A NOVEL APPROACH TO THE ASSESSMENT OF POWER SYSTEM DAMPING

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Abstract – This work describes a new approach to on-line assessment of power system damping, which combines Prony analysis with the SIngle Machine Equivalent (SIME) method. SIME is a hybrid direct–time-domain transient stability method, which reconciles accuracy and flexibility skills of time-domain programs with interesting additional advantages of direct approaches. In particular, it identifies unambiguously the system relevant machines, and acts as a reduction technique, by compressing the information about the multi-machine system dynamics into that provided by an appropriate one-machine infinite bus system. The use of SIME helps improving drastically the performances of Prony analysis while, at the same time, shedding more light on the oscillatory phenomena. The approach is illustrated by means of transient stability simulations performed on two different systems and yielding two different modes of oscillations: a plant mode on the EPRI 627-machine test system, and an inter-area mode on the EPRI 88-machine test system.

Keywords: Damping assessment, Prony analysis, modal identification, transient stability, SIME method.

1 INTRODUCTION

The on-line assessment of power system damping is becoming a concern in the operation of power systems, given the increasing complexity of their dynamics resulting from the interconnection of power utilities and their operation near to their limits, especially in the context of electric industries restructuring. Indeed, in many cases, insufficient damping may become a limiting factor, as, for example, in the calculation of available transfer capabilities in critical transmission corridors.

Damping assessment can be considered as part of transient security assessment (TSA). TSA, in general, aims at evaluating the stability and quality of the transient processes between pre-contingency and post-contingency states. More specifically, TSA aims at exploring whether the system is able to withstand the occurrence of a contingency and, if the system is dynamically secure, to ascertain that the transients caused by such a contingency are well damped, of small amplitude and with little impact on the quality of service [1, 2].

Recently, attempts have been made to design methods able to assess on-line power system damping. One of these approaches uses the peak values of some generator power angle curves to find an exponential function in which the decreasing rate of change represents the damping of the system. Another approach is the Prony analysis, a methodology that extends Fourier analysis. Single- and multi-channel Prony algorithms aim at finding the damping of the system considering one or several generator angle curves at a time [3, 4, 5]. A difficulty of both approaches is that the accuracy of the results depends on the choice of the generator curves [5, 6]. Since power systems are usually composed of hundreds of generators this choice may become problematic.

The approach proposed in this work aims at evading the above difficulty, by combining a Prony algorithm with the Single Machine Equivalent (SIME) transient stability method, which “synthesizes” the main characteristics of the multi-machine system dynamics into those of a One-Machine Infinite Bus (OMIB) system properly defined [7, 8].

In short, the SIME method calls upon a time-domain program to get the multi-machine information required by the equal-area criterion, which is used to assess the OMIB dynamics. The thrust of SIME is recalled below, in Section 3. Let us only mention at once two noteworthy properties. (i) By refreshing the OMIB parameters at each step of the time-domain (T-D) simulation, SIME achieves an assessment as accurate as the one of the T-D program. (ii) SIME complements this assessment with multiform information typical of direct methods.

So far, the SIME method has been applied to on-line transient stability assessment and control [8, 9]. More recently, it was used as a component of a modal analysis tool, able to complement the panoply of traditional methods of small-signal analysis [10]. The work presented in this paper is at the crossroads of the above two approaches: it extends the SIME method to characterize the damping and nature of the power system mode oscillations excited by a system contingency by precisely determining the dominant modes of oscillation and the system machines that have a greater influence on the ensuing oscillatory phenomena. This approach simplifies the application of existing modal identification methods, and complements them with additional possibilities. The method is particularly attractive for the on-line study of inter-area mode phenomena and may be extended to aid in the design of system controllers and for assessment of dynamic security.

However, various extensions and by-products that can be expected from further developments are presented and discussed.

2 PRONY ANALYSIS: A DIGEST

2.1 Foundations

Prony's method fits a series of damped sinusoids $\hat{y}(t)$, to an observed function y(t) [6, 11]:

$$\hat{y}(t)=\sum_{i=1}^{q} A_i e^{\alpha_i t}\cos(2\pi f_i t+\phi_i)=\sum_{i=1}^{N} B_i e^{\lambda_i t} \qquad (1)$$

where, for each one of the q components of the estimated signal, A is the amplitude, B the signal residue, α the damping, $\lambda=\alpha\pm j\omega$ the associated eigenvalue, f the frequency and ϕ the phase angle. The damping ratio defined by:

$$\zeta=\frac{-\alpha}{\sqrt{\alpha^2+\omega^2}} \qquad (2)$$

is used for measuring the rate of decay of the amplitude of the oscillation.

The approximating function has a structure very similar to that of Fourier series, but the basis functions are more general. They can be damped and their frequencies need not be related harmonically or to the duration of the signal. Further, sample points of the signal should be equally spaced.

The reconstructed signal does not usually fit the observed one exactly. An appropriate measure of the quality of this fit is the signal to noise ratio (SNR) defined as

$$SNR = 20\log\left\| y(k)-\hat{y}(k)\right\| / \left\| y(k)\right\| \qquad (3)$$

where $\|\bullet\|$ denotes the root-mean-square norm and the SNR is in decibels (dB).

2.2 Practical considerations

When Prony analysis is applied to power system signals, they have to be close to linear, if a direct comparison with modal analysis is required. In a system record (or a signal obtained from transient stability simulation, like in the present work) this if often the case at the end of the data window, rather than at its inception, where the amplitude of the transients may be large [6].

In this approach, additional modes can be encountered, needed to fit signal offsets and noise[1] [11]. A sampling technique, known as "sliding window solutions" is useful for detecting changing signal characteristics (due to non-linearities or hidden inputs) and for distinguishing essential modes from those that are mere accessories to the fitting process [12]. For more details, please refer to [13].

3 SIME AT A GLANCE

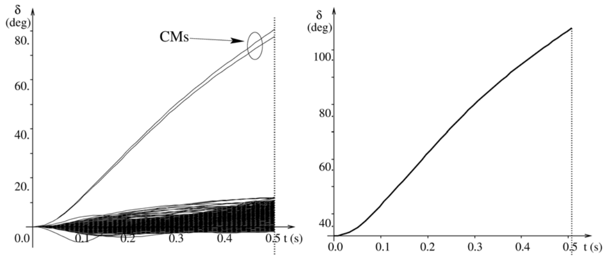
3.1 Foundations

Basically, SIME transforms the multi-machine power system parameters provided by a time-domain program into those of a one-machine infinite bus (OMIB) system that it refreshes at each time step of the program. Further, at each time step, SIME explores the stability of the OMIB using the Equal Area Criterion (EAC), and stops the procedure as soon as the (in)stability conditions of the EAC are reached [7, 8].

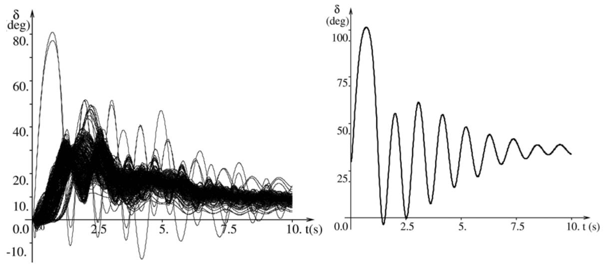
More precisely, after a contingency inception and its clearance, SIME, coupled with a time-domain program, performs on-line the following tasks:

(i) identify the critical and non-critical machines and aggregate them into two groups;
(ii) replace these groups by successively a two-machine, then an OMIB equivalent system;
(iii) assess transient stability of this OMIB, using the EAC.

These various steps are briefly described below and illustrated in Figs 1a and 1b drawn for the 627-machine system simulated in Section 5. Note that this method uses the output data of a transient stability program and therefore allows for the detailed representation of the power system. For more details about SIME see [7 to 9].



Unstable case. Critical machines power = 2204 MW
(a) Multi-machine swing curves (b) OMIB swing curve



Stable case. Critical machines power = 2128 MW
(c) Multi-machine swing curves (d) OMIB swing curve

Figure 1: Unstable and Stable cases simulated on the EPRI 627-machine test system (Clearing time of both cases: 67 ms).

3.2 Identification of the Critical Machines and OMIB

By definition, the critical machines (CMs) are those that cause the loss of synchronism of a system, when subject to a disturbance. To identify them, SIME drives a time domain transient stability program, and, as soon as the system enters the post-fault phase, it starts considering a few candidate decomposition patterns, by:

(i) sorting the machines according to their rotor angles ;
(ii) identifying the very first largest rotor angular deviations ("distances") between adjacent machines ;

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[1] Signal offsets generally produce modes near 0 Hz or near the Nyquist frequency, 1/(2Δt), where Δt is the signal sampling rate [11].

(iii) considering as candidate CMs those which are above each one of the (say, 5) largest distances.

The procedure is carried out until a candidate group of CMs and corresponding OMIB reaches the unstable conditions (7) defined below. This candidate is then declared to be the critical OMIB of concern or simply the OMIB.

3.3 OMIB parameters, (in)stability conditions and margins

The OMIB parameters δ, ω, M, P_m, P_e, are computed from corresponding individual machines parameters, using the partial center of angle aggregation [see in Fig. 1b the OMIB trajectory plotted from the multimachine trajectories (swing curves) of Fig. 1a]. On the other hand, the EAC states that the stability margin is the excess of the decelerating area over the accelerating area.).[2] Accordingly, the following analytical expressions for unstable and stable margins are derived:

$$\eta_u = -\frac{1}{2} M \omega_u^2 \qquad (4)$$

$$\eta_{st} = \int_{\delta_r}^{\delta_u} |P_a| \, d\delta. \qquad (5)$$

In these expressions,

- the accelerating power is the difference

$$P_a = P_m - P_e \qquad (6)$$

- subscript “u” (for unstable) refers to the angle δ_u, speed ω_u, and ***“time to instability”*** t_u, where the ***OMIB instability conditions*** are met:

$$P_a = 0; \dot{P}_a > 0 \qquad (7)$$

- subscript “r” (for return) refers to the angle δ_r and time t_r where δ starts decreasing and ω vanishes (***OMIB stability conditions***):

$$\omega = 0; P_a < 0 \qquad (8)$$

Remark

Strictly speaking, SIME cannot assess positive margins (margins computed on a stable simulation) since, by construction, OMIB and CMs are determined on unstable scenarios only. Note, however, that, by continuation, the OMIB and CMs determined on an unstable simulation can still be used on a stable simulation, provided that these two simulations are “close enough” to each other; “close enough” are meant to be simulations performed with contingency clearing times very close to the critical clearing time, or with power levels very close to the power limit.

For the sake of correctness, the CMs identified on an unstable simulation will be re-named “relevant machines” (RMs) whenever referring to a stable simulation “close enough” to this unstable simulation.

3.4 Search of stability limits

The above-defined stability margins have the remarkable property to vary almost linearly with the stability conditions (contingency clearing time for given system’s operating conditions (power level), or operating conditions for given contingency clearing time [8]). This property simplifies considerably the search of stability limits, i.e., of the conditions, which cancel out the stability margin: critical clearing time (CCT), or power limit (PL). Indeed, thanks to the linear behavior of the margin, the contingency CCT or PL may be calculated by successive margins linear extra- (inter-) polations.

Generally, the accurate computation of a stability limit requires 2 to 4 margin values of which one must be positive (evaluated on a stable simulation), whenever multi-swing phenomena are sought. Indeed, to assess multi-swing stability limits, it is necessary to find a simulation that is stable on the entire integration period, rather than up to the return time t_r, defined in §3.3.

4 PROPOSED APPROACH

4.1 Essentials of damping assessment procedure

Damping assessment relies on modal identification. This involves, in general, the determination of system dynamic behavior from measurements or transient stability simulations using non-linear models. The proposed approach combines Prony analysis and SIME transient stability method, with the twofold objective:

(i) to compress the dynamic behavior of the multimachine swing curves into that of the OMIB ;

(ii) to identify the critical machines (CMs) and the dominant power system modes of oscillation excited by a given contingency. The “relevance” of a CM is assessed in terms of its angle (absolute or relative to a reference ; e.g., to the angle of the most advanced non-critical machine), evaluated at t_u, the above-defined time to instability.

Accurate knowledge of these characteristics provides insight into the mechanism of inter-area mode separation phenomena and may be useful in the design of system controllers and dynamic security assessment. It should be emphasized that, by construction, SIME determines the OMIB and CMs on unstable simulations only, whereas Prony analysis determines damping characteristics on a stable simulation. The following observations allow reconciling this seemingly incompatibility, and

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[2] Note that the above criterion for identifying the CMs and corresponding OMIB obeys the necessary and sufficient conditions derived from EAC. This unambiguous identification of the CMs is a major advantage of hybrid one-machine equivalent methods over hybrid multi-machine methods. Besides, the criterion is free from any pragmatic consideration, unlike time domain (T-D) methods which call upon pragmatic criteria to detect instability. Finally, the procedure is computationally very unexpensive: it requires computation of candidate OMIB parameters (which is straightforward) and, in addition, it allows saving number and duration of T-D simulations (the OMIB-EAC instability conditions are generally reached much earlier than the instability conditions used in multi-machine T-D simulations).

further, uncovering interesting possibilities of the method.

(a) According to the remark of §3.3, the OMIB and CMs determined on an unstable simulation will be, by continuation, still usable on a stable simulation, provided that these two simulations are "close enough" to each other, i.e., simulations performed under conditions just below and just above the stability limit.
(b) Under the above conditions, the Prony analysis performed on the OMIB swing curve calculated on the stable simulation will provide both, the damping and frequency of the critical mode.
(c) Knowledge of the CMs (which on the stable simulation become the "relevant machines (RMs)) along with their relevance allows Prony analysis to assess the impact (sensitivity) of (the, or of some selected) RMs on the overall power system damping.

The foregoing considerations yield the following practical procedure.

4.2 Practical damping assessment procedure

For a given contingency, the procedure may be summarized in the following four steps.

(i) Run SIME to compute the critical clearing time (CCT) or the power limit (PL) as appropriate. According to §3.4, this computation requires 2 or 3 unstable simulations and 1 stable simulation.
(ii) On the least unstable simulation used above, identify, at t_u, the CMs and corresponding OMIB.
(iii) At this time t_u, determine the relevance of each one of the CMs.
(iv) On the stable simulation used in (i), perform Prony analysis to assess damping of the OMIB swing curve.

5 SAMPLE OF SIMULATION RESULTS

5.1 General description

The simulations reported below have been performed on two real-world power systems: the EPRI test system A, comprising 4112 buses, 6091 lines and 627 machines, and the EPRI test system C comprising 434 buses, 2357 lines and 88 machines [14]. Detailed power system models are used in all presented simulations.

The contingencies considered are 3-phase short-circuits applied at a bus and cleared by tripping one or several lines. They yielded oscillatory plant-modes (test system A) and inter-area modes (test system C). The SIME method was coupled with the EPRI ETMSP time-domain program [15].

The spectrum function of the EPRI Output Analysis Program (OAP) was used for performing the Prony analysis. This analysis relies on stable simulations obtained according to the procedure of §4.2, performed over a 10 second integration period.

5.2 Objectives

The simulations have been pursuing the following many-fold objectives:

- to validate the modal identification procedure on realistic situations
- to illustrate the application of the procedure on the two types of oscillations
- to gain familiarity with the proposed technique
- to get more insight into similarities and specifics of the oscillatory phenomena
- to get suggestions for further exploration and developments.

5.3 Results with plant mode oscillations

The proposed method was applied to the 627-machine system subject to a contingency, which creates plant mode oscillations. The resulting swing curves of the considered post-fault stable case are displayed in Fig. 1c.

More specifically, the Prony analysis was applied to the OMIB swing curve of Fig. 1d, which, as above-mentioned, has been defined on the unstable simulation displayed in Figs 1a and 1b.

Note that the critical machines, labeled #2075 and 2074 and defined on this unstable simulation, are easily identified as the relevant machines on the stable simulation, too. Hence, in this particular case, the choice of the generators to be analyzed is quite obvious; the SIME method and resulting OMIB are therefore used here more to illustrate and validate the proposed approach than to improve the Prony technique.

Prony analysis computations have been applied to the OMIB swing curve for increasing number of sample points and decreasing sampling rate, until reaching a satisfactory signal to noise ratio (SNR of about 40 dB [13]). Three such sets of simulations have thus been performed for various sliding windows. Table 1 summarizes the resulting damping features obtained with each one of these sets, found for the best window.

Table 1: Comparison of the results of Prony analysis of the OMIB swing curve using different data points and sampling rates (SRs) for the EPRI 627-machine system (Figs 1d and 2).

Period (s)	SR (ms)	α (rad/s)	ω (rad/s)	f (Hz)	ζ (%)	SNR (dB)
Nr of data points: approx. 125						
4.0– 9.0	40	-0.423	5.88	0.936	7.16	34.28
Nr of data points: approx. 250						
4.0 – 8.9	20	-0.418	5.88	0.937	7.09	34.17
Nr of data points: approx. 250						
4.7 – 7.1	**10**	**-0.483**	**5.84**	**0.930**	**8.23**	**42.35**

As shown in the table, the computations performed with 250 data points and a sampling ratio of 10 ms provide the best results (with the largest SNR). Note that, anyhow, the damping features provided by the three sets of simulations are quite close to each other.

As a test for Prony analysis validation, Fig. 2 sketches the curve estimated by Prony with the original OMIB curve for the period from 4.7 – 7.1 s, presented in Table 1. The two curves fit almost perfectly.

To check the validity of the above results, we performed Prony analysis on the two relevant machines identified by SIME, (labeled 2075 and 2074), using the best conditions determined above. Figure 3 portrays the OMIB and relevant machines' swing curves, while Table 2 gathers their damping features.

Observe that the frequency of the three curves is almost the same, while the value of the damping ratio of the OMIB is in between that of machines 2075 and 2074. These numerical results are reflecting well the shapes and relative positions of the three curves.

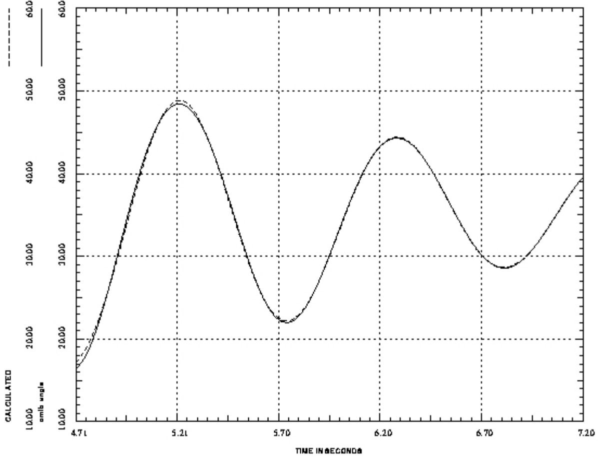


Figure 2: Comparison of the original OMIB swing curve with respect to the estimated one using Prony's method, for the stable case simulated on the EPRI 627-machine test system (Figs 1d and 3). Number of data points: 250; sampling rate: 10 ms; period of study: 4.7-7.1 s; SNR = 42.9 dB.

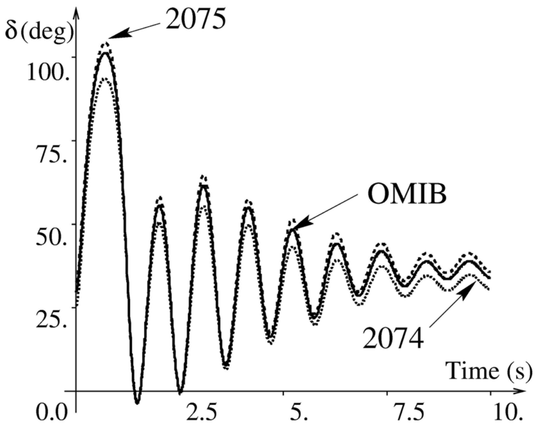


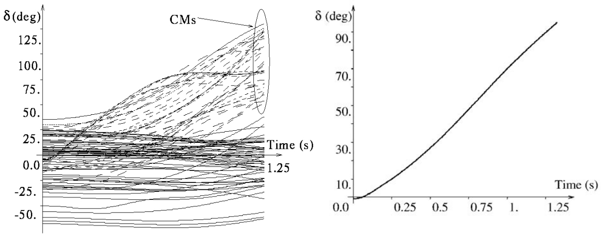
Figure 3: Comparison of the swing curves of the OMIB and the relevant machines (Nrs 2075 and 2074) of the stable case simulated on the EPRI 627-machine test system

5.4 *Results with inter-area mode oscillations*

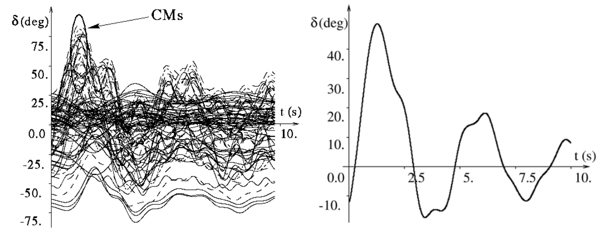
The inter-area oscillations considered in this series of simulations concern the stability case portrayed in Fig. 4c, and analyzed via the OMIB curve of Fig. 4d. Again, an unstable simulation close to the stable one is used to define the OMIB structure and identify the critical machines. The swing curves corresponding to this unstable simulation are displayed in Figs 4a and 4b. On this unstable simulation, 36 machines were found to be critical; they are identified in Table 3, along with their degree of severity assessed according to the procedure of §4.1 (angle in degrees, listed between brackets). Note that the angle of the most advanced non-critical machine (next to machine 2521) is 69.2 degrees.

Table 2: Results of Prony analysis of the swing curves of the OMIB and relevant machines 2075 and 2074 of the EPRI 627-machine test system. Number of data points: 250; sampling rate: 10 ms; period of study: 4.7 – 7.1 s.

α (rad/s)	**ω (rad/s)**	**f (Hz)**	**ζ (%)**	**SNR (dB)**
		OMIB		
-0.483	5.84	0.930	8.23	42.35
		Machine # 2075		
-0.509	5.83	0.927	8.7	43.27
		Machine # 2074		
-0.474	5.83	0.928	8.0	35.89



Unstable case. Critical machines power = 26 162 MW
(a) Multi-machine swing curves (b) OMIB swing curve



Stable case. Critical machines power = 25 379 MW
(c) Multi-machine swing curves (d) OMIB swing curve

Figure 4: Unstable and Stable cases simulated on the EPRI test system C. (Clearing time of both cases: 95 ms).

Table 3: Identification and ranking (angles in degrees) of the 36 critical machines of the EPRI 88-machine system.

Machine # (angle)	Machine # (angle)	Machine # (angle)
3007 (121.8)	2666 (112.7)	1783 (105.5)
3015 (121.3)	846 (112.5)	11771 (105.1)
3011 (120.2)	1826 (108.6)	11804 (104.7)
2658 (117.3)	1871 (108.0)	11859 (102.2)
1778 (117.2)	2723 (107.3)	11864 (101.0)
1834 (115.9)	11870 (106.4)	11854 (98.9)
2665 (115.3)	11877 (106.3)	11856 (98.5)
2202 (115.0)	11873 (106.3)	1847 (93.4)
1781 (114.7)	11878 (106.0)	2516 (90.7)
2659 (113.7)	11806 (106.0)	2645 (90.6)
2604 (113.6)	2609 (105.8)	2400 (87.5)
1782 (113.1)	11855 (105.7)	2521 (81.2)

Observe that in this case the relevant machines identification is greatly facilitated by SIME.

Following the same procedure as in §5.3, Prony analysis with sliding windows determines OMIB's damping characteristics, under various numbers of data points, sampling ratios (SRs) and periods of analysis. The results are gathered in Table 4; those having the best score (SNR) are marked with bold face characters. Note that these results are still quite close to those scored with lower SNRs.

As a test of Prony analysis validation, the original OMIB curve provided by SIME and that computed by Prony with the best set of data are drawn in Fig. 5. The two curves fir perfectly well.

Table 4: Results of Prony analysis of the OMIB swing curve of the EPRI 88-machine system using a sliding window technique for several sampling rates and periods of analysis. Number of data points: 250

Period (s)	SR (ms)	α (rad/s)	ω (rad/s)	f (Hz)	ζ (%)	SNR (dB)
3.0-7.9	20	-0.141	1.484	0.236	9.4	33.0
		-0.184	5.141	0.818	3.5	
2.0-6.9	**20**	**-0.150**	**1.481**	**0.235**	**10.1**	**45.8**
		-0.175	**5.110**	**0.813**	**3.4**	
2.0-8.0	30	-0.142	1.478	0.235	9.61	34.3
		-0.184	5.130	0.816	3.5	
2.2-9.2	30	-0.152	1.488	0.236	10.2	25.8
		-0.154	5.117	0.814	3.0	
1.0-9.9	40	-0.149	1.504	0.239	9.9	25.8
		-0.084	5.131	0.816	1.6	
2.0–9.9	40	-0.149	1.503	0.239	9.8	22.2
		-0.079	5.144	0.818	1.5	

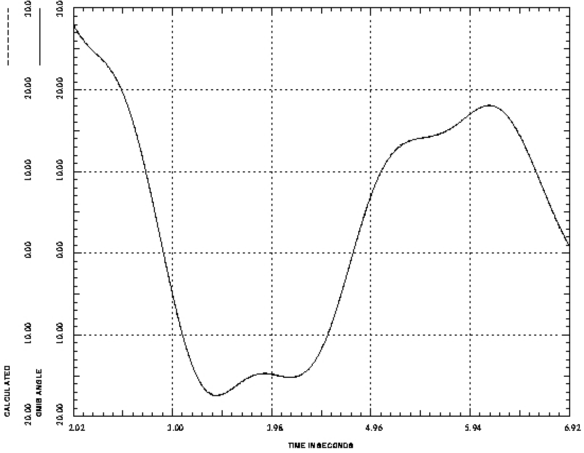


Figure 5: Comparison of the original OMIB swing curve with respect to the estimated one using Prony's method, for the stable case simulated on the EPRI 88-machine test system Fig 4 d). Number of data points: 250; sampling rate: 20 ms; period of study: 2.0 - 6.9 s; SNR = 45.8 dB.

Finally, the OMIB characteristics of the above analysis were compared with the characteristics of three relevant machines, namely: machine # 3007 (most advanced relevant machine), # 11870 (middle of the list of Table 3) and machine # 2521 (bottom of the list). The results of this investigation are gathered in Table 5. Observe that, here, the OMIB exhibits sort of intermediate behavior with respect to that of the other three machines. This is in good agreement with the drawing of Fig. 6.

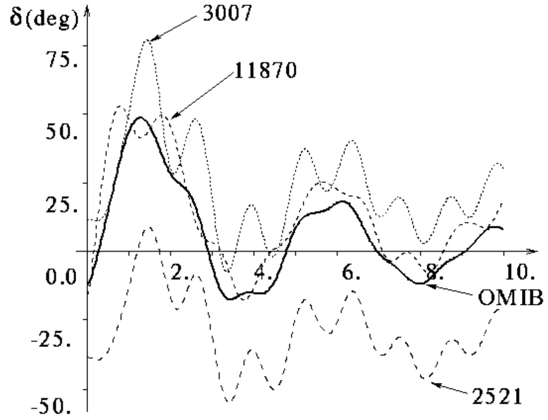


Figure 6: Swing curves of the OMIB and of selected relevant machines of the stable case simulated on the EPRI 88-machine test system.

Table 5: Results of Prony analysis of the swing curves of the OMIB and relevant machines 3007, 11870 and 2521 of the EPRI 88-machine test system. Number of data points: 250; sampling rate: 20 ms; period of study: 2 – 6.9 s.

α (rad/s)	ω (rad/s)	f (Hz)	ζ (%)	SNR (dB)
		OMIB		
-0.150	1.481	0.235	10.1	45.8
-0.175	5.110	0.813	3.4	
		Machine # 3007		
-0.243	1.529	0.243	15.7	29.28
-0.176	5.153	0.820	3.4	
		Machine # 11870		
-0.101	1.379	0.219	7.3	31.26
-1.020	3.703	0.589	26.5	
-0.213	5.638	0.897	3.7	
		Machine # 2521		
-0.247	1.519	0.241	16.056	36.90
-0.128	5.123	0.815	2.508	

5.5 Further validations and extensions

The above preliminary results are very encouraging. Nevertheless, they should be complemented with eigenvalue analysis, in order to fully validate the proposed procedure, and also to shed additional light.

Another investigation worth exploring concerns sensitivity aspects. Such an investigation would consist of comparing the impact of a generator as provided by the participation factors with the degree of relevance as provided by SIME. In this context, a preliminary attempt was made in Ref. [10] on a three-machine system, with very encouraging results, with the ultimate objective to alleviate heavy computations of participation factors. This exploration should now be revisited, in particular on realistic power systems, as those used in this work.

More generally, many other sensitivity matters could be thought of and investigated, based on the SIME method.

Such validations and extensions are now under way.

6 CONCLUSION

A new approach to on-line damping assessment has been proposed. It consists of combining the Prony technique with the SIME method. In particular, it applies Prony analysis to the One-Machine Infinite Bus (OMIB) equivalent swing curve provided by SIME.

This paper has presented some preliminary results. The focus has been on investigating, illustrating and validating the approach by means of simulations performed on realistic systems. More specifically, two large systems have been considered, which, upon contingency inception, experience plant and inter-area mode oscillations.

Prony analysis has been used to explore the OMIB swing curve and relevant generators' curves, and to compare resulting damping features.

This exploration has suggested at least the following two ways Prony analysis may benefit from SIME.

(i) SIME as a reduction technique, to compresses the damping information of the multi-machine, multi-variable system into that of the OMIB. This OMIB shows to be an interesting substitute for assessing main damping features of the multi-machine power system in an accurate, computationally efficient and physically transparent way.

(ii) SIME as an identification technique, to determine unambiguously the system machines and dominant power system modes of oscillation relevant to the oscillatory phenomena of concern. These relevant machines play a central role in the damping process of the multi-machine power system.

More generally, the investigations have shown that the approach is, indeed, able to improve significantly Prony techniques; at the same time, they have revealed existence of various other possibilities and extensions, suggesting that additional applications may be expected from this new technique. But this was beyond the scope of this paper, which essentially aimed at showing the method's suitability and attractiveness.

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