USING DIGSILENT IN SMALL SIGNAL STABILITY STUDIES

Eng. **Stativă Andrei** PhD Student, Prof. Eng. **Mihai GAVRILAŞ** PhD,

"Gheorghe Asachi" Technical University of Iasi, Faculty of Electrical Engineering,
Department of Power Systems Engineering, Iaşi, Romania

REZUMAT. În această lucrare este propusă o metodă inovatoare de abordare a problemelor de stabilitate prin utilizarea simultană a două aplicații, şi anume, Matlab (MathWorks) şi DIgSILENT (PowerFactory). Astfel, între cele două aplicații se crează o interfață de comunicare care foloseşte ca strat intermediar de comunicare, fişiere cu extensia .csv. În problema proiectării optimale a stabilizatorului de putere folosind abordari metaeuristice, această aplicație se poate folosi cu succes uşurând semnificativ întreg procesul de determinare a parametrilor PSS. Prin urmare, algoritmul de optimizare este implementat în Matlab, iar sistemul electroenergetic şi controlerele sunt modelate în DIgSILENT. Descrierea întregului proces de comunicare este prezentat în cadrul unei aplicații practice care constă în optimizarea parametrilor PSS în ipoteza folosirii semnalelor de la distanță. Această abordare nu se restrânge doar la problema proiectării PSS, ci poate fi folosită în orice problemă care necesită utilizarea simultană a celor două aplicații.

Cuvinte cheie: DiGSILENT, Matlab, PSS, stabilitatea sistemului electroenergetic.

ABSTRACT. In this paper, a novel method is proposed in approaching power system stability problems by using simultaneously two applications, in terms of Matlab (MathWorks) and DIgSILENT (PowerFactory). Thus, between these applications a communication interface is created that uses as a link layer .cvs files. In the complicated problem of designing power system stabilizer using metaheuristics, this application can be used successfully simplifying considerably the whole searching process. Accordingly, the optimization algorithm is implemented in Matlab and the power system and the controllers are modeled in DIgSILENT. The whole process will be presented throughout an application that involves the optimal tunning of PSS considering using remote signals from key points of the network as inputs. This model doesn't apply only to the problem of determining the PSS parameters, but it can be used in any problem that envolves both platforms working together.

Keywords: DiGSILENT, Matlab, PSS, power system stability.

1. INTRODUCTION

In power system context, the stability problem has become a very important issue in nowadays due to the growth of interconnections between power systems and heavy load conditions. Therefore, the stability problem becomes a key factor in power systems analysis and has lead to intensive studies even from the beginning of development of large overhead transmission lines because of large reactance which eventually leads to loss of synchronism of the involved generators. Over time, the most frequent stability problem encountered in the majority of power systems was the transitory instability. As the dimension and the complexity of the system grow, the stability problems become more e complex and they manifest in different ways [1, 2].

Due to importance of power system stability, significant research and development have been done in optimal design of PSS. Despite the good performance of the classical methods of PSS tuning, such as linear matrix inequalities, pole-shifting or H_2 control, in the past few years, heuristic approaches gain more and more concern. Such techniques are characterized by their simplicity of implementation and they find the optimal solution with less computational effort.

2. AUTOMATIC DATA EXCHANGE MATLAB-DIGSILENT

The choice of using Matlab and DIgSILENT together consists from the difficult task of implementing both the optimization algorithm and the power system analysis in one application. Thus, the ease of programming with Matlab language using matrix calculus and the ability to identify and correct programming errors is combined with one of the most realistic modeling of power systems, DIgSILENT.

However, because of the modal analysis module, DIgSILENT has the advantage of easily determining the eigenvalues of the system necessary for the study and analysis of power system stability. It should be noted that the simultaneous use of the two platforms lies in the need to evaluate each particle modeled by the optimization algorithm in Matlab as a multi-objective function which is based on the eigenvalues of the system obtained using DIgSILENT platform.

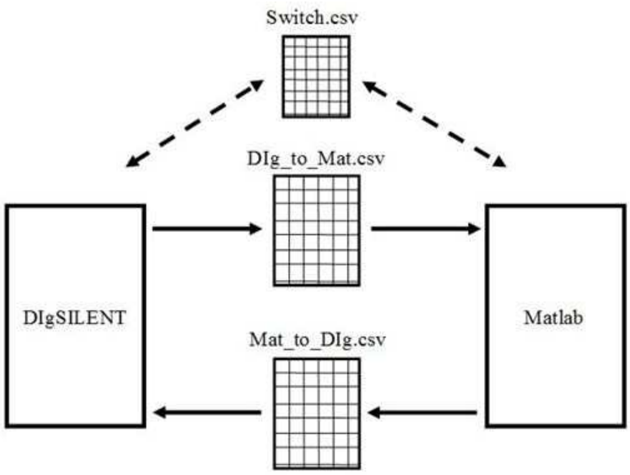

Fig. 1. Automatic data exchange between Matlab and DIgSILENT.

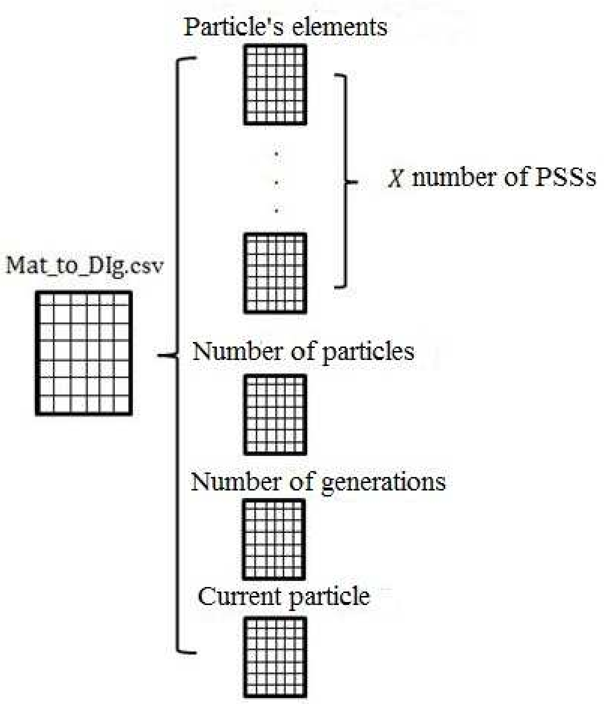

Fig. 2. Mat_to_Dig.csv structure

Communication procedure between the two platforms is illustrated in Fig. 1. Thus, communication is achieved through some .csv files according to a communication protocol:

-*Mat_to_DIg.csv* - in which the particles are written / read;

-*DIg_to_Mat.csv* - in which the eigenvalues of the system for each particle are written / read.

Note that *Mat_to_DIg.csv* file is a set of .csv files in which are written the elements of the particle specific to each PSS, informations about the number of particles, the number of generation units considered in the optimization process and the current particle. All these information are needed by the DIgSILENT script to achieve the most efficient communication protocol.

In Fig.2, is the file structure *Mat_to_DIg.csv*, in which the number of files that contain the elements of the particles specific to each PSS varies from case to case, depending on the number of PSSs considered in the optimization process. Working order of the two platforms is dictated by *Switch.csv* file that can be 0 or 1.

Although, such a data exchange involves a thorough knowledge of Matlab platform and the programming language specific to DIgSILENT (DIgSILENT Programming Language - DPL), this was done only using read / write commands throughout .csv files.

The commands of reading and writting into .csv file in Matlab are done using the following lines code:

-for reading:

load Eigen.csv - this command loads into the Matlab workspace the system eigenvalues written by DIgSILENT in *Eigen.csv* file;

-for writing:

csvwrite ('Particle.csv' particle) - This command writes into the file *Particle.csv*, the particle resulted from the specific operations of the optimization algorithm modeled in Matlab.

Sequences of reading and writing into a .csv file in DIgSILENT are performed using the following lines of code (exemple code):

-for reading:

```
fopen('C:\Users\Andrei\MyDocuments\Matlab\10 Gen 39 Bus v.10\ nr_particle.csv','r',7);
fscanf(7,'%f\t', nr_particle);
fclose(7);
```

-for writing:

```
fopen('C:\Users\Andrei\MyDocuments\Matlab\10 Gen 39 Bus v.10\ Switch.csv','w',8);
x=0;
fprintf(8,'%f\t', x);
fclose(8);
```

To assign a degree of performance for each particle of the population, it must pass throughout the following loop:

- the particle and information about the number of particles and the number of generation units are written by Matlab into *Mat_to_DIg.csv* file;
- DIgSILENT reads *Mat_to_DIg.csv* and determine the eigenvalues of the system;
- DIgSILENT writes the eigenvalues of the system corresponding to that particle into *DIg_to_Mat.csv* file;
- Matlab reads the eigenvalues from *DIg_to_Mat.csv* file and use them to calculate the objective function corresponding to that particle.

3. STUDY CASE

In this study case, the objective is to optimize the PSS parameters in a multimachine power system utilizing remote signals from key points of the network. The optimization technique employs the use of particle swarm optimization algorithm in order to optimally determine the PSS parameters. As it was mentioned at the beginning, the optimization process is made using Matlab and DIgSILENT working together in a genuine automatic data exchange procedure which has been presented in chapter 2.

The power system under study is part of the Romanian power system and comprises 12 generators and 29 nodes. The links of the subsystem with the rest of the Romanian power system are modeled throughout equivalent loads and generators using equivalancing techniques. The subsistem under study is represented in Fig. 3.

In order to optimaly design the wide area PSS and to compare it's performances in damping the power oscillations, the following steps must be take into consideration:

- applying modal analysis, the eigenvalues of the system and participation factors of generators to existing modes of oscillation are determined;
- identifying the mode of oscillation on which is intended to act. This mode of oscillation is characterized by a relatively low damping factor;
- on the basis of participation factors, the PSS is placed at the generator which contributs the most to the oscillation mode that is intended to be damped out.
- the optimization procedure that employs the above mentioned techique is applied first for the classical PSS structure, and then for the case of using remote signal to the input of the PSS. Must be mentioned that the wide area PSS structure used in this studie is described in detail in [3].

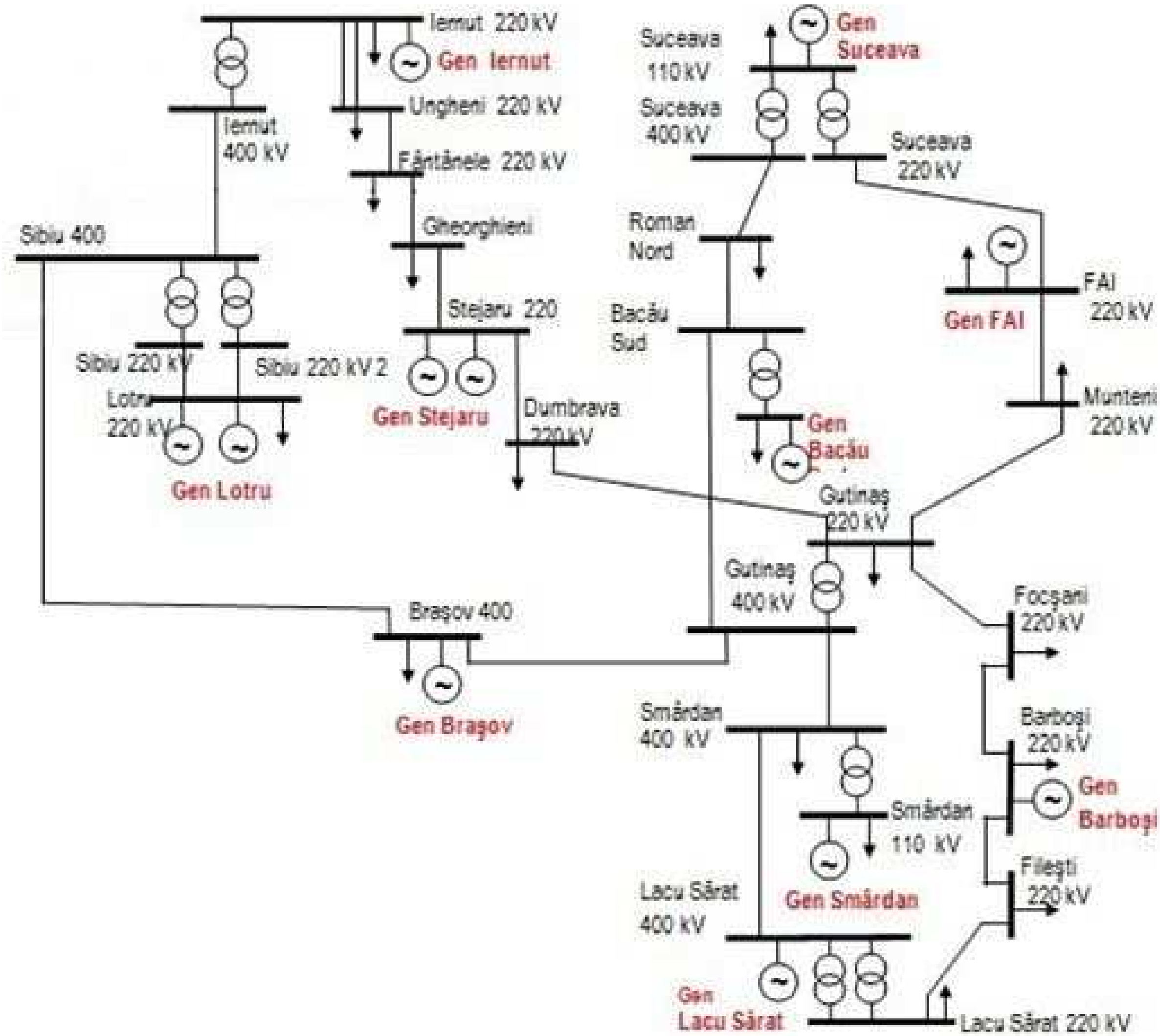

Fig. 3. The power system under study

Table 1

System eigenvalues without PSS

Name	Mode of oscillation / damping factor
m1	-1.821 ± j·11.746/ 0.153
m2	-1.791 ± j·11.187/ 0.158
m3	-0.942 ± j·4.732/ 0.195
m4	-2.29 ± j·11.298/ 0.199
m5	-1.512 ± j·6.336/ 0.232
m6	-1.281 ± j·4.655/ 0.265
m7	-2.011 ± j·6.634/ 0.290
m8	-3.478 ± j·16.458/ 0.206
m9	-3.135 ± j·10.171/ 0.294
m10	-5.066 ± j·13.252 / 0.357
m11	-3.611 ± j·8.38/ 0.395

- analyze the results obtained in both cases and draw conclusions.

Taking all these in consideration, first are determined the system eigenvalues and the participation factors of each generator to every mode of oscillation. These parameters are given in Table 1 and Table 2. Must be mentioned that further are represented only the participation factor for the least most undamped oscillation modes.

Further, we consider to improve in this study the mode *m3*, which has a low damping factor, as well as the lowest frequency from all the modes. According to the Table 2, the generator which participate the most to that mode is the equivalent generator from bus Lacu Sarat. Thus , the PSS with the clasical structure, as well as the PSS which uses remote signals are instaled at the generator from bus Lacu Sarat.

In the case of using remote signals for the wide area PSS, according to Table 2, it can be seen that the generator from bus Brasov participate as well to this mode, therefore, the frequency signal for the wide area PSS from Lacu Sarat is measured and transmited from bus Brasov. The other signal considered is the active power from a tie line between generator Lacu Sarat and Brasov.

After these considerations, first is applied the optimization procces for the classical architecture of PSS, and then for the wide-area PSS using the approach explaned in chapter 2.

After the optimization process of the both structure under study, the system eigenvalues are presented as follows (Table 3):

- the use of remote signals such au frequency from bus Brasov and the tie line power between the involved generators, used by the wide area PSS from Lacu Sarat, have significantly improved the damping of mode *m3*.

Table 2

Participation factor for the system without PSS

Generator	Modes of oscillation				
	m1	***m2***	***m3***	***m4***	***m5***
Lacu Sarat	0.021	0	**0.842**	0.021	0.087
Iernut	0	0.181	0.005	0	0.052
Barboşi	**1**	0.001	0.017	0.027	0
Smârdan	0.033	0.001	0.009	**1**	0.001
Lotru G_1	0	0,935	0.004	0	0.001
Lotru G_2	0	**1**	0.004	0	0.001
Braşov	0	0.036	0.427	0	0.105
Bacău Sud	0	0	0.004	0	0.011
FAI	0.001	0	0.011	0	0.468
Suceava	0	0	0.002	0	0.040
Stejaru G_5	0	0.006	0	0	0.867
Stejaru G_6	0	0.003	0	0	**1**

Table 3

System eigenvalues in the case of classical and wide area PSS

	Classic PSS at generator *Lacu Sărat*	Wide area PSS at generator *Lacu Sărat*
m1	-1,769 ± j·11,832/ 0,147	-1,77 ± j·11,730/ 0,149
m2	-1,792 ± j·11,187/ 0,158	-1,84 ± j·11,196/ 0,162
m3	**-1,278 ± j·4,607/ 0,267**	**-1,453 ± j·3,979/ 0,343**
m4	-2,25 ± j·11,479/ 0,192	-2,213 ± j·11,34/ 0,191
m5	-2,04 ± j·6,60/ 0,295	-1,442 ± j·6,401/ 0,158

- the use of such signals have lead to improvement of other modes such as, *m1* and *m2*.
- also, mode *m5* was affected, and it has a lower damping ratio then in the case of classical PSS. For this, actions must be taken in order to improve this mode.

To study the effects of both structures of PSS upon the system variables, time domain simulations are involved.

First, an event is triggered to excite the mode *m3*, as follows:

- at simulation time t=1 s, we consider an increase in the mechanical torque of generator Brasov by 1%, and a decrese in the mechanical torque of generator Lacu Sarat by 1%.

From Fig. 4 it can be observed that using remote signals to the PSS from the generator Lacu Sarat, the mode *m3* is damped out much faster than the other two cases considered. The profile of the active power from line Smardan – Lacu Sarat is well damped and improved in terms of settling time and overshot.

The same conclusions can be drown in the case of rotor speed from generator Lacu Sarat. The influence of the remote signals used as input to PSS Lacu Sarat make the oscillation to be damped out much faster then in the case of CPSS (Fig. 5).

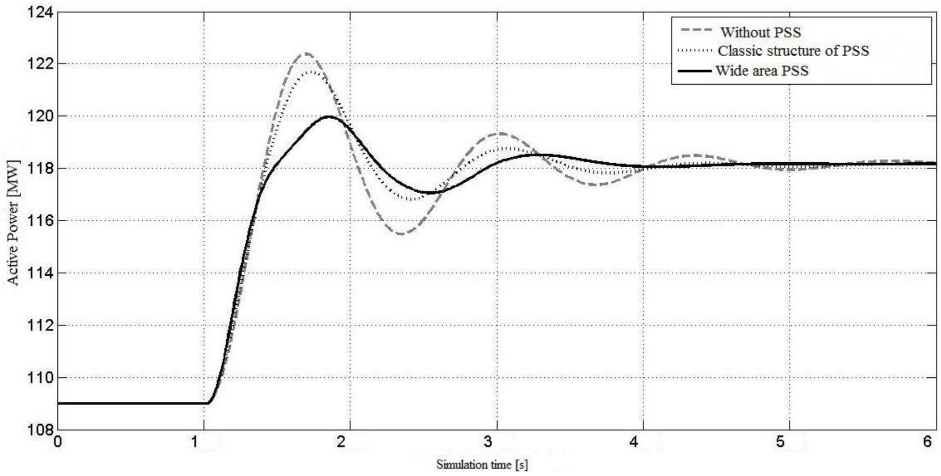

Fig. 4. Active power from line Smardan - Lacu Sarat in the case of the system without PSS, The case of using CPSS to generator Lacu Sarat, the case of using wide area PSS at generator Lacu Sarat

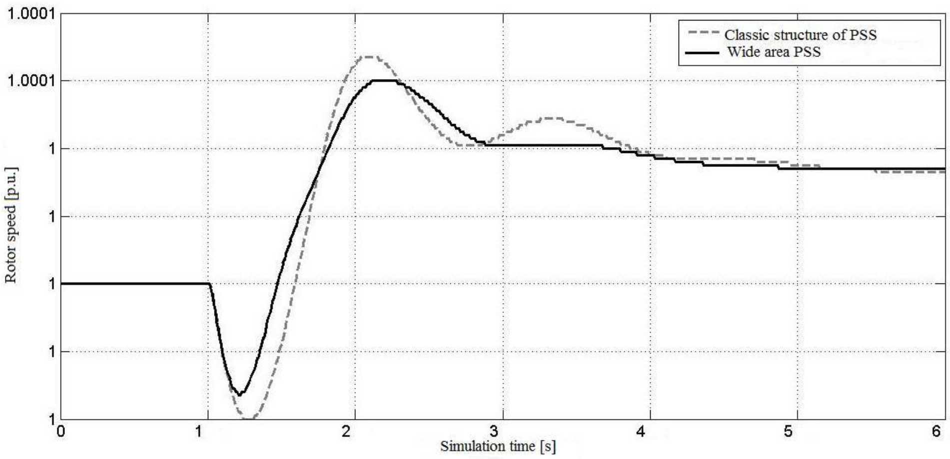

Fig. 5. The rotor speed of the generator Lacu Sarat in the case of using classical structure of PSS and in the case of using wide area PSS

6. CONCLUSION

In this paper the problem of optimal tuning of PSS using remote signals was resolved throughout an original method of using together Matlab and DIgSILENT in an automatic data exchange procedure.

Also, the analisys was performed for a part of the Romanian power system which comprises 12 generators. According to the results from time domain simulations and modal analisys it is obvious that the use of remote signals from key locations of the network supplementary enhance the power system stability.

BIBLIOGRAPHY

[1] P. Kundur, *Power system stability and control*, McGraw-Hill Inc., ISBN 0-07-035958-x, 1994

[2] Gavrilaş M., *Stabilitatea şi controlul sistemelor electroenergetice*, Vol. 1, Editura Politehnium, Iaşi, România, 2011A. Stativa and M. Gavrilas, *A metaheuristic approach for power system stability enhancement*, World Energy Systems Towards Sustainable and Integrated Energy Systems, ISSN: 1224-7928, pp. 483-488, July 2012.

[3] Stativă A., Gavrilaş M., *Optimal Design of Multi-Input Speed Based Power System Stabilizer using Genetic Algorithm*, ACTA ELECTROTEHNICA Proceedings of the 5th International Conference on Modern Power Systems (MPS), Vol. 54, Issue 5, ISSN: 1841-3323, pp. 464 – 469, 2013
[4] O. Abedina, M. S. Naderi, A. Jalili and B. Khamenehpour, "Optimal tuning of multi-machine power system stabilizer parameters using genetic-algorithm," 2010 International Conference on Power System Technology (POWERCON), ISBN: 978-1-4244-5938-4, pp. 1-6, 24-28 October 2010.
[5] ***, DiGSILENT Technical Documentation, DIgSILENT GmbH, Germany, 2011

About the authors

Eng. **Andrei STATIVE,** PhD
Gheorghe Asachi Technical University of Iaşi
email:stativa_andrei@yahoo.com

He graduated the "Stefan Procopiu" High School in Vaslui, in 2004. He received his BSc in Power Engineering Specialization in 2009, from the Technical University "Gheorghe Asachi" of Iaşi, the Faculty of Power Engineering. Since October 2009, is following MSc studies in Energy Management Systems. Competence areas: power system stability, artificial intelligence, applications in power systems. He is candidate for the PhD degree in the Power Systems field.

Prof. Eng. **Mihai GAVRILAŞ**, PhD.
Technical University" Gheorghe Asachi", Electrical Engineering, Energetics and Applied Informatics Faculty, Department of Power Systems Engineering, Iasi, Romania.
email:mgavril@ee.tuiasi.ro

He was born in Iasi, Romania. He received his M.S. and Ph.D. degrees from the Technical University of Iasi in 1984 and 1994, respectively. He has worked in the power utility industry for four years. Since 1988 he has joined the Technical University of Iasi. At present he is Professor with the Power Systems Department. His research interests are in power system analysis, particularly issues involving artificial intelligence application in power.