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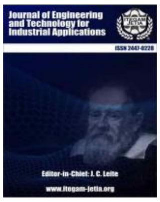

RESEARCH ARTICLEOPEN ACCESS

THE IMPACT STUDY OF FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEM ON TRANSIENT STABILITY OF POWER SYSTEMS USING MATLAB CODE AND POWER WORLD SIMULATOR

Abdelhafid Hellal[1], Aissa Souli[2], Redha Djamel Mohammedi[3] and Mohamed Elbar[4]

[1] Polytechnic National School of El Harrach, Algiers, Algeria
[2] Electrical Engineering Department. Nuclear Research Center of Birine. Djelfa, Algeria
[3,4] Applied automation and industrial diagnostic Laboratory (LAADI), Faculty of Science and Technology, University of Djelfa, Algeria.

[1]http://orcid.org/0009-0000-2823-7868, [2]http://orcid.org/0009-0001-5463-8267, [3]http://orcid.org/0000-0003-4170-543X ,[4]https://orcid.org/0000-0002-2636-9469

Email: [1]hfdhellal@gmail.com, [2]a.souli@crnb.dz, [3]r.mohammedi@univ-djelfa.dz, [4]m.elbar@univ-djelfa.dz

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ABSTRACT

The purpose of this work is the study of the influence of FACTS on transient stability of power systems using a Power World Simulator software, and the computer code transient stability code 'TRANS_STAB_CODE' 'which was created in MATLAB. We tried in the introduction of this work to provide a description on the transient stability: definition, transient stability criteria, and equations. Then we gave an overview on the modelling of FACTS in power systems, the definition and types of Flexible Alternating Current Transmission System, their schemes, and their equations, then presented the model of UPFC (Unified Power Flow Controller) as an example. Secondly, we discussed the code, 'TRANS_STAB_CODE' that was created in MATLAB by giving a description of the code and their structure with graphics windows, and then I described privately the Power World Simulator simulation software. Then we presented the test electrical network, and the results of transient stability of this network systems with the code 'TRANS_STAB_CODE' 'and with Power World Simulator where no and where there Flexible Alternating Current Transmission System. At the end, we analyzed the results of both programs in both cases: with and without Flexible Alternating Current Transmission.

I. INTRODUCTION

Transient stability analysis is used to investigate the stability of power system under sudden and large disturbances, and plays an important role in maintaining security of power system operation [1],[2].

The transient stability analysis is performed by combining a solution of the algebraic equations describing the network with numerical solution of the differential equations.

However, due to the non-linearity of the differential equations, the solving process is tedious and complicated.

Flexible alternating current transmission systems (FACTS) technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines.

The Unified Power Flow Controller (UPFC) is a second-generation FACTS device, which enables independent control of active and reactive power besides improving reliability and quality of the supply. This paper describes the transient stability in power systems by placing the UPFC at the sending end of an electrical power transmission system. The transient stability of power systems with the UPFC is compared with that without UPFC [3],[4].

Simulations are carried out in MATLAB Code 'which was created in MATLAB, and with Power Word Simulator to validate the results obtained and to see the performance of the UPFC.

Behavior of the power system transient is usually obtained on the basis of a model consisting of a differential equation system with a strong nonlinearity; the solution based on time can be obtained in the general case only by applying some suitable numerical integration methods [5],[6] Behavior of a synchronous machine for stable and unstable operation is illustrated in the Figure 1.

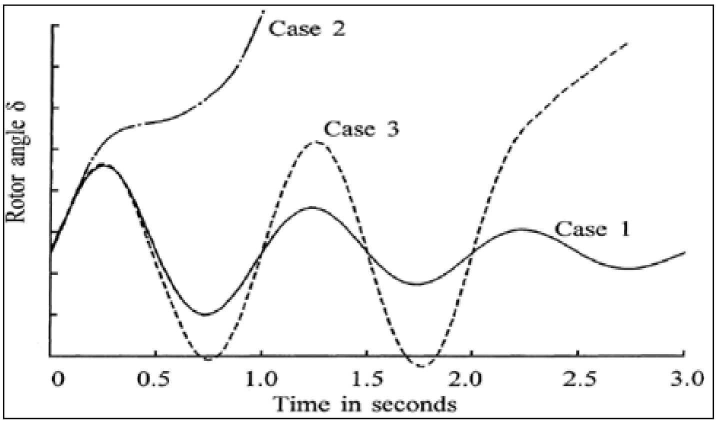

Figure 1: Rotor angle responses to transient disturbances.
Source: Authors, (2024).

In case 1, the rotor angle increases to a maximum and then decreases and oscillates with decreasing amplitude until it reaches a study state.

In case 2, the rotor continues to increase steadily until synchronism is lost. This type of instability is referred to as first swing instability and is caused by insufficient synchronizing torque.

In case 3 the system is stable in the first swing but becomes unstable as a result of growing oscillations as the end is approached. This form of instability generally occurs when post fault steady state condition itself is small signal unstable, and this is not necessarily as a result of the transient disturbance [7].

II. THE FACTS DEVICES

FACTS is a Flexible Alternating Current Transmission System, these devices have been developed by (EPRI) in the 80s.

It is a Power Electronic based system and other static equipment that provide control of one or more transmission system parameters to enhance control ability and to increase power transfer capability [8],[9].

FACTS devices are used to optimize already the existing transmission lines

FACTS devices are:

1. Serial Controllers: SSSC, IPFC, TCSC,
2. Parallel Controllers: STATCOM, SVC,
3. Serial - serial controllers,
4. Series - parallel controllers: UPFC, IPC,

II.1 USES OF FACTS DEVICES

1. To enhance the control ability of the transmission Network.
2. To increase the power transfer capability of transmission network.

II.2 OPPORTUNITIES OF FACTS

FACTS technologies opens up new opportunities for controlling power and enhancing the usable capacity of present as well as new and upgraded transmission lines .

FACTS controller controls the inter-related parameter that governs the operation of transmission lines including series impedance, Shunt impedance, current, voltage, Phase angle.

FACTS technologies also lead to extending usable transmission limits in step-by-step manner with incremental investment as and when required.

II.3 BENEFITS OF FACTS CONTROLLER

1. It increases the loading capability of the lines to their thermal capabilities.
2. It provides secured tie-line connections to the neighboring utilities.
3. It provides greater flexibility in setting new generations.
4. It helps in upgrading the transmission network.
5. It increases the utility of lowest cost generation.
6. It reduces Reactive Power flow thus allowing the lines to carry more active Power.

II.4 UNIFIED POWER FLOW CONTROLLER (UPFC)

The UPFC is made out of two voltage-source converters (VSCs) with semiconductor devices having turn-off capability, sharing a common dc capacitor and connected to a power system through coupling transformers. The basic structure of UPFC is shown in Figure 2.

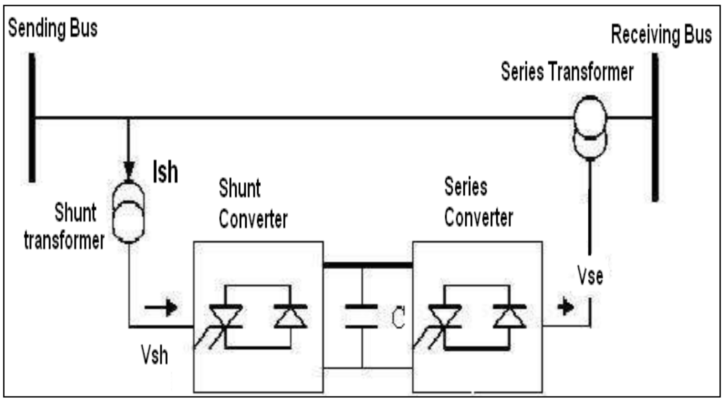

Figure 2: Basic Structure of an UPFC.
Source: Authors, (2024).

The shunt converter is primarily used to provide the real power demand of the series converter at the common dc link terminal from the ac power system. It can also generate or absorb reactive power at its ac terminal, which is independent of the active power transfer to (or from) the dc terminal.

Therefore, with proper control, it can also fulfill the function of an independent advanced static VAR compensator providing reactive power compensation for the transmission line and thus executing indirect voltage regulation at the input terminal of the UPFC [10].

II. DESCRIPTION OF THE COMPUTER TOOLS

II.1 MATLAB-CODE

Our program is called TRANS_STAB_CODE was developed to studies of transient stability of electrical networks [11],[12].

TRANS_STAB_CODE can analyze and studies of transient stability of electrical networks in two cases:

Trans_Stab_Linear_Loads where the loads are linear and Trans_Stab_Harmonic _Loads where there are non-linear loads (SVC, TCR, and UPFC) [13],[14].

TRANS_STAB_CODE is a computer code produced in MATLAB [15], and allows you to run multiple applications and functions (MATLAB files).

TRANS_STAB_CODE structure is based on graphical interfaces [16] performed by MATLAB (GUI).

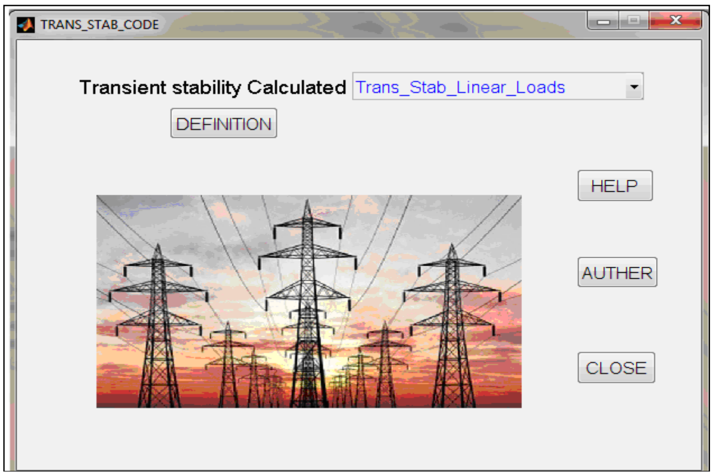

Figure 3: Principal Window of TRANS_STAB_CODE program.
Source: Authors, (2024).

The graphical interface TRANS_STAB_CODE program (Figure 3) contains a title, which signifies the objective of this program "Transient Stability Calculated", and two functions:

Trans_Stab_Linear_Loads, and Trans_Stab_Harmonic Loads with four push buttons:

The first button Definition: the definition of transient stability of power systems.

The second button Help: gives an overview of the program

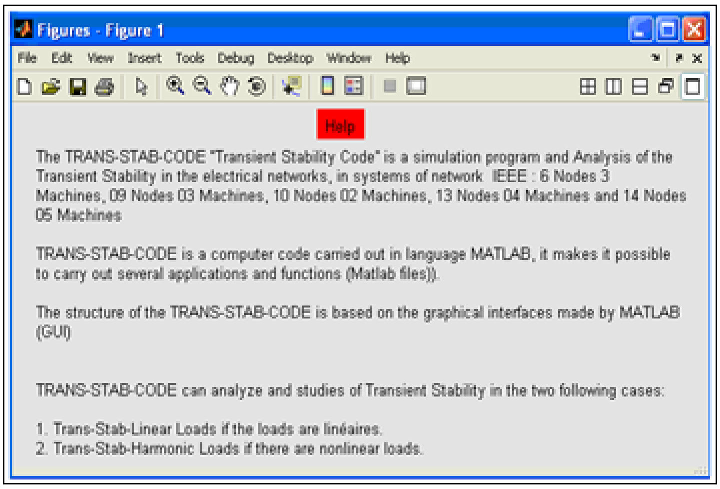

Figure 4: Help window of TRANS_STAB_CODE program.
Source: Authors, (2024).

The third button Réalised by: the author of this program.

The fourth button close: You can quit the programTRANS_STAB_CODE (Figure 4).

If we click on Trans_Stab_Linear_Loads, another window pops up and we can choose to study the electrical network systems (Figure 5).

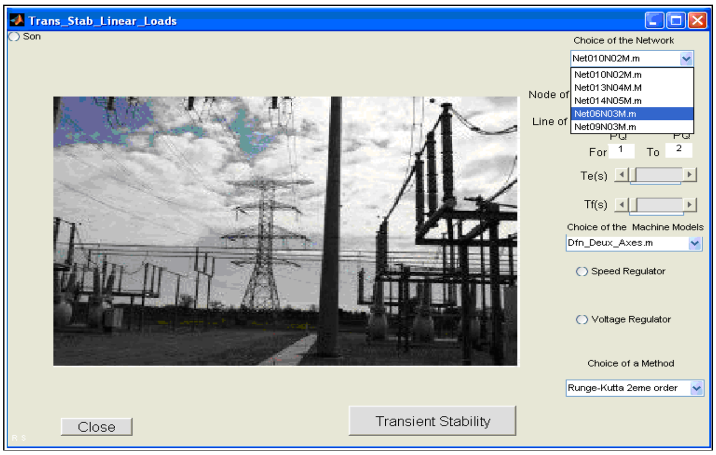

Figure 5: Electrical network system selection for studies of transient stability with linear loads.
Source: Authors, (2024).

If we press the button "Net06N03M, the block diagram of the network appears as follows (Figure 6):

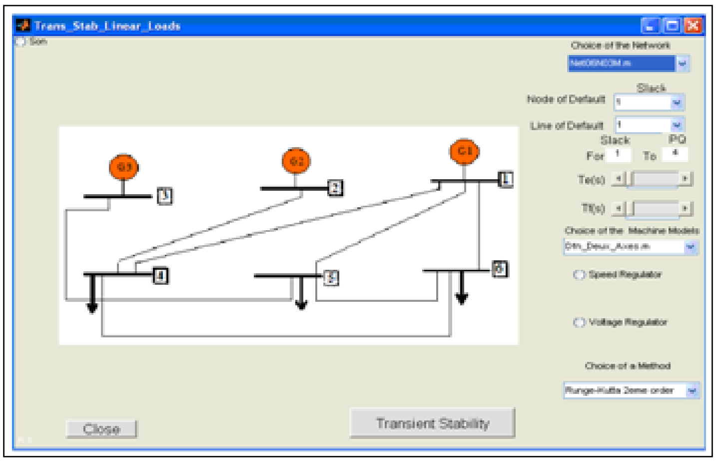

Figure 6: Synoptic diagram of network system 03 machines 6 bus.
Source: Authors, (2024).

If we press the button "Net09N03M (Figure 7), the block diagram of the network appears as follows:

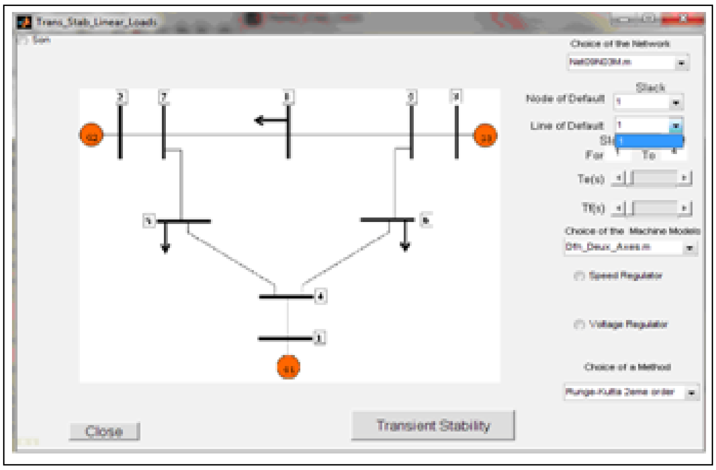

Figure 7: Synoptic diagram of network system 03 machines 09 bus.
Source: Authors, (2024).

If we click on Trans_Stab_Harmonic_Loads, another window pops up and we can choose to study the electrical network systems (Figure 8).

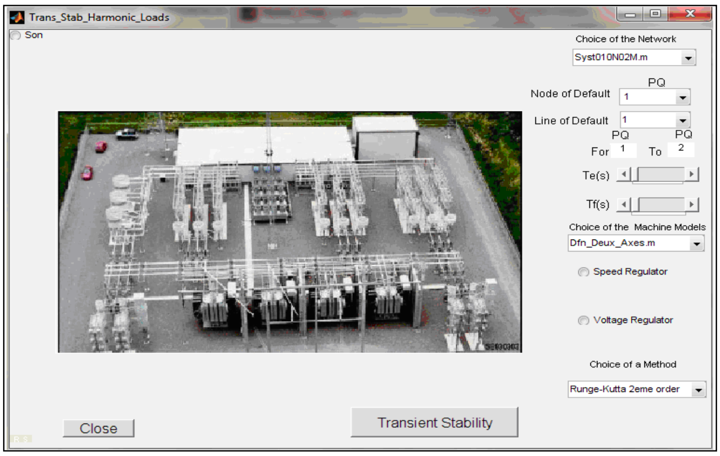

Figure 8: Electrical network system selection for studies of transient stability with non-linear loads.
Source: Authors, (2024).

If we press the button "Syst06N03M (Figure 9), the block diagram of the network appears as follows:

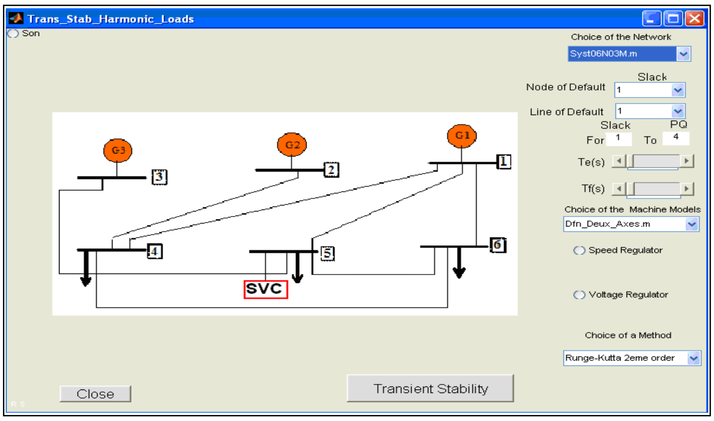

Figure 9: Synoptic diagram of network system 03 machines 6 bus with SVC.
Source: Authors, (2024).

If we press the button "Net09N03M (Figure 10), the block diagram of the network with UPFC appears as follows:

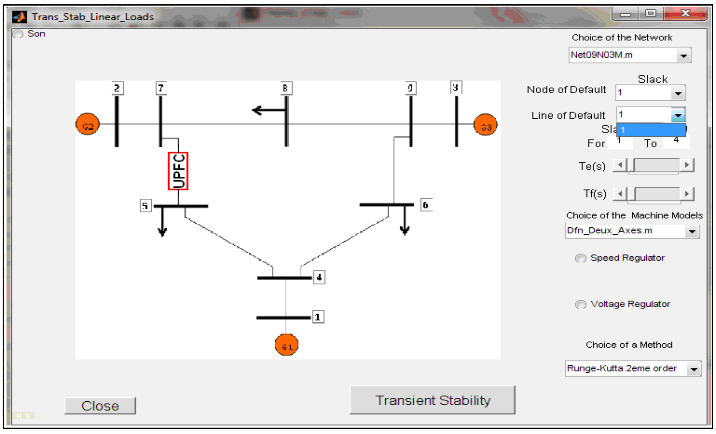

Figure 10: Synoptic diagram of network system 03 machines 09 bus, with UPFC.
Source: Authors, (2024).

II.2 POWER WORLD SIMULATOR

Power World Simulator [17] is an interactive power system simulation package designed to simulate high voltage power system operation on a time frame ranging from several minutes to several days. The software contains a highly effective power flow analysis package capable of efficiently solving systems of up to 100,000 buses.

Simulator runs under Microsoft Windows 95, 98, 2000, NT, or XP.

Key elements of power systems that are modelled include:

1. Load flow (power flow study),
2. Short circuit,
3. Transient stability,
4. Optimal dispatch of generating units (unit commitment),
5. Transmission (optimal power flow).

III. TEST NETWORK

A 9-bus 3-machine system [18], the system includes three generators and three large equivalent loads connected in a meshed transmission network through transmission lines as shown in Figure 11.

The total generation is 519.5MW and total load is 315MW.

The test system contains six lines connecting the bus bars in the system. Each generator is connected to network through step up transformer at 230kV transmission voltage.

We study the transient stability (a three-phase fault on bus 8 at 0.2 sec) in two cases:

1. Where linear loads,
2. Where non-linear loads (UPFC in line (5-7))

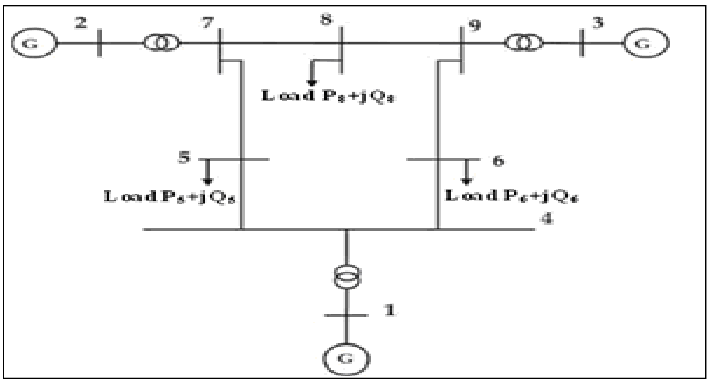

Figure 11: Synoptic scheme of System IEEE, 9 Bus.
Source: Authors, (2024).

Figure 12 shows the Network Test with Power Word Simulator.

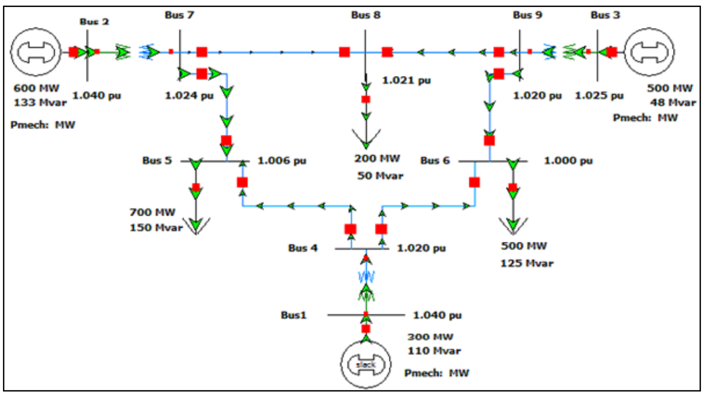

Figure 12: Test network with Power Word Simulator.
Source: Authors, (2024).

IV. RESULTS AND DISCUSSION

IV.1 With Power World Simulator

Without FACTS

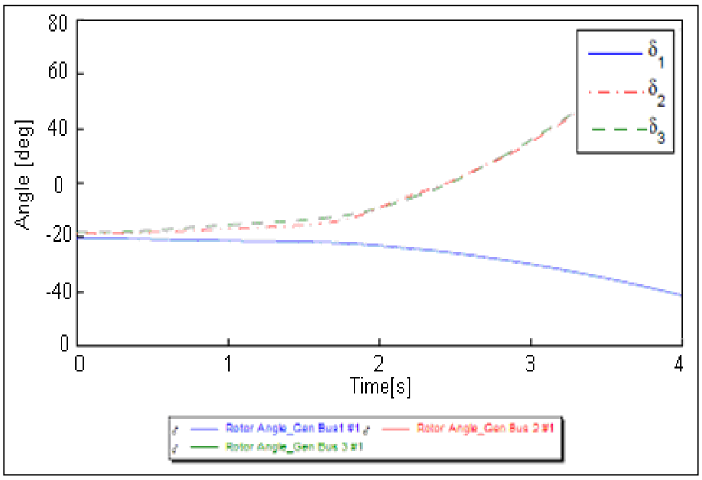

Figure 13: Rotor Angle of generators.
Source: Authors, (2024).

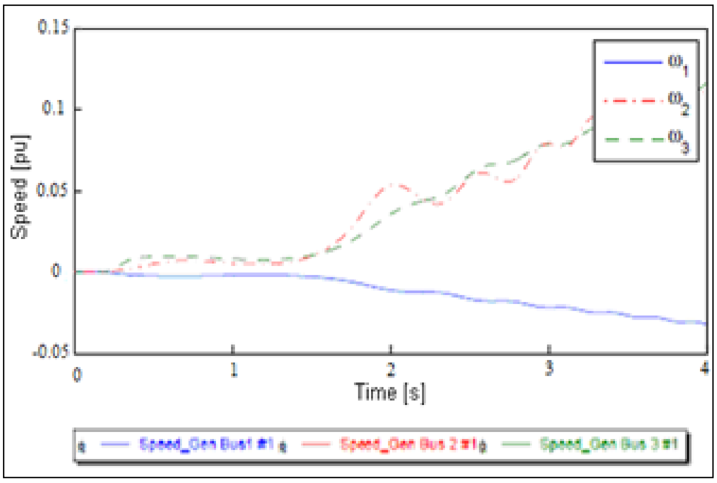

Figure 14: Angular speed of generators.
Source: Authors, (2024).

With FACTS

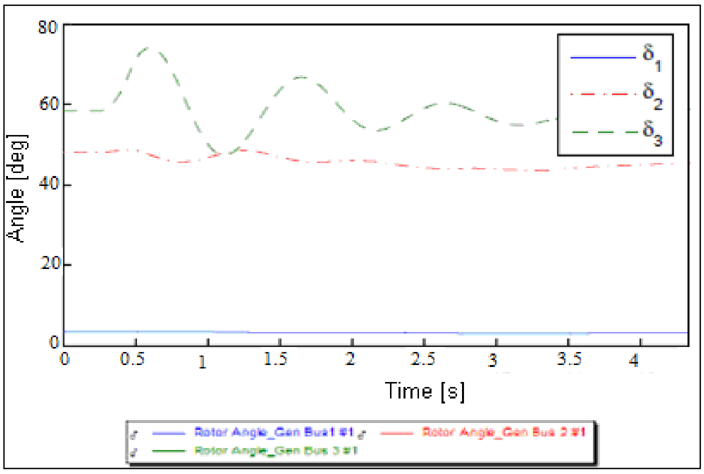

Figure 15: Rotor Angle of generators.
Source: Authors, (2024).

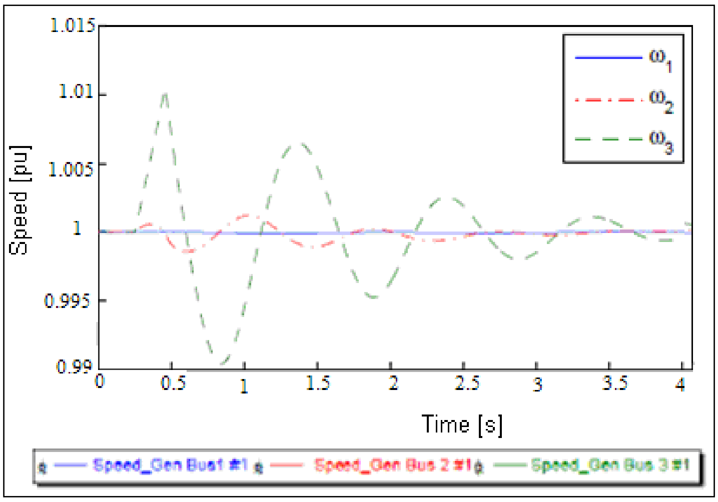

Figure 16: Angular speed of generators.
Source: Authors, (2024).

IV.2. With MATLAB CODE

Without FACTS (UPFC)

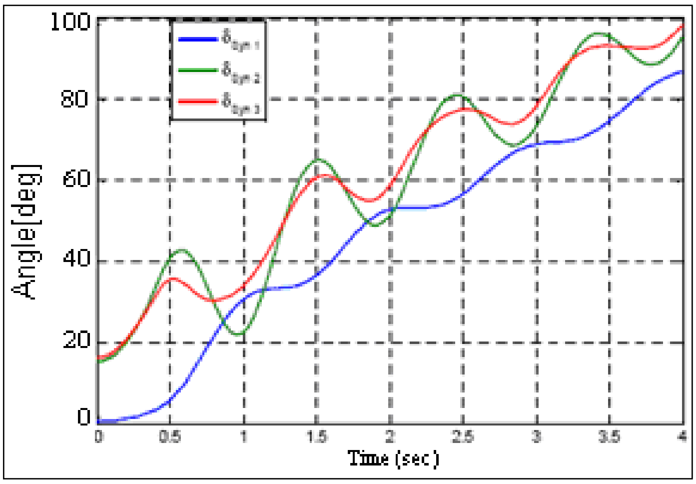

Figure 17: Rotor Angle of generators.
Source: Authors, (2024).

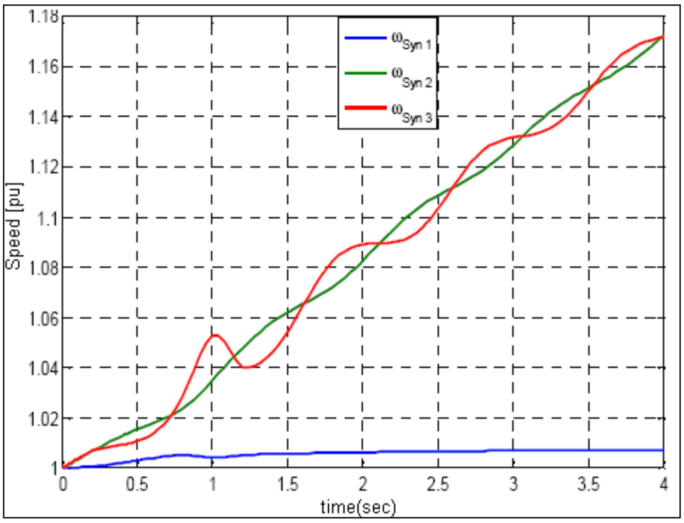

Figure 18: Angular speed of generators.
Source: Authors, (2024).

With FACTS (UPFC)

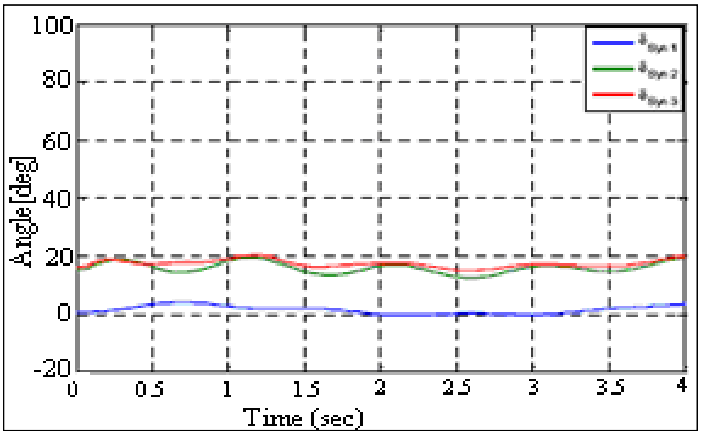

Figure 19: Rotor Angle of generators.
Source: Authors, (2024).

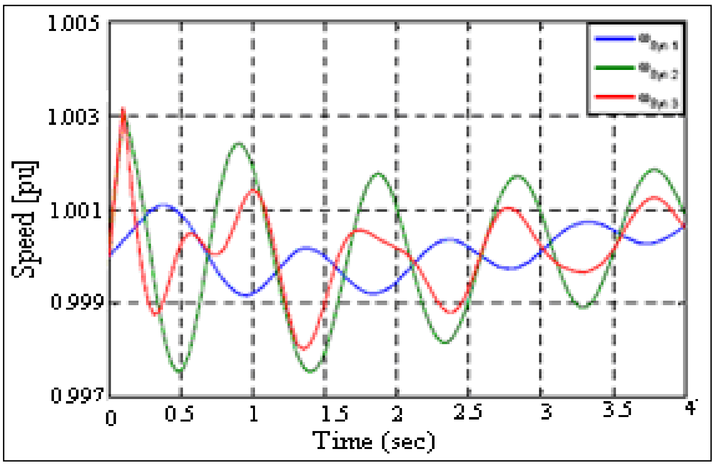

Figure 20: Angular speed of generators.
Source: Authors, (2024).

For our network system IEEE9 bus nodes, and a short circuit fault at the bus 8 (f t = 0.2 sec, c t=0.7sec) in the case where the normal load (not a UPFC), we note that the rotor angles curves of generators (2 3 d,d) of our network system are diverged by using the both software's: Power World Simulator (Figure 13), and MATLAB CODE (Figure 17), we observe also that after the fault the speed generators curves (2 3 w,w) are diverged by using the both software's: Power World Simulator (Figure 14), and MATLAB CODE (Figure 18), and consequently therefore the network system is not stable even after cleared the fault.

For the same system (IEEE 9bus) and for the same fault but if we set an UPFC in the line (5-7) as presented in the block diagram of (Figure 10), the curve of the rotor angles of machines2 and machine3 (2 3 d,d) of our network system are converged by using the both software's: Power World Simulator (Figure 15), and MATLAB CODE (Figure 19), we note also that after the fault the speed generators curves (2 3 w,w)are converged by using the both software's: Power World Simulator (Figure 16), and MATLAB CODE (Figure 20), and consequently therefore the network system is stable after cleared the fault.

IV. CONCLUSION

In this paper, the transient stability of the standard network system IEEE 9bus with and without using UPFC is studied.

FACTS device such as UPFC is employed for enhancing transient stability. The simulation results obtained from the use of different softwares shown in figure15, figure19 illustrates how the transient stability has been improved through the use of the UPFC.

The TRANS_STAB_CODE program is called « Transient Stability CODE ", developed in MATLAB environment has been tested on several nonlinear loads such as: SVC, TCR, UPFC, and gave entire satisfaction for the simulations performed confirming the relevance of this code.

Through these results one can say that the transient stability enhancement is achievable with UPFC, As well as the UPFC is extremely effective by handling disturbances of dynamic system.

The results have virtually the same appearance and overlap completely with those obtained with the Power World Simulator and MATLAB CODE, which shows the reliability of software Power World Simulator and MATLAB CODE in the study of the Transient Stability.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Methodology: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Investigation: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Discussion of results: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Writing – Original Draft: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Writing – Review and Editing: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Resources: Abdelhafid Hellal, Aissa Souli.
Supervision: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.
Approval of the final text: Abdelhafid Hellal, Aissa Souli, Redha Djamel Mohammedi and Mohamed Elbar.

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