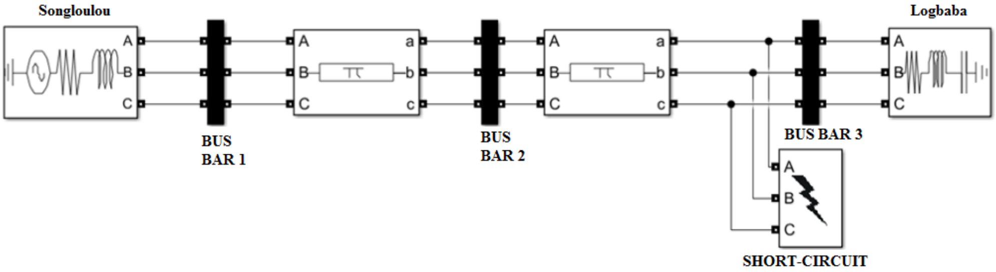

Figure 10: *Transmission network influenced by short-circuit without controllers*

3.2.1 Network voltages and currents with short-circuit without controllers

As soon as a disturbance occurs, the network presents short-circuit conditions. The modifications which occur on the network are illustrated in Fig.11.

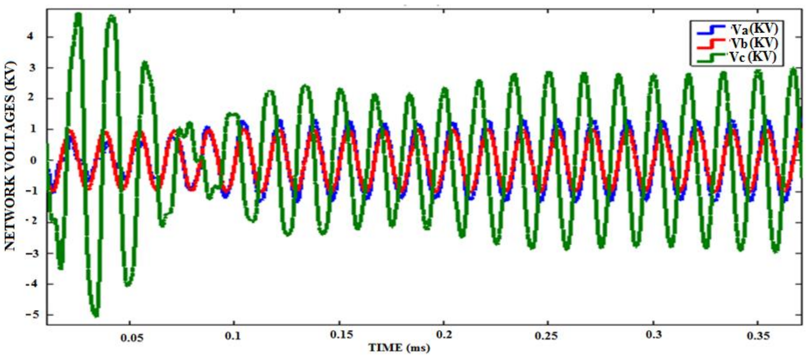

Figure 11: *Network voltages influenced by short-circuit without controllers*

A rigorous observation of Fig.11 shows the evolution of three phase voltages Va, Vb and Vc. Considering the temporal range 0<t<0.1ms, the red and blue curve voltages are superimposed and they vary between -1kV and +1kV as depicted in Fig.11. However, the green curve voltage varies between -5kV and +5kV for 0<t<0.1ms. If t>0.1ms, the blue and red curve voltages maintain their amplitude and their oscillating behavior. This behavior is normal compared to that illustrated in Fig.8. Further, for t>0.1ms the green curve voltage decreases its amplitude from +5kV to +2.5kV as seen in Fig.11. This amplitude continues to increase from +2.5kV to +3kV. In fact, the green curve voltage Vc maintains high value compared to the red and blue curve voltages Va and Vb. It appears that the voltage Vc undergoes short-circuit since it maintains high voltage values compared to Va and Vb.

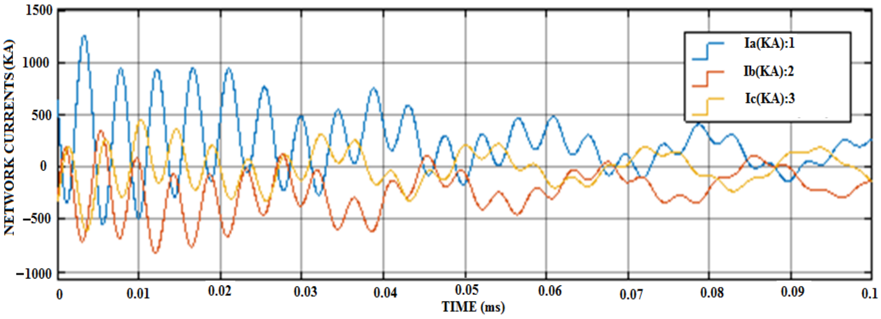

Figure 12: *Network currents influenced by short-circuit without controllers*

According to currents, the corresponding curves present a strong distorted behavior as seen in Fig.12. It appears that the three curves are not superimposed. Each of them exhibits non periodical oscillations suggesting the introduction of high perturbations in the system as depicted in Fig.12. Further, the first phase current (Ia) presents high distortions between -500kV and 1250 kV for 0<t<0.03ms. Considering an increase of time such as t>0.03ms, the distortions of the blue curves (Ia) randomly decrease as observed in Fig.12. Moreover, the two other curves (Ib) and (Ic) adopt similar random distorted behaviors. The random distortions exhibited by the currents in Fig.12 constitute the main signature of short-circuit on the network. The table below gives information on the differences that appear on the network when short-circuit comes into play.

Table 2: *Network status with short-circuit and without controller*

Quantities	Before short-circuit	With short-circuit	Time (ms)	After short-circuit	Relative error
φ(°)	12	58.34	0.1	0	46.34
P(Mw)	228.88	192.34	0.1	0	36.54
Q(MVar)	48.65	499.06	0.1	0	450.4

Table 2 presents the variations of the network parameters. Before short-circuit, we have (φ=12°; P=28.88Mw; Q=48.65Mvar) which are the parameters of the power supply at the beginning of the network. During short-circuit, those parameters are transformed such as (φ=58.34°; P=192.34Mw; Q=499.06Mvar). It appears that the transport angle φ and the reactive power Q have increased their values after the introduction of short-circuit and the active power Q decreases its value as seen in Tab.1. These modified values are harmful for the network since they induce distortions in the system. After short-circuit, all those parameters are vanished such as (φ=0°; P=0Mw; Q=0Mvar) since at the end of the network there are not loads able to maintain unvarnished values as seen in Fig.10. The last column of Tab.2 shows relative errors between original vales and modified values.

3.2.2 Network voltages and currents with short-circuit and controllers

The above analysis shows that short-circuit is harmful for the network. So, this perturbation should be controlled to maintain the stability of the system. Further, we introduce controllers as a dual IPCs in the system as seen in Fig.13.

We then introduce in our network two IPCs 30 to control the stability of the line as seen in Fig.13. This network contains the following elements. (1) The generator which produces a network voltage of 225kV. (2) The transformers which exhibit apparent powers S=234MVA. (3) The phase shifting transformers which control the reactances Xc1 and Xc2. (4) The phase-shifting transformers which control the susceptances BL_1 and BL_2. These two kinds of phase shifting transformers can manage the transport angular φ(°) in order to modify the active power P. (5) The interphase power controllers (IPCs) which constitute a dual system of two IPCs. They manage the stability of the network. (6) The devices which generate short-circuit in the network. (7) The network loads.

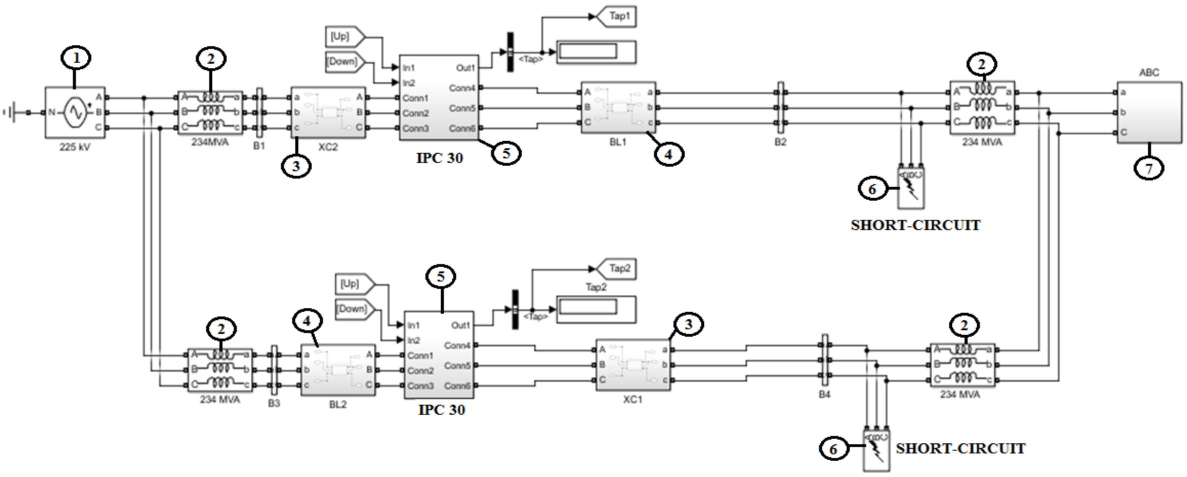

Figure 13: *Transmission network influenced by short-circuit when dual controllers act*

3.2.3 Network voltages and currents with short-circuit with controllers

After the harmful distortions previously observed in the system, we now introduce the dual IPCs and the modifications are seen in Fig.14.

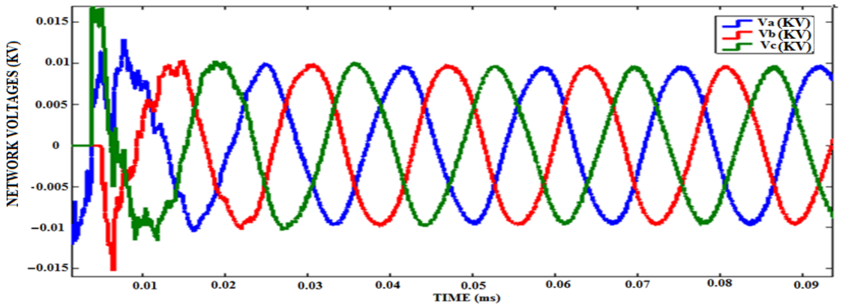

Figure 14: *Network voltages influenced by short-circuit when dual IPCs act*

The high perturbations are deleted by the introduction of the dual IPCs. In fact, for 0<t0.02ms the network still undergoes high perturbations which induce distortions acting between -0.015kV and 0.015kV as presented in Fig.14. However, as the time increases the controller actions progressively restore the original behavior of the network voltages as illustrated in Fig.14. Considering the time such as t>0.03ms the original behaviors of the network voltages are completely restored as seen in Figs.8 and 14. Considering the loads positioned at the end of the network, it appears that load voltages illustrated in Fig.15 exhibit different behaviors compared to those previously depicted in Fig.14.

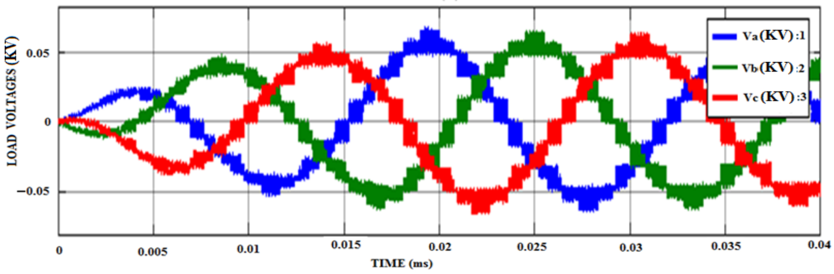

Figure 15: *Load voltages influenced by short-circuit when dual controllers act*

In fact, for 0<t<0.01ms the load voltages present attenuated behaviors as seen in Fig.14. However, when the time is taken such as t >0.01ms, the periodical oscillating behaviors of load voltages are completely restored. It clearly appears that the amplitudes of loads voltages progressively increase as the time increases for 0.0.1<t<0.00.02ms as depicted in Fig.15. Further, the system maintains constant amplitudes for t >0.02ms. This particular behavior is due to the action of loads in the system.

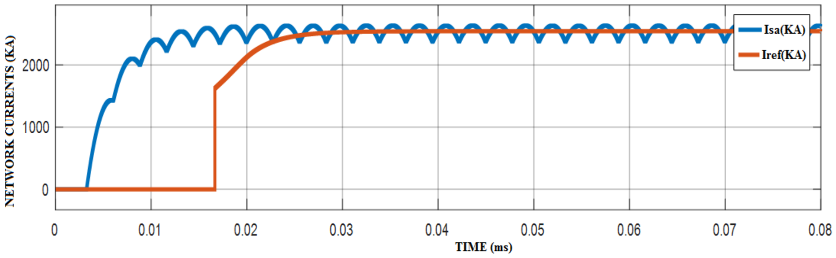

Figure 16: *Network currents influenced by short-circuit when dual controllers act*

The modified behaviors of network currents are illustrated in Fig.16. In fact, blue solid curve represents the first stable current (Isa). It is important to note that the stable current (Isa) exhibits a same behavior as that presented by the other stable currents (Isb) and (Isc). So, we only illustrate one of those three currents since they exhibit identical behaviors. The quantity (Iref) stands for reference current provided by the constructor. The observation of Fig.16 shows two time domains. The first one is 0<t<0.02ms, here the network current (Isa) gradually increases and adopts distorted behaviors different to periodical oscillating behavior often exhibited by network currents. In the second time domain t>0.02ms, the behavior previously exhibited is similar to a continual generation of a small waves' train as seen in Fig.16. This strange distorted behavior is not well reproduce the behavior exhibited by reference current as depicted in Fig.16. Thereafter, we summarize the results in Tab.3.

Table 3: *Network status with short-circuit when dual controllers act*

Quantities	Before short-circuit	With short-circuit	Time (ms)	After short-circuit	Relative error
φ(°)	12	13.77	0.05	12	1.77
P(Mw)	228.88	216.88	0.05	293	12
Q(MVar)	48.65	34.65	0.05	99	14

We now observe that before short-circuit the parameters are (φ=12°; P=28.88Mw; Q=48.65Mvar). Those parameters are modified by short-circuit when IPCs act as (φ=13.77°; P=216.88Mw; Q=34.65Mvar). It appears that the high values of parameters previously obtained in the network without controllers are significant modified. Those values are now near to reference values. This situation is justified by the relative error whose values have significantly reduced compared to precedent values as seen in Tabs.2 and 3. It is important to note that, after short-circuit the parameters at the end of the network are not vanished (φ=12°; P=293Mw; Q=99Mvar) as previously seen in Tab.2 since the loads have been introduced at the end of the network.

All those values have been obtained for a fixed value of the time such as t=0.05ms. After the evaluation of short-circuit, we now analyze the impact of phase lost on the network behavior.

3.3 Network influenced by phase-lost

3.3.1 Network representation with phase lost without dual controllers

The network is now modified to introduce a device able to induce phase lost and we obtain Fig.17.

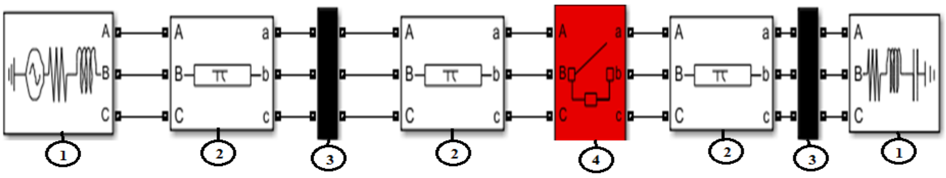

Figure 17: *Network influenced by phase lost when dual controllers act*

We now consider the network influenced by a phase lost without dual controllers. The network is constituted by the following elements. (1) The generator at the beginning and the receiver device at the end of the network. (2) The phase shifting transformers. (3) The bus bars. (4) The phase lost device.

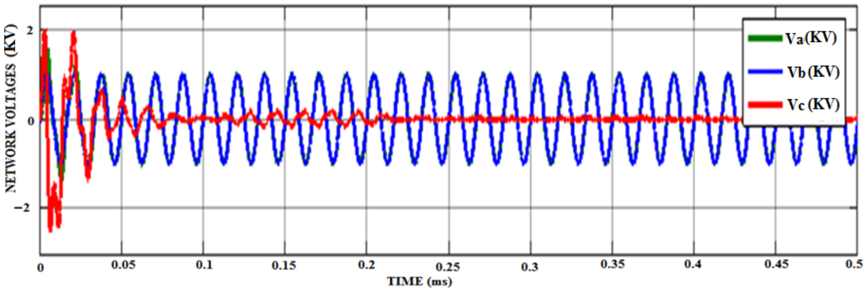

Figure 18: *Network voltages influenced by phase lost without dual controllers*

The network voltages obtained after the introduction of phase lost leads to Fig.18. We observe two domains of time. The first time domain corresponds to 0<t<0.05ms, here the three curves are subjected to high distortions between -3kV and +2kV as seen in Fig.18. This strange behavior corresponds to the introduction step of the fault (phase lost) in the network. Further, considering an increase of time such as t>0.05ms, the green and blue solid curves maintain their periodical sinusoidal behaviors similar to original behaviors. However, the las red curve exhibits small oscillations and its value vanishes as illustrated in Fig.18. This fact suggests that the phase lost corresponds to network voltage (Vc).

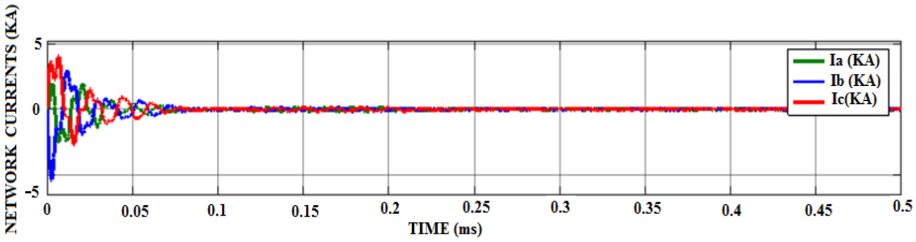

Figure 19: *Network currents influenced by phase lost without dual controllers*

After the analysis of the network voltages, we now observe the impact of phase lost on network currents depicted in Fig.19. It appears that at the beginning of the process for 0<t<0.1ms, the introduction of the phase lost in the system induces the high perturbations observed in Fig.19. After, this time domain, we consider t>0.1ms and all the network currents are vanished. This situation is normal since the introduction of phase lost modifies the network voltages, but vanishes the network currents as illustrated in Figs.18 and 19. Moreover, the impact of phase lost on network parameters is illustrated in Tab.4.

Table 4: *Network status influenced by phase lost without dual controllers*

Quantities	Before phase lost	With phase lost	Time (ms)	After phase lost	Relative error
φ(°)	12	20.11	0.5	0	67.58
V(MV)	225	153.04	0.5	0	31.98
I(KA)	2.8	1.79	0.5	0	36.07

Before the phase lost the network parameters are given as (φ=12°; V=225KV; I=2.8KA). The introduction of phase lost modifies the network parameters such as (φ=20.11°; V=153.04KV; I=1.79KA). The network voltage and current decrease as seen in Tab.4. However, the transport angle increases from 12° to 20.11°. The relative errors exhibit high values justifying strong distortions presented in the system as previously observed. This situation leads to the instability observed in the network.

3.3.2 Network representation influenced by phase lost when dual controllers act

After the analysis of the impact of phase lost in the network, we now introduce a dual IPCs in the system as depicted in Fig.19.

The network is now influenced by a phase lost when the dual controllers act as seen in Fig.20. This structure is constituted as follows. (1) The power supply at the beginning and the receiver at the end of the network. (2) The phase-shifting transformers which control the active powers P. (3) The phase-shifting transformers which control the reactive powers Q. (4) The phase lost device. (5) The phase-shifting transformers which also act on the reactive powers Q. (6) The interphase power controllers (IPCs) which introduce stability in the network.

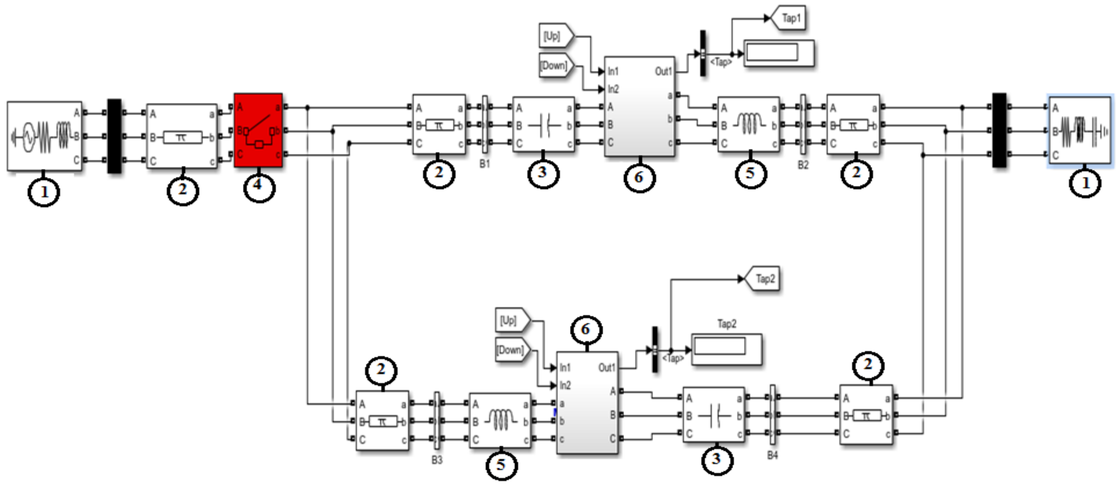

Figure 20: *Network representation influenced by phase lost when dual IPCs act*

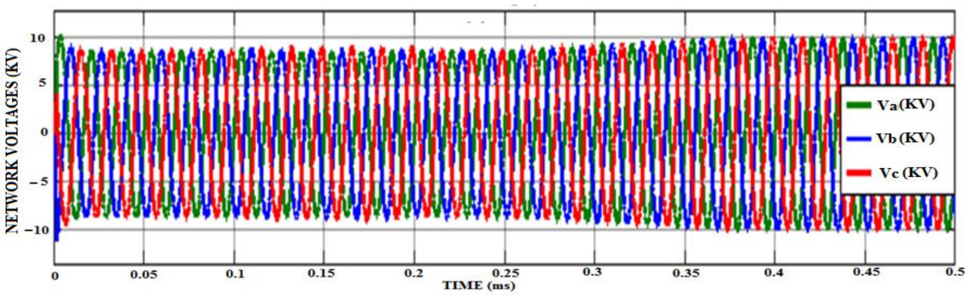

Figure 21: *Network voltages influenced by phase lost when dual IPCs act*

The observation of the network voltages depicted in Fig.21 correspond to those obtained after the introduction of the dual IPCs. It appears that the network voltages are restored. Besides, the dual IPCs generate narrow periodical oscillating behaviors as seen in Fig.21 compared to those presented in Fig.14.

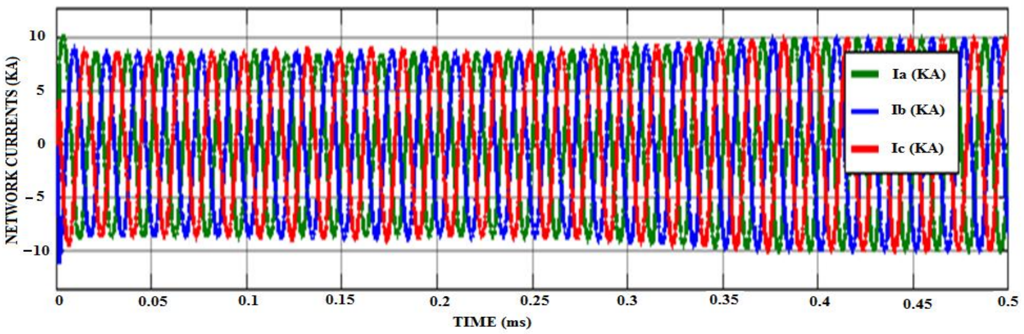

Figure 22: *Network currents influenced by phase lost when dual IPCs act*

The particular fact which appears in Fig.21 is that the three curves restored are not superimposed. Those network voltages appeared each in the alternative way as seen in Fig.21. Moreover, this alternative behavior combined to narrow periodical oscillating behaviors are responsible to the general aspect of the structure depicted in Fig.21. It appears that network voltages vary between -10kV and 10kV as seen in Fig.11. Besides, the network currents act in the same way as seen in Fig.22. Consequently, the network voltages and currents exhibit similar behaviors as illustrated in Figs.21 and 22.

The new parameters obtained after the phase lost introduction are represented in Tab.5.

Table 5: *Network status influenced by phase lost when dual IPCs act*

Quantities	Before phase lost	With phase lost	Time (ms)	Relative error
φ(°)	12	12.86	0.5	0.86
V(MV)	225	219	0.5	6
I(KA)	2.8	3	0.5	0.2

The network parameters before the fault introduction are given as (φ=12°; V=225KV; I=2.8KA). Those parameters as (φ=12.86°; V=219KV; I=3KA) when the phase lost comes into play as seen in Tab.5. It appears that the relative errors present weak values compared to those shown in Tab.4. Consequently, those weak values suggest that the network voltages and currents have been well restored by the dual IPCs. It clearly appears that the introduction of dual controllers composed with two IPCs have improved the network stability by deleting the distortions of parameters. We remark that the dual IPCs' system have produced good results.

4. Conclusion

In summary, the paper has investigated the impact of short-circuit and phase lost in a particular transmission network located in south region in Cameroon (Central Africa). The network is located between two towns known as Songloulou and Logbaba. First of all, using Matlab Simulink software, we have modelled the transmission network without fault (short-circuit or phase lost), the transmission network with fault (short-circuit or phase lost). Thereafter, we also have modelled the transmission network with dual IPCs when fault (short-circuit or phase lost) come into play. Secondly, we have presented the network parameters for each case. We have found that the network currents and voltages have presented a periodical sinusoidal behavior. That corresponds to perfect oscillations to the currents and voltages. If the single phase short-circuit comes into play, one voltage among the three presented, has undergone non periodical sinusoidal behavior with several different amplitudes. The two other voltages have maintained their precedent behaviors. This corresponds to the signature of the single phase short-circuit. However, phase lost has exhibited a different behavior compared to that presented by short-circuit. Further, the introduction of a dual IPCs' system has deleted the irregular distortions which have previously modified the network powers, currents and voltages. It appears that the dual IPCs' system has improved the network stability.

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