Multiparameter control modeling of electrical signal in a medium voltage network by Markov random approach

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Abstract— **In this paper, the electrical signals coupled to the fields present in a medium voltage network are analyzed by the random Markov approach. This approach with the contribution of the "Yakam Matrix" is studied to establish the quantitative approximations of the current I and the voltage V in non-steady state conditions in order to efficiently deduct the error percent between the experimental and the simulated results. Also, the aim was to determine the functional constant with infinite duration through multi-variable stabilization in commandability and controllability process. The development of the transition and observability matrices of the electrical signals behavior to establish the initialization's system of Dirichlet is presented where the vector π by the hidden Markov approach revealed to be almost stable. The multiparameter analysis in non-steady state conditions is conducted to show the maximum probability of the injected signals. The comparison of the experimental results with the simulation is presented with a 4% error obtained by using MATLAB. Since the function current I(t) remains in (0 < I ≤ 20)A conditions in case of phase disconnection. However, the application of the Markov random approach in electrical networks control modeling still require further studies and clarifications.**

Keywords- signals, network, voltage, multiparameter, Markov random approach.

I. INTRODUCTION

The daily need of electrical energy of the modern society is fulfilled by means of an efficient production of the electricity, its transportation, its distribution and its consumption. Let us focus on the distribution network which is an utmost part of the power system carrying power within the last step [1], in the process of electrical energy transport from production plant [6-7], [9-11] to consumers by regulation [8]. It conventionally consists of passive electric circuits [9] in which the active and reactive power flows from the high to the low voltages through the lines or cables. Recent studies show that 80% of distribution networks experience temporary instabilities and are categorized by monthly, weekly even every moment [10] [11]. Despite the computerization of the electricity grid, the monitoring of signals in the transmission lines against unpredictable fluctuations and disturbances remains a concern in this field. These instabilities are presented as statistical data collected on each fluctuated point [5]. In this paper, a statistical method is used, which is based on the random approach of Markov chain [1-4], [12], to quantify and forecast the instabilities of the distribution network system. This approach represents a triplet matrix model taking several load variables of the network. However, the voltage and the current of the initial current are considered as variables. Since the Markov random approach can be one of the output routes in the medium voltage network comparing to its characteristics.

II. STATE OF THE ART

The multiparameter analysis of an electrical signal in a medium voltage network is based on the study of the transmission lines of energy from a given point A to another point B. Since these lines are components of electrical systems [8]. In the Figure 1 the alternating current is defined in a sinusoidal state.
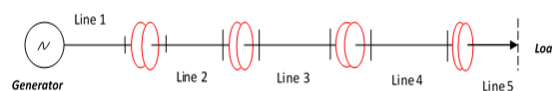

Figure 1. Simplified diagram of the radial network between source and load.

The aggregation methods encountered in the literature are based on analytical and mathematical modeling. We analyze how signals; current and voltage can propagate in a line. The laws of the propagation of voltages V and currents I are derived from the so-called telegraphist equations [14] [15]. In order to establish these equations, the unitary line length of the

length x between x and x + dx composed of longitudinal elements Rdx, Ldx, and transversal elements Cdx and Gdx. The voltage and current are respectively V(x,t) and I(x,t) at the input, and V(x + dx,t) and I(x + dx,t) at the output. The change of the current and voltage are obtained by applying the mesh current method [8]. The figure 2 illustrates a unitary line system evolving over time developed in [13]. The quantities involved can be assimilated to time signals. Mathematically the behavior of this system can be expressed by the integral differential equations (1).
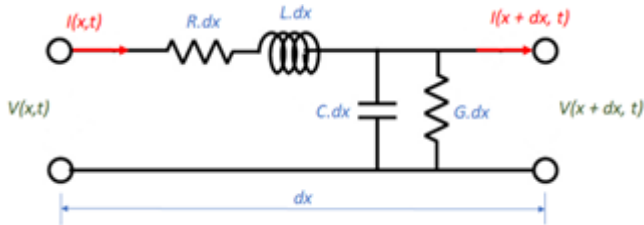

Figure 2.   Infinitesimal mode in π.

The equations connecting the different quantities involved consider all the phenomena to describe the entire system [6]. Since the system is linear, the equations derived from the laws of electricity [19] governing the behavior of a signal is illustrated in the equation (1).

$$V(x,t) = RI(x,t) + L\frac{dI(x,t)}{dt} + \frac{1}{c}\int_0^t I(x,t)dt \qquad (1)$$

This equation generates a system of partial differential equations where the tension and the current are studied on the elementary length dx. Since the tension is V=V(x,t,∂V/∂x,∂V/∂t). The theory of voltage and current propagation in the two regimes; anytime and sinusoidal would not be competitive to establish the entire controllability and commandability for the unpredictable fluctuations in a medium voltage network. Equations (2) and (3) developed in the theory of propagation of the two regimes [6-7], [16] are mathematical models to describe nonlinear behavior with less probabilistic approach. The propagation of voltages and currents on a medium voltage network is described in the same way as telegraphists [20], [17] under the variation of time ∂t regime (2).

$$\begin{cases} \frac{\partial^2 V}{\partial x^2} = LC\ \frac{\partial^2 V}{\partial t^2} + (RC + LG)\frac{\partial V}{\partial t} + RGV \\ \frac{\partial^2 I}{\partial x^2} = LC\ \frac{\partial^2 V}{\partial t^2} + (RL + LG)\ \frac{\partial I}{\partial t} + RGI \end{cases} \qquad (2)$$

Contrarily to the previous regime, the sinusoidal includes the inductance and the series resistance [22] given by the complex linear impedance Z and the capacitor and the parallel conductance by a linear admittance Y.

$$\begin{cases} \frac{d^2 V}{dx^2} = ZY\ V(x,t) \\ \frac{d^2 I}{dx^2} = ZY\ I(x,t) \end{cases} \qquad (3)$$

At each node of the line corresponds a certain number of variables which define the state of this node, it is about the voltage V, the intensity of the current I of the phase angle θ

with the node considered relative to a reference phase, the active powers P and reactive Q taken at this node of the line.

III.   STOCHASTIC MODEL BY MARKOV CHAIN

Formally, the methodological approach can be used to analyze the behavior of the signal in the transmission lines in a probabilistic way against the random and unpredictable instability phenomena on the network. As stated in [24] [25], the concept of stochastic approach is adapted to this type of problem, it makes it possible to eliminate superfluous information. Thus, the reality of physical equations is partly translated in random terms because the variations are unpredictable. The generated stochastic behavior is such that the system evolves under the influence of a random force, even if the motion is governed by the dynamic equations.

A. Markov process stochastic chain

Stochastic process is any process describing the evolution in time of a random phenomenon [1-2]. Mathematically it is defined as a collection of random variables defined on a common probability space, taking values in a common set and indexed by a variable *t,* usually representing time [1-3], [27]. Let X(t) be a random variable evolving over time. The sequence of index rolls 1, 6, 2, 5 where X1 = 1, X2 = 6, X3 = 2, X4 = 5 is defined as Markovian process if its evolution does not depend on its past but only on its present state. This process can be established by a theoretical model called Markov Model [25]. The approach proceeds with two main states, the hidden state and the observable state, the first of which considers that the states of the system are not observable but emit observable signals that are weighted by their probability. The second is said to be observable because the states are directly observable from the transition matrix and that of initialization. The Markov model, Hidden Markov Model (HMM) λ, in Figure 4 is characterized by the components defined as following [26]: Let {π, A, B} be the triple matrix variables whose matrices of initial probabilities, probabilities of transitions and probabilities of observations of the hidden Markov model. The states are represented by vertices, the alphabet of states: S= {S1, S2, ..., Sn}, a set of events O = {O1, O2, ..., Ok} that occur when one enters a state. They are also called emissions or observations. A transition probability matrix A={aij = P (sj |si)}, verifying $\sum_{j=1}^{N} a_{ij} = 1$, an initialization vector π={π_t = P(st)} verifying $\sum_{t=1}^{N} \pi_t = 1$ Probabilities of starting: these are the probabilities of starting in one state or another (point 0) and a matrix of probabilities of observations B={bt(0t) : P(0t|st)} also called emission probabilities, each expressing the probability of an observation of generated in state st. Also $\sum_{j=1}^{T} b$t(oj) =1.
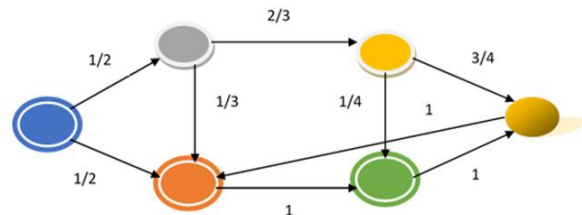

Figure 3.   Model of a finite state Markov chain [21].

B. *Choice of the states lines transmission*

The system considered being the transmission lines are characterized by the passage of magnitudes in the circuit. Each node and each point contain several variables that must be monitored, including voltage, phase angle, powers, and current intensity. We consider the whole of each point of the studied line as a universe where we do not know each other when and where the signal can undergo perturbations, fluctuations or variations. The universe is symbolized by S and represents the states of the system or length of the aluminum line with a voltage of 20kV.

C. *Adaptation*

States: S.

They give at a given moment, the description of the system. They correspond to the classes of our model (s1, s2, s3, s4, s5, s6, s7, s8, s9, s10). These 10 states model the hidden state of the system.

Transitions: A.

They are the state changes. These are the probabilities of moving from one class to another. We propose in Figure 4, the model knowing the possible states of the system, which can appear the perturbation with the distribution of probability.
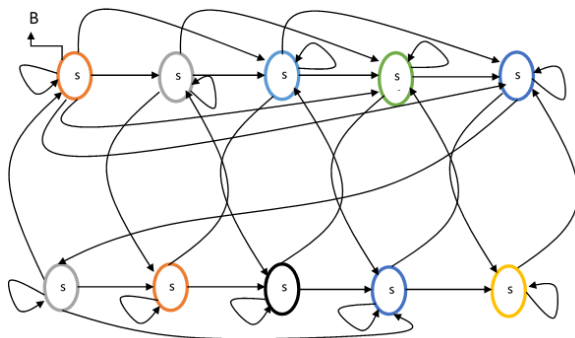
D. *Proposed model*

Figure 4. Left-right model of the hidden process will correspond to the state of the system.

This model from "Yakam Matrix" developed into interface of plasma signals in electric network is appropriated and can have some applications in renewable energy and hydroelectric energy [8]. Traditionally, nonblocking networks are designed to reduce the number of the cross-points. Since this is the most expensive part in a network. Even though in many modern technologies, the cost of cross-points is no longer a main issue as per the physical dimension and the control complexity of a network [23]. In this model, the set of routes has one vertex for every first stage switch in the network and one vertex for every third stage switch in the network. An edge is added between a vertex in the first set and a vertex in the second set for every single connection that needs to be routed from an input of the switch corresponding to the first vertex then an output of the switch corresponding to the second vertex. A key advantage of the Markov random approach is that it has rigorously provable performance bounds rooted in deep results in mathematical statistics. From a practical point of view, this approach based on the hidden Markov Approach uses all the macroscopic information about the unpredictable fluctuations

and disturbances in a medium voltage network to compute the actual the state and the parameters of the distribution system. Furthermore, this approach with the contribution of the "Yakam Matrix"[8] allows to establish the quantitative approximations of the current I and the voltage V in non-steady state conditions in order to efficiently deduct the error percent [18] between the experimental and the simulated results. However, this approach still needs further consideration for an effective controllability of the electrical signal instabilities.

IV. RESULTS AND PERSPECTIVES

In this part, we consider two variables which are voltage and current intensity. We will observe their behavior against different demands. First, we initialize the parameters $\{\pi, A, B\}$. The size considered is that of 10 states that can generate possible transitions of the random events for MCMES: Multiparameter control modelling electrical signal.

A. *Initialization of Matrix Indicators*

The electrical signals of this study covered by Markov lead to some specificities of the system for its observability during the phase transition of what is initialized. Therefore, the matrix A is that of transition, B is that of observation and π leads to the conditions of Dirichlet of initialization.

a) *Transition Matrix: A*

$$A: \begin{array}{cccccccccc} S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & S_8 & S_9 & S_{10} \end{array}$$

$$A: \begin{bmatrix} 1/2 & 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 \\ 0 & 1 & -3/4 & 0 & 0 & 0 & 0 & 0 & 0 & 3/4 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 2/6 & 0 & 0 & 2/6 & 2/6 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 0 & 0 & 1/2 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1/4 & 0 & 0 & 0 & 0 & 0 & 1/4 & 1/4 & 1/4 & 0 \\ 0 & 0 & 0 & -1/2 & 1 & 0 & 0 & 1/2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1/2 & 0 & 0 & 1/2 \end{bmatrix} \begin{array}{l} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \\ S_{10} \end{array}$$

b) *Emission Matrix: B*

$$\begin{array}{ccccc} I(t) & V(t) & p(t) & q(t) & \theta(t) \end{array}$$

$$B: \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1/2 & 1/2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1/3 & 0 & 1/3 & 0 & 1/3 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 1/4 & 1/4 & 1/4 & 1/4 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1/2 & 1/2 \\ 1/3 & 1/3 & 0 & 1/3 & 0 \end{bmatrix} \begin{array}{l} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \\ S_7 \\ S_8 \\ S_9 \\ S_{10} \end{array}$$

c) *Initialization vector*

$$\pi = [1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0]$$
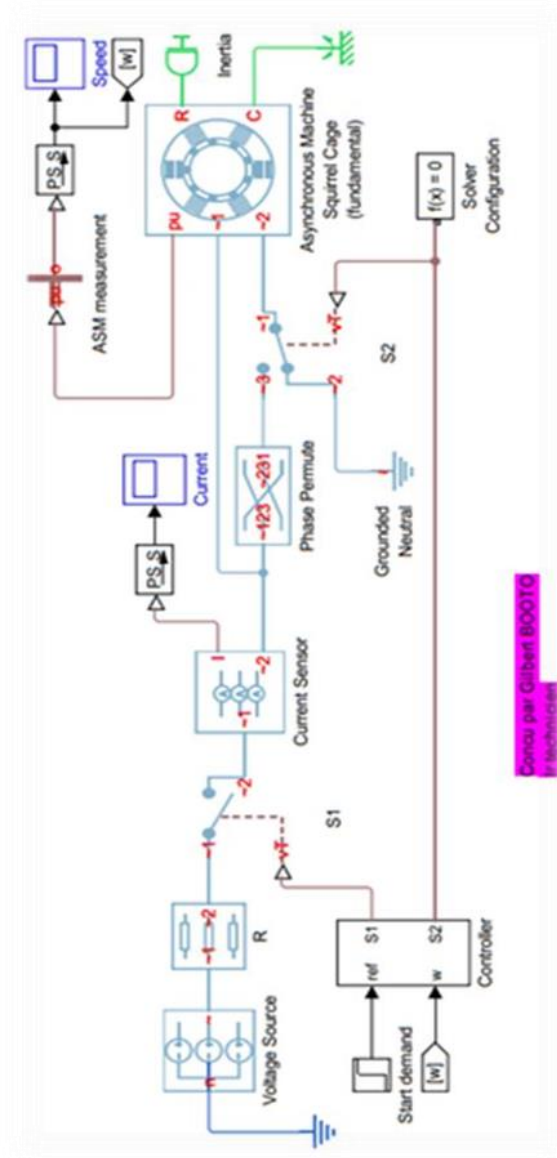
Figure 5.   Model of a network designed to simulate the signal of the quantities.

B. Simulation

Using MATLAB, we designed the typical network of Figure 5, the latter consists of the sensors installed at the posts, the loads at one end and the other the three-phase source with phase considered the section AB of figure 1, the sensors (sensors) installed on poles allowed to visualize the different behaviors. The signals were unpredictable load, instability of the source and the disconnection of one phase.

The result presented in (Figure: 6-9) are states that have the maximum probability of having generated the possible signals injected.
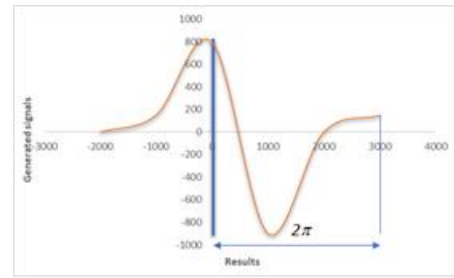
(a)
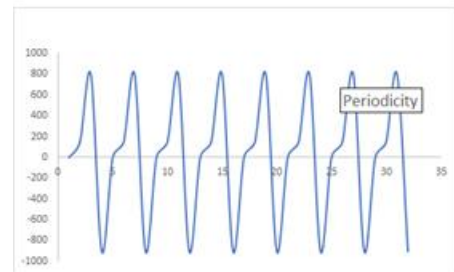
(b)

Figure 6.   (a) (b). Model λ result by the initialization parameters without any solicitation.

In the figure 6 (a), each element of the data series is given by the sum of the signal contribution Si, which corresponds to the voltage caused by electrical currents injected shown under a periodical model $Si = S\sin(2\pi/J+\varphi)$; φ is the phase of the signal [23], [28]. The random noise with zero mean and more regular disturbance, whose average value is not constant during data acquisition is only applied on sinusoidal trend.
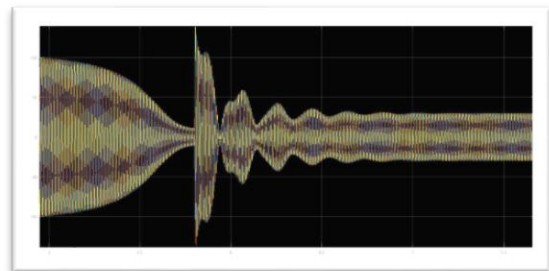

Figure 7.   Signal of the intensity of the current is subjected to stressing of the overloads (electric motor) to the state s3 of its universe.

This result applies in electrotechnics for the random phenomena observed in medium voltage network at microscopic scale.
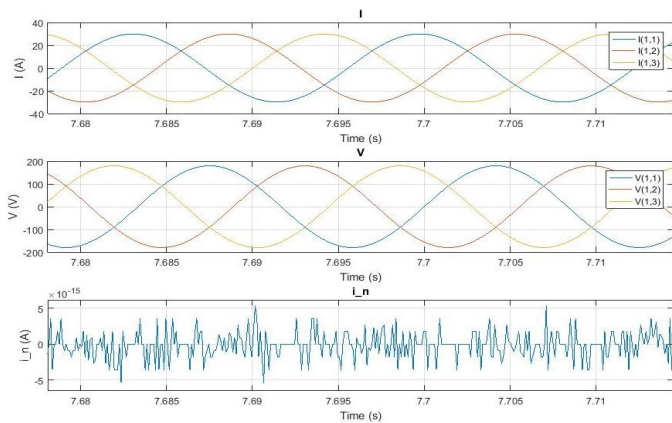
Figure 8.   Normal three-phase behavior of the signals I (t), V (t) and the behavior in case of the instability of the generator of i_n.
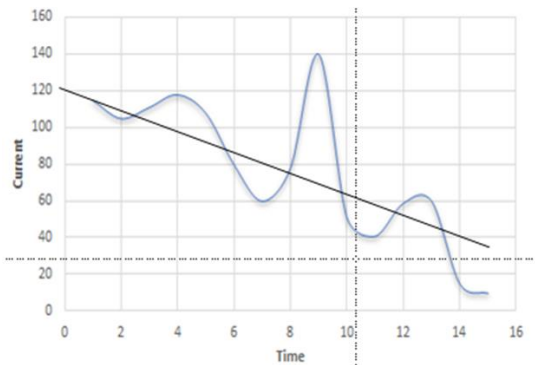

Figure 9.   Instability of I(t) in case of disconnection of a phase of 3. This figure shows that the current I can drop to less than 20A while remaining higher than zero.
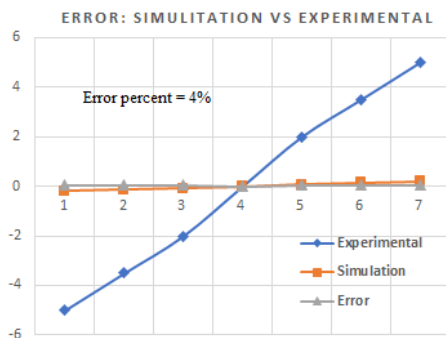

Figure 10. Simulation vs experimental results error percent based on the normal three-phase behavior of the signals I(t) and V(t) in non-steady state conditions of the Figure 8.

In the production, transport and the distribution of the electrical energy, there is significant wastage of this and the ferromagnetic effects that randomly make variate the network parameters; current and voltage through the transportation phase and during the displacement time. This compromises to the expected power supply against the utilization demand [16]. The Markov random approach with the application of the network parameters as per the fluctuations below studied opens in the electrical systems random behavior, significant conditions of the current periodicity as shown in Figure 6. However, the Figure 9 shows that the current trend remains higher than zero although the existing fluctuations at the input, throughout the network and at the output.

V.   CONCLUSION

From this investigation, it is obvious that the electrical signals in the medium voltage networks constitute a multivariable system whose dynamic states and the related behaviors are unpredictable because of the random effects and the risks to be managed at any time. The number of variables to be defined is not exhaustive and converges to an infinite sequence difficult to manage in the classical topological space of functions. The network is exactly a multivariable MIMO (multiple input and multiple output). The statistical approach and the probability approach seem to require the filtering of the matrix of the advanced probability triplet (π, A, B). With the help of MATLAB, the typical virtual network seems to agree with the realities of ground in the exploitation with the National Society of Electricity. The Figures 7 and 8 demonstrate the coherence of the theoretical probabilistic method based on the Markov random approach and provide satisfactory deviations in term of amplitude which is at most 5. Even though these results obtained by using MATLAB involve such an error, the application of the Markov random approach in electrical networks still requires further improvement. However, this approach with the application of the network parameters as per the fluctuations observed in the 7, 8 and 9 tends to establish an advanced model that can take in account both the electrical systems random behavior and the steady state conditions of the current periodicity. Finally, the results of MCMES was used to predict the instabilities of ferromagnetism effect, Foucault current, white noise [29], electrical fire [30] and others in electrical network since production in various hydroelectric power and further random renewable energy solar or wind.

REFERENCES

[1] A. Paul, Gagniuc, Markov chains: from theory to implementation and experimentation. USA, NJ: John Wiley & Sons. Pp. 1–256. ISBN 978-1-119-38755-8.J. 2017.

[2] F. Baudouin, Stochastic processes, Int. encyclopedia of educatio, p 451-452, https://doi.org/10.1016/B978-0-08-044894-7.01369-5. 2010

[3] A. Carpinone, M. Giorgio, R. Langella and Testa, "Markov chain modeling for very-short-term wind power forecasting". Electric power systems research. 122. 2015.

[4] J. Munkhammar, D. M. Van der Meer and J. Widén, "Probabilistic forecasting of high-resolution clear-sky index time-series using a Markov-chain mixture distribution model". Solar Energy. 184. 2019.

[5] W. Ahmadi, A. Mehdizadeh, M. Chrigui and A. Sadiki: Numerical evaluation of unsteadiness in particle dispersion modeling, Journal of Fluids Engineering 137 (3), 034502 (7 pages), https://doi.org/10.1115/1.4028660.

[6] S. Alexander, Analyse des circuits électriques, De Boeck, Bruxelles, pp15-20

[7] A. Bouzid, Modélisation et simulation des réseaux électriques,A/AMIRA-BEJAIA, pp15-22. Alger, 2010.

[8] L. Y. Kabeya Mukeba, Régulation & systèmes asservis, Editions Universitaires Européennes,Cologne 2019.

[9] T.Neffati, Electricité génerale, 2ᵉ ed. Dunod, ,pp8-32, Paris, 2008.

[10] Internet : wikipedia.org/electricalsignal, (consulted on 20 novembre, 2017).

[11] T. Wildi, Electrotechnique,,3ᵉ édit. Deboek,bruxelle, p1000-1002

[12] B. Farid, Les modèles de Markov caché et leur application dans un processus industriel, A/AMIRA-BEJAIA, pp42-61, Alger,2015

[13] M. Boussalam, Etude et modélisation de structures de transmission non uniformes applications a l'adaptation d'impédance et au filtrage, vol.1N°2504,2007

[14] T. Ditchi, Lignes de transmission, UPMC, pp5-28, Paris-sud, 2016.

[15] M. Melik, Sureté de fonctionnement des réseaux de distribution en présence de production décentralisée, pp59-72, INPG, Grenoble, 2009.

[16] T. A. Tuan, Modélisation de la propagation des signaux HF dans un réseau d'énergie électrique, pp96-101. N° D'ORDRE : E.C.L. Lion, 2006

[17] T. Debu, Lignes aériennes. Paramètres électriques, ,pp2-20, CERT, Paris, 2015

[18] A. Gilat and V. Subramanian, Numerical methods for engineers and scientists. An introduction with applications using MATLAB, 3rd Edition. Wiley. USA 2014 http ://clients.rtefrance.com/lang/fr/visiteurs/vie/bilan_RTE.js. [En ligne][consulté le 10 Octobre, 2017.

[19] O. Mathieu, Modélisation par chaines de Markov homogènes ergodique des appels de puissance d'un parc de chauffe-eau électriques, , pp60-66, Grenoble – INPG, Grenoble, 2016.

[20] S. Debbal, Simulation par ordinateur de la ligne Haute Tension en régime permanent dans les conditions aléatoires, ISSN 1813-548X,2005, pp4. 2005.

[21] P. J. Ossouah, Analyse paramétrique des réseaux électriques sur matlab, pp 20-73, Montreal,2010.

[22] M. Djebabra, Etude de sureté de fonctionnement d'un système électrique simple, pp 7-8, ISSN 18136548X, 2006

[23] E. Elhoussin, Y. Amirat, G. Feld, F. Le Gall and M. Benbouzid, Diagnostique et détection des défauts dans les machines asynchrones par des méthodes avancées de traitement du signal, pp2-4, 3EI n°91, Janvier 2018.

[24] A. Spataru, Fondements de la théorie de la transmission de l'information, EPFL-ecublens, p1-38 Lausanne, 2000.

[25] D. Jerome, Chaînes de Markov et applications, Centre D'enseignement De Grenoble, 2005.

[26] G. Besbes, Modélisation de dialogues à l'aide d'un modèle markovien caché, Laval, Quebec, pp78-79.

[27] S. Kay, Intuitive probability and random processes using MATLAB, Technology & Engineering, 2006.

[28] A. Luigi and G. Mavre., Determination of electrical Signal Masked by Random Noise using a Super-Averaged Funcyions. Annali di Geofisica. Vol 43 No 3. Pp249-258, 2000.

[29] E. Harth, T. Kalogeropoulos, Multipara-meter optimiwation circuit, US Patent, march 27, 1990.

[30] Xuezu Jia, Ke Zhang, Yi Chai and Yuan Li, A multi-sensor characteristic parameter fusion analysis based electrical fire detectionmodel; Springer Nature; Singapore Pte Ltd, 2019.

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