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CONTINUOUS WAVELET TRANSFORM FOR FERRORESONANCE PHENOMENON IN ELECTRIC POWER SYSTEMS

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ABSTRACT

This study is related to determination of the ferroresonance phenomenon for Seyitomer-Isiklar part of the Electric Power System of 380 kV in Turkey. In this manner, Simulation data, which is produced from the Matlab-Simulink model, is considered for voltage variation of the R-Phase of the power system and then the continuous wavelet transform (CWT) is applied to this voltage variation. Results are examined on the time-scale plane and most dominant scale can be determined as a feature of the ferroresonance phenomenon. Hence, it can be shown that this extracted feature provides all pre-definitions of the ferroresonance event. Consequently, the ferroresonance phenomenon can be determined by overvoltage variations from the sub-scales of the original voltage variation.

Keywords: Ferroresonance, Power System, Wavelet Analysis, Feature Extraction.

1. INTRODUCTION

Ferroresonance phenomenon is one of the most serious problems in electrical power systems. In this sense, it is related to the existence of over-voltages resulting under a ferroresonant condition. Therefore, the ferroresonance phenomenon is known as a nonlinear phenomenon that causes over-voltages in power systems. The ferroresonant conditions generally occur when the system is unbalanced, like switching or the series connections of the capacitors with transformer magnetizing impedance. This situation causes to some failures in transformers, cables, and arresters as well as over-voltages [1-13]. The ferroresonance phenomenon composes to the high voltage levels because of the relative ratios of losses, magnetizing impedance and cable capacitance fall into its more favorable range [7,8,10].
The effect of the ferroresonance is not only be described as the jump to a higher fundamental frequency state, but also is given with bifurcations to the sub-harmonic, quasi-periodic, and chaotic oscillations in any circuit containing a nonlinear inductor. Also, the abnormal rates of harmonics can often be dangerous for most electrical equipments in the power systems. Therefore, in the related literature, the ferroresonance phenomenon is defined as a general term, which is applied to a wide variety of the interactions between capacitors and iron-core inductors [1-19].
In this paper, the ferroresonance phenomenon is introduced for Seyitomer-Isiklar part of the Electric Power System of 380 kV in Turkey. In this sense, continuous wavelet transform (CWT) is applied to one of the phase (phase-R) voltages of the sample power network. Hence, as a result of the CWT analysis, overvoltage variations on the data can be easily shown.

2.CONTINUOUS WAVELET TRANSFORM

The use of wavelet transform is particularly appropriate since it gives information about the signal both in frequency and time domains. Let *f(x)* be the signal, the continuous wavelet transform of *f(x)* is then defined as

$$W_f(a,b) = \int_{+\infty}^{-\infty} f(x)\psi_{a,b}(x)dx, \qquad (1)$$

Where;

$$\psi_{ab}(x) = \frac{1}{\sqrt{|a|}}\psi\left(\frac{x-b}{a}\right) a,\, b \in R,\, a \neq 0 \qquad (2)$$

And it provides the admissibility condition as below

$$C_\psi = \int_0^{+\infty} \frac{|\psi(\omega)|^2}{\omega} d\omega \langle \infty \qquad (3)$$

And for this reason, it is

$$\int_{-\infty}^{+\infty} \psi(x)dx = 0 \quad (4)$$

Here $\psi(\omega)$ stands for the Fourier transform of $\psi(x)$. The admissibility condition implies that the Fourier transform of $\psi(x)$ vanishes at the zero frequency. Therefore ψ is called as a wave or the mother wavelet and it have two characteristic parameters, namely, dilation (a) and translation (b), which vary continuously. The translation parameter, "b", controls the position of the wavelet in time. A "narrow" wavelet can access high-frequency information, while a more dilated wavelet can access low-frequency information. This means that the parameter "a" varies with different frequency. The parameters "a" and "b" take discrete values, a = a_0^j, b = nb0a_0^j, where n, j $\in$ Z, a0 >1, and b0 >0 [20,21].

3. FERRORESONANCE PHENOMENA AND ITS MODELING

Ferroresonance is a jump resonance, which can suddenly jump from one normal steady-state response (sinusoidal line frequency) to another ferroresonance steady-state response. It is characterized by overvoltage, which can cause to dielectric and thermal problems in transmission and distribution systems. Due to the nonlinearity of the saturable inductance, ferroresonance possesses have many properties associated with a nonlinear system, such as:

Ferroresonance is highly sensitive to the change of initial conditions and operating conditions.

Ferroresonance may exhibit different modes of operation which are not experienced in linear system.

The frequency of the voltage and current waveforms may be different from the sinusoidal voltage source.

Ferroresonance possesses a jump resonance, whereas the voltage may jump to an abnormally high level.

In this section, the ferroresonance phenomena is introduced for electric power systems and its modeling is realized using the real power system parameters for Seyitomer-Isiklar Electric Power System network of 380 kV in Turkey as indicated in the Figure 1.

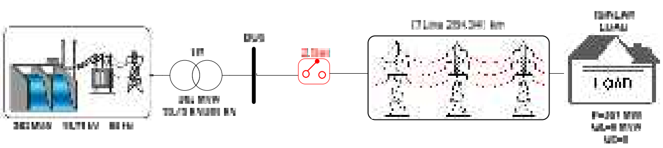

Figure 1. *Seyitomer-Isıklar Electric Power Network.*

The system, which is shown by the Figure 1, is modeled under the MATLAB-SIMULINK environment as shown in Figure 2.

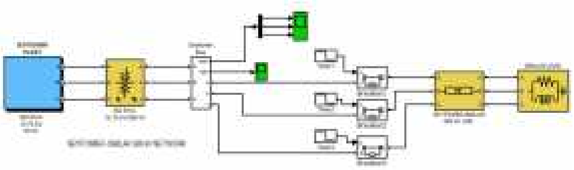

Figure 2. Seyitomer-Isıklar Matlab-Simulink Model.

5. APPLICATION TO THE SIGNALS

Simulation data to be used in this study is generated by the MATLAB-Simulink model of the power system. In this manner, voltage variation obtained for one phase of the power system is illustrated by the following figure.

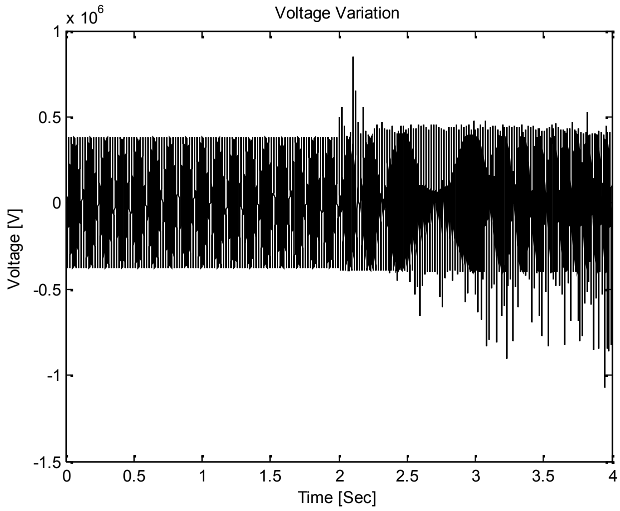

Figure 3. *Voltage Variation of the Power Systems.*

As seen in Figure 3. Voltage amplitudes are at around 380 kV for normal operation condition. However, after the 2 nd second, some effects of the ferroresonance phenomenon are observed. In order to define this disturbed waveform of the ferroresonance part, the CWT approach is applied to the voltage variation. Hence three dimensional plot of the time-scale and amplitude variation is represented by Figure 4.

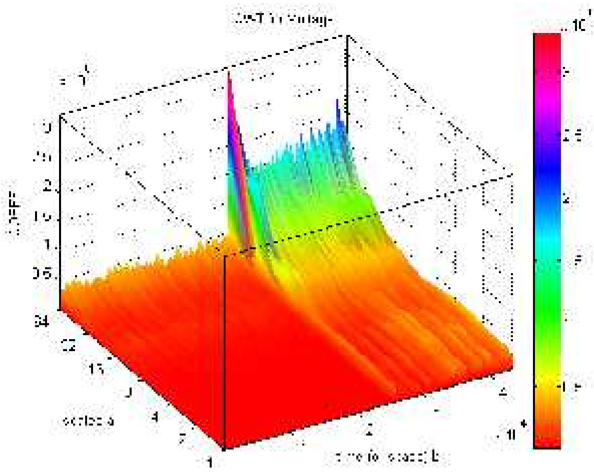

Figure 4. *Three dimensional plot for the CWT of the voltage variation.*

Here the number of the scales is determined as 64. This scale number is presented by power of an integer (n=0, 1, 2,…). In terms of the frequency values, high scales are related with low frequency values while the low scales are defined at high frequencies. In this application, the scale 64 is represented at around (0-135) Hz. Hence, in order to get the low frequency

region of overall voltage variation, time-scale representation of the overall voltage is shown by Figure 5.

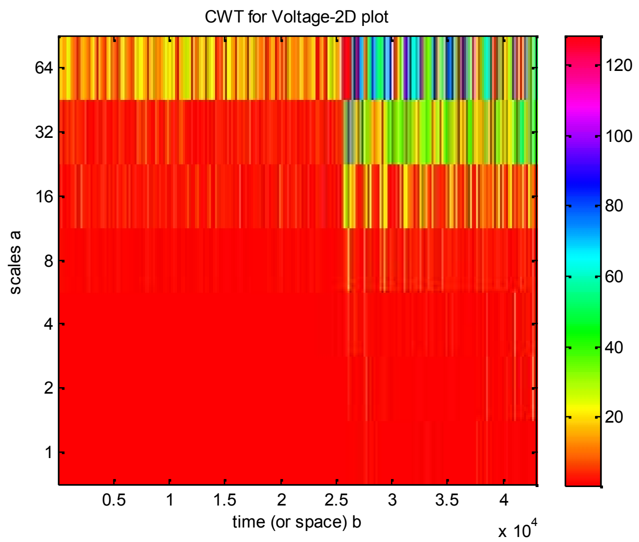

Figure 5. *Time-scale representation of the voltage variation.*

As seen in Figure 5, most dominant frequency diversities of the time-scale representation appears at scale 64. Therefore, this scale can be accepted as a feature of the ferroresonance phenomenon. Hence this extracted feature can be shown by Figure 6.

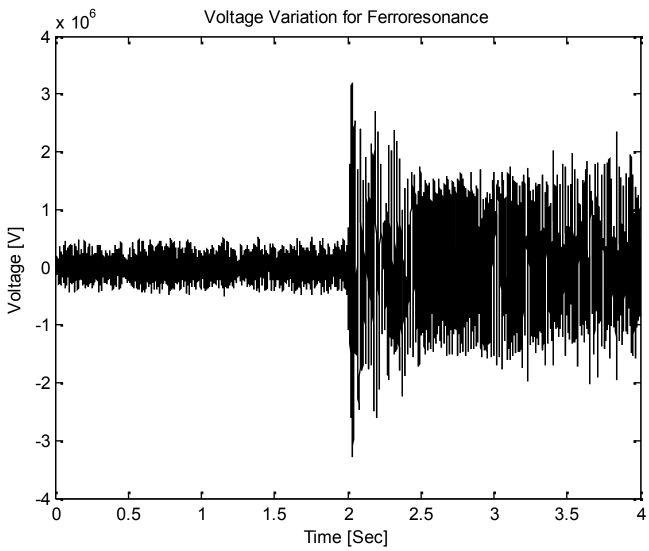

Figure 6. *Voltage variation obtained from the extracted feature.*

Regarding to this feature, the ferroresonance event begins with huge amplitudes from 2 nd second. These huge amplitudes are related to the overvoltage characteristics of the ferroresonance phenomenon.

6.CONCLUSIONS

This study is based upon the voltage variation for one phase of the power system, which is considered for West Anatolian Electric Power Network, under the ferroresonance phenomenon. Hence, the voltage variation shown in Figure 3 is examined to get the ferroresonance related features. For this purpose, the CWT approach is applied to this raw data and hence, its most dominant Time-scale properties are extracted. Regarding to this extraction, highest scale is determined as fundamental feature related to the ferroresonance and it is shown by the Figure 6. The Figure 6 reflects the fundamental properties of the ferroresonance phenomenon because it includes the overvoltage.

Consequently, it can be said that the overvoltage values increase four times of the voltage variation in normal condition.

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