Compensation Schemes for Transient Stability Assessment and Control

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Abstract: A method is proposed to appraise the amount of parameters variation necessary to stabilize an otherwise transiently unstable power system. It uses stability margins together with compensation schemes designed so as to cancel out these margins. The method relies on SIME, a hybrid time-domain – direct transient stability method. Two types of parameters are considered, namely : (i) the clearing time of a disturbance applied under given operating conditions; (ii) the mechanical power of a system subjected to a disturbance and its clearing scenario. The compensation schemes devised for the former type yield contingency filtering tools appropriate for preventive transient stability assessment. Those designed for the latter type determine actions appropriate for preventive as well as for emergency control. The compensation schemes are illustrated on simulations performed on the South-Southeast Brazilian system under various operating conditions.

Keywords: Transient stability assessment and control; SIME; contingency filtering; compensation schemes; real-time preventive control.

1 INTRODUCTION

A real-time preventive transient stability assessment software must cover the following three tasks : (i) contingency screening to distinguish harmless from potentially harmful contingencies; (ii) close scrutiny of these latter; (iii) control actions to stabilize them, if necessary. This paper aims to improve existing and/or to elaborate new tools appropriate for the above tasks, by devising compensation schemes (CSs).

The purpose of CSs is to assess the amount of a parameter adjustment necessary to stabilize a power system. Their derivation relies on stability margins computation and critical machines identification. These pieces of information are provided by the SIME method which transforms a multimachine power system into a "generalized" one-machine infinite bus (OMIB) equivalent [1] and applies the equal-area criterion. In particular, two types of CSs are thus devised.

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The one addresses the question : assuming that under a given clearing time a preassigned disturbance drives the system to instability, determine the clearing time decrease necessary to stabilize it. This will be achieved by assessing the stabilizing area necessary to compensate for this case's unstable margin. Stated otherwise, this type of CSs aim at approximating a disturbance critical clearing time, using a sole unstable simulation and corresponding margin. Among various applications of this procedure, we quote the derivation of straightforward screening tools.

The second type of CSs addresses the question : assuming that under a preassigned stability scenario the power system is found to be unstable, determine the amount of mechanical power decrease necessary to stabilize it, i.e. to compensate for its unstable margin. Here, in addition to margins, the critical machines identification is also essential for the proper rescheduling of the equivalent OMIB's power among the system machines. This type of CSs furnishes suggestions for preventive as well as for emergency control.

The paper is organized as follows. Section 2 outlines SIME's essentials. Sections 3 and 4 propose CSs respectively of the above first and second types. Section 5 explores main properties of the derived CSs via simulations performed on the South-Southeast Brazilian power system. Section 6 draws conclusions.

2 SIME IN SHORT

2.1 Introduction

The SIME method is expounded in [2,3]. This section gives a mere, brief description of its practical use; it is illustrated in Fig. 1, corresponding to a real stability case, run on the Brazilian system; it is labelled Nr 672 in Section 5, where the simulation conditions are described.

Basically, SIME uses time-domain parameters of the multimachine power system in order to : identify the mode of machines' separation, construct the corresponding OMIB and compute its margin. According to whether the time-domain parameters are given by simulating stability cases computed with a time-domain transient stability program, or are real-time measurements reflecting an actual stability case, the procedure yields the preventive or the emergency SIME. Without loss of generality, below we will describe the procedure of the preventive SIME, which results from the coupling of SIME with a time-domain transient stability program.

2.2 Critical machines and OMIB

On an unstable time-domain trajectory, the critical machines are those which cause the system loss of synchronism. To identify them, SIME observes the post-fault swing curves of the system machines computed via a time-domain program. At each step, it sorts the machines in decreasing order of their rotor angles, identifies the very first largest angular deviations (largest "gaps") between any two adjacent machines thus sorted, and considers as *candidate* critical clusters of concern those which are "above these largest gaps". The corresponding candidate OMIB's trajectories are computed as explained in § 2.3. The procedure is carried out until a candidate OMIB reaches its unstable angle δ_u (defined in § 2.4) : it is then declared to be the critical OMIB.

Observe that a critical OMIB is defined on an unstable case only. By continuation, it is considered to be also valid on a borderline stable case.

Figs 1 illustrate the critical machines identification procedure.

2.3 Critical OMIB parameters

Let C denote the group of critical (or advanced) machines and N that of the non-critical (or backward) machines. Here, the critical cluster is composed of one machine only (machine labelled 2712 in Section 5); the non-critical cluster is thus composed of 55 machines.

The corresponding critical OMIB parameters δ, ω, M, P_m, P_e are readily computed as follows.

(i) Transform the two clusters into two equivalent machines, using their corresponding partial center of angle. E.g., for cluster C this results in

$$\delta_C(t) \triangleq M_C^{-1} \sum_{k \in C} M_k \delta_k(t) \text{ with } M_C = \sum_{k \in C} M_k \, . \qquad (1)$$

Similar expressions hold for cluster N, and yield the angle δ_N.

(ii) Reduce this two-machine system into an equivalent OMIB system whose rotor angle is defined by

$$\delta(t) \triangleq \delta_C(t) - \delta_N(t) \qquad (2)$$

and whose rotor speed, ω, is defined in a similar way.

(iii) Define the equivalent OMIB mechanical power by

$$P_m(t) = M \left(M_C^{-1} \sum_{k \in C} P_{mk}(t) - M_N^{-1} \sum_{j \in N} P_{mj}(t) \right) \qquad (3)$$

where $M = M_C M_N / (M_C + M_N)$ is the equivalent OMIB inertia coefficient. The OMIB electrical power P_e takes on a similar expression.

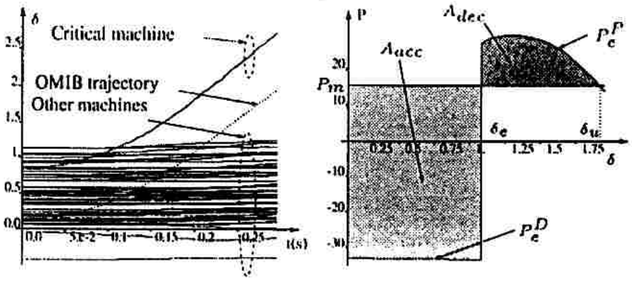
Fig. 1a portrays the OMIB trajectory plotted from the multimachine system swing curves.

2.4 Calculation of stability margins

The equation of motion of the OMIB equivalent

$$M\ddot{\delta} = M\dot{\omega} = P_m - P_e = P_a \qquad (4)$$

where P_a is the accelerating power, expresses in particular its power-angle dynamics.



(a) Critical OMIB identification
Nr of critical m/nes : 1
Nr of non-critical m/nes : 55
---- Critical OMIB trajectory
—— Multimachine trajectories

(b) Power-angle OMIB representation
Resulting equal-area crit.
$t_e = 167$ ms ; $t_u = 360$ ms ;
(CCT = 141 ms)

Fig. 1: Time-domain machines' and OMIB's trajectories; resulting equal-area criterion. Stability case Nr 672.

The well-known equal-area criterion uses the notion of stability margin :

$$\eta = A_{dec} - A_{acc} \qquad (5)$$

and states that : *for a given stability scenario the OMIB system is unstable (resp. stable) if* $\eta < 0$ *(resp.* $\eta > 0$ *). The borderline case,* $\eta = 0$ *, provides the limit (in)stability condition, in terms of critical clearing time or power limit.*

The above unstable and stable margins are expressed respectively by eqs (6), (7) :

$$\eta_u = -\frac{1}{2} M \omega_u^2 \qquad (6)$$

$$\eta_{st} = \int_{\delta_r}^{\delta_u} |P_a| \, d\delta \, . \qquad (7)$$

In these expressions,

- suffix u (for unstable) refers to the angle δ_u and time t_u where $P_a = 0$, $\dot{P}_a > 0$;
- suffix r (for return) refers to the angle δ_r and time t_r where δ starts decreasing and ω vanishes.

Fig. 1b illustrates the equal-area criterion in the slightly unstable case portrayed in Fig. 1a (A_{acc} is larger than A_{dec} : $\eta = -3$). Note that the computation of the unstable margin requires a time-domain simulation performed until reading t_u. (Here, $t_u = 360$ ms).

Remark. The above considerations show that t_u (respect. t_r) is the simulation period needed to compute an unstable (respect. a first-swing stable) margin. Observing further that the computation of a stability limit (critical clearing time or power limit) requires about 2 to 3 unstable and 1 stable margins suggests that this computation amounts to about 2 seconds of time-domain integration.[1]

2.5 Contingency filtering, ranking, assessment

Contingency filtering. The purpose of filtering (generally a large list of) contingencies is to discard the harmless ones (generally the major part of the list), and keep the potentially harmful contingencies for further scrutiny.

The standard "filtering SIME" procedure [2] uses two margin values computed for two (relatively close) stability conditions

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[1] Except whenever multiswing instability phenomena are sought, in which case an entire stable simulation is needed.

that extra- (inter-)polates to get an approximate limit value; its comparison with the preassigned threshold value allows discarding or keeping the contingency, as appropriate.

This procedure is found to be consistently reliable. On the other hand, whenever simplified power system models make sense, substantial gains may be obtained by using a sequence of filters with increasing modeling details.

Finally, observe that screening contingencies in terms of critical clearing times (CCTs) is as valid but much faster than in terms of power limits. This advocates using filtering steps in terms of CCTs, then refining the assessment of the potentially harmful contingencies in terms of power limits, if necessary. This observation is on the basis of the CSs for CCT assessment devised below, in Section 3.

Contingency ranking. The severity of the potentially harmful contingencies as identified by the filtering step may further be subdivided into dangerous and non-dangerous ones.

To fix ideas, when the simulations are performed with detailed power system modeling, the boundary between harmless and potentially harmful contingencies may be of 200 ms; among these latter contingencies, those whose CCT is below 10 cycles may be declared to be dangerous.

Contingency assessment. It may be worth refining the CCT assessment of contingencies found by the filtering SIME to be potentially harmful. This simply amounts to using one margin value, i.e. one simulation additional to those of the filtering step; this simulation should correspond to a stable scenario, if multiswing instabilities are sought.

Moreover, for the potentially harmful contingencies, it may be worth to compute their power limits for a given clearing time (e.g., for CCT = 10 cycles, i.e. 167 ms).

Illustration. The above filtering procedures are illustrated on the stability scenario Nr 672 of the Brazilian power system. The results are portrayed in Figs 2. Note that the margins appearing in these figures are normalized by the OMIB inertia coefficient : $\eta = \omega_u^2/2(\text{rad/sec})^2$.

Fig. 2a shows that the filtering SIME finds a CCT of 145 ms, by extrapolating the (negative) margin values corresponding to two clearing times (CTs) : 200 ms and 180 ms. According to the above chosen threshold values, this contingency is therefore found to be not only potentially harmful but also dangerous. Choosing an additional CT of 140 ms (smaller than 145 ms) allows refining the CCT assessment by interpolating between the positive margin and the last negative one; this yields 141 ms.

Fig. 2b illustrates a similar extrapolation procedure performed to compute the power limit corresponding to a CT of 167 ms.

3 COMPENSATION SCHEMES (CSs) FOR CCT ASSESSMENT

The purpose of such CSs is to assess approximately a contingency's critical clearing time (CCT) on the basis of a sole *unstable* simulation and the resulting negative margin. More specifically, the approach consists of computing the margin value corresponding to a clearing time (denoted CT or t_e) and assessing "how much" the CT should be decreased to compensate for this margin.

Many CSs may be thought of. They are suggested by the shape of the P_e curves variation with CT (or equivalently with the clearing angle δ_e), as those drawn in Fig. 3.

In this paper, four different CSs are thus designed, using four different ways of compensating for the margin. They are sketched in Figs 4[2], where this margin is also represented by the shaded rectangular area. This negative (normalized) margin amounts to $-14.7\,(\text{rad/s})^2$ as computed for $t_e = 167\,\text{ms}$. The margin is compensated in four different ways of increasing the decelerating and/or decreasing the accelerating areas. They yield four different estimated δ_{ci}'s (and hence estimated CCT$_i$'s). Note that Figs 4a to 4d yield increasing t_{ci} values (of 125, 136, 143 and 144 ms respectively).

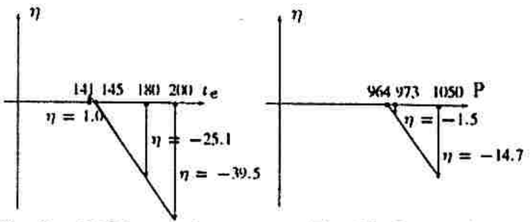

Fig. 2a CCT search under base case conditions

Fig. 2b Power limit search; CT = 167 ms

Fig. 2: Contingency filtering and assessment

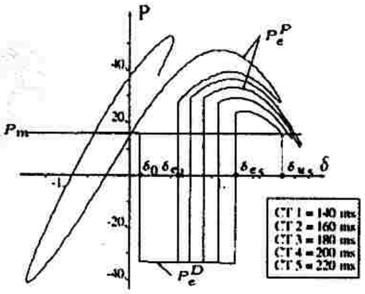

Fig. 3: Curves P_m , P_e vs $\delta_e(t_e)$ for stability case Nr 672 (CCT = 141 ms).

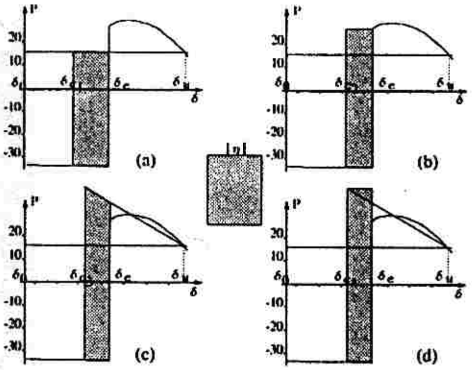

Fig. 4: Four CSs for CCT assessment. Stability case Nr 672. t_e = 167 ms ($\delta_e = 0.82\,\text{rad}$); $\eta = -14.7$.

The reason for testing various approximations is to determine those which provide upper and lower bounds of the actual CCT.

More generally, it is quite likely that the closer the chosen CT to the actual CCT and the better the approximate CCT$_i$'s. Also, the degree of modelling sophistication of a power sytem is likely to influence the CSs performances.

The above CSs may have various practical applications, in particular, the following two.

- For filtering purposes, whenever the CT is not too far away from the actual CCT, the CSs may save one out of the two simulations used by the extrapolation filtering SIME of § 2.5. The resulting CPU gains are particularly interesting

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[2] The CSs portrayed in Figs 4b and 4c were proposed by Y. Zhang [4].

for simulations run with detailed power system models. The gains may be even more important when the composition of the critical cluster changes from one simulation to the other(s).

- For CCT assessment, whenever the initial CT is far away from (i.e. much larger than) the actual CCT, using new CTs suggested by the CSs may contribute to speed up significantly the convergence procedure with respect to the pure extrapolation procedure described in § 2.5.

The performances of the CSs proposed in this section are compared in Section 5.

4 CS FOR CONTROL

The CS proposed in this section aims at stabilizing an otherwise unstable scenario, by decreasing the OMIB mechanical power; once the amount of decrease has been determined, a rescheduling of the multimachines' generation power must be performed. Thus, actually, the proposed compensation procedure addresses the following two questions : (i) how much to decrease the OMIB mechanical power ? (ii) how to convert this decrease into the actual machines' generation change ?

Fig. 5 helps to answer question (i). It shows that lowering the mechanical power from P_m to P'_m modifies the accelerating and decelerating areas of the OMIB $P - \delta$ representation. More precisely, it increases the decelerating area (by areas A_2 to A_5), decreases the accelerating area (A_1 and A_6), and increases the accelerating area (A_7). Thus,

$$|\eta| = \sum_{i=1}^{6} A_i - A_7 . \tag{8}$$

Expression (8) links directly $|\eta|$ to the amount of P_m decrease. Actually, decreasing P_m implies increasing P_e^P, thus adding one more decelerating area, say A_8, comprised between curves $P_e^{P'}$ and P_e^P. But its computation would imply another time-domain simulation. On the other hand, neglecting A_8 gives a pessimistic assessment, i.e. an overestimation of $\Delta P_m = P_m - P'_m$, which moreover is not very important (a few percentage, see footnote [4]).

The computation of all other areas (A_1 to A_7) merely requires an additional load-flow for determining δ'_0, which, moreover, may be neglected in a first approximation.

With regard to above question (ii), observe that the distribution of the OMIB ΔP_m among actual machines' generation must obey eq. (3). This equation suggests that decreasing P_m implies decreasing generation of critical machines (CMs) and increasing generation of non critical machines (NMs) according to :

$$- \Delta P_m = - \frac{M_N}{M_N + M_C} \Delta P_C + \frac{M_C}{M_N + M_C} \Delta P_N \tag{9}$$

where

$$\Delta P_C = \sum_{k \in C} P_{mk} \; ; \; \Delta P_N = \sum_{j \in N} P_{mj} \; . \tag{10}$$

Now, the distribution of ΔP_C (respect. ΔP_N) among CMs (respect. NMs) has many degrees of freedom, depending on the rescheduling conditions sought. For example, when the concern is to keep unchanged the overall system generation, the condition [3]

$$\Delta P_N = - \Delta P_C \tag{11}$$

yields, according to eq. (9) :

$$\Delta P_N = - \Delta P_C = - \Delta P_m = \Delta P. \tag{12}$$

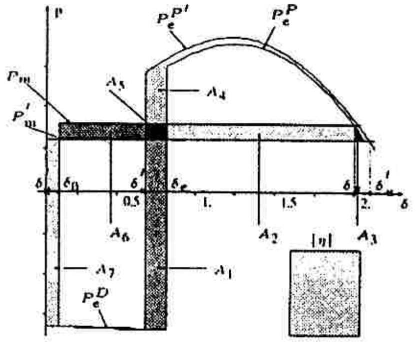

Fig. 5: Cs for control actions assessment. Stability case Nr 672. $t_e = 167\,\text{ms}$; $\eta = -14.7$; $P_m = 324 MW$; $P_C = 1050 MW$.

In the example case of contingency Nr 672 considered in Fig. 5, the computation of ΔP_m via expression (8) yields 91 MW, vs 85 MW provided by a pure (but much more tedious) time-domain procedure.[4] Hence, according to eq. (12), the generation of the critical machine (Nr 2712) will be decreased by 91 MW and that of non-critical machines increased by the same amount.

The above matters are illustrated below in Section 5, in both cases of single- and multi-machine critical clusters.

5 SIMULATION RESULTS

5.1 Simulations description

Study system. The considered South-Southeast Brazilian power system is modeled with 56 machines, 1188 buses and 1962 lines; the voltage levels range from 138 to 765 kV. The considered base case corresponds to a peak load scenario of 32,538 MW forecasted for May 1998 [5].

Power system modeling. In this system, the standard simplified model makes sense. But the simulations described here use the current detailed model where 46 machines are equipped with AVRs, 8 with PSSs, and 7 with prime movers/governors.

Contingency type. The considered contingencies are three-phase short-circuits applied at 138 to 525 kV buses and subsequently cleared by opening one line or transformer adjacent to the faulted bus. They are identified by the bus number where they are applied.

Additional information. SIME is coupled with the ST600 program of Hydro-Québec [6]. This program is also used alone as the reference.

Contingency preselection. In a previous study [5], a total of 712 contingencies were considered and screened through a filter using the simplified system model and a threshold CCT of 300 ms. This filter discarded 644 contingencies and "sent" to the "extrapolation" filtering SIME, used with detailed model, the remaining 68 contingencies for further exploration. This latter identified 20 contingencies to be "potentially harmful", i.e. to have a CCT smaller than 200 ms. Finally, among these 20 contingencies, the regular SIME found 14 "dangerous" contingencies, i.e. whose CCT is below 167 ms.

The simulations of next paragraphs are concerned with these potentially harmful and dangerous contingencies.

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[3] neglecting variation of losses.

[4] This 7 % discrepancy is because of neglecting the area A_8 between curves $P_e^{P'}$ and P_e^P ; indeed, the computation of this area provides 6 MW.

TABLE I:CCTs OF THE VARIOUS CSs. $t_e = 200\,\text{ms}$.

1	2	3	4	5	6	7	8
Cont. #	η	t_{c1}	t_{c2}	t_{c3}	t_{c4}	SIME	Ref.
687	-47.3	50	–	126	134	119	117
656	-36.8	57	12	130	137	133	132
686	-17.9	136	149	174	175	136	138
672	-39.4	82	116	132	137	141	143
630	-30.9	95	105	153	157	146	147
680	-35.6	100	132	145	149	149	152
708	-34.9	103	134	148	151	149	152
598	-35.0	103	134	148	152	150	152
629	-30.8	95	107	153	157	153	152
463	-34.6	104	136	149	152	154	152
692	-29.1	103	116	157	160	156	157
707	-33.6	108	139	151	154	157	157
690	-22.2	117	126	164	166	161	162
437	-69.3	110	151	159	163	165	162
434	-64.0	119	158	165	168	170	168
689	-16.4	143	155	177	178	173	173
628	-16.8	141	153	176	177	173	173
522	-57.3	130	166	171	173	175	173
362	-15.8	145	157	178	179	177	178
516	-43.3	150	177	180	181	183	183

5.2 CSs for CCT assessment

The CSs proposed in Section 3 and described in Figs 4 are used in this paragraph to assess contingency severity.

Results. Table 1 collects the CCTs of the 20 potentially harmful contingencies previously identified. They are obtained by the 4 different CSs, using a sole margin corresponding to a clearing time (CT) of 200 ms.

All t_{ci}'s ($i = 1$ to 4) and CCTs are expressed in ms. The actual CCT of column 7 is provided by the regular SIME; as a validation, column 8 provides the CCTs computed by the ST600 program.

Discussion. Table 1 shows that :

- t_{c1} provides a lower bound of the actual CCT (though sometimes much smaller than it);
- t_{c2} behaves in a similar way, though with some failures;
- t_{c3} is sometimes larger and sometimes smaller than CCT;
- t_{c4} is generally larger than the actual CCT; and whenever smaller, it is very close to CCT[5]. It may thus provide an upper bound of the CCT.

The above observations suggest in particular that :

- t_{c1} may be used as a "safeguard", i.e. to avoid missing dangerous or potentially harmful contingencies;
- t_{c2} , t_{c3} show to be less interesting;
- t_{c4} may be used for the purpose of filtering and for conducting accurate CCT assessment computations. (Remember, SIME approaches limits mainly "from the right", i.e. with values larger than the limit sought and their corresponding negative margin values).

Various other interesting applications may also be thought of, inasmuch as computating t_{ci}'s is virtually unexpensive.

Finally, observe the good agreement of SIME with ST600.

5.3 CS for control and rescheduling assessment

5.3.1 General procedure

The general procedure for stabilizing contingencies relies on the CS devised in Section 4. Thus, for a given unstable contingency, the first step of this procedure amounts to computing the corresponding (negative) margin and from there on ΔP_C and ΔP_N defined by (8), (12). The second step concerns the generation allocation of ΔP_N among NMs, and also of ΔP_C among CMs, whenever there are many. Observe further that, since the ΔP value computed via eq. (8) is only approximate, the procedure will be performed iteratively.

Experience shows that the efficiency of this iterative procedure depends only marginally on the generation reallocation of ΔP_N among NMs (though it may be of great importance with respect to other concerns such as maximum power transfer or economy). But it may depend significantly on the way the ΔP_C generation is allocated among CMs; in addition, the efficiency of a pattern can change from one case to another. In what follows, the reallocation of ΔP_C among the critical machines is made according to their degree of criticalness, appraised by the product $M * g$; thus, the ratio of power reallocation between machines k and j is chosen such that :

$$\frac{\Delta P_{ck}}{\Delta P_{cj}} = \frac{M_k g_k}{M_j g_j} \qquad (13)$$

where M_k denotes the inertia coefficient of the k-th critical machine and g_k its angular deviation with respect to the most advanced NM at time t_u .

A final observation relating to the iterative nature of the procedure : since, by construction, SIME benefits from a succession of negative, rather than positive margins, it is advisable to consider ΔP values somewhat (e.g. 10 %) smaller than those computed from eq. (8).

5.3.2 Simulation results

Table 2 collects the main results of these simulations using the 14 dangerous contingencies of Table 1.

Iteration # 1 : Column 2 lists the normalized margins η_1 in $(\text{rad/s})^2$, as computed by SIME, for a clearing time of 167 ms. Column 3 provides the corresponding total generation change provided by the CS, ΔP_1 , by which the critical cluster should be decreased. If this cluster comprises many CMs, the power reallocation is determined according to (13). Column 4 collects results concerning the resulting generation reallocation among CMs. Thus, for a given contingency, one reads in a row : the name of the CM followed between brackets by the gap between this CM and the most advanced NM, and the generation decrease resulting from the proportionality rule (13). All ΔP values are expressed in MW.

Thus, Iteration # 1 requires one stability margin computation per contingency, preceded by one load flow (LF), common to all contingencies.

Iteration # 2 : At the end of Iteration # 1, a LF is run for each contingency, in order to take into account the power increase on CM(s) and the same amount of power decrease on NMs. (E.g., for contingency Nr 672, a decrease of 82 MW is imposed on machine Nr 2712). This LF is followed by a SIME's computation which yields the new margin value (-0.5 for the case 672). Further, extra-(inter-)polating margins η_1 and η_2 provides a new ΔP value by which the generation of CM(s) should be modified (-3 MW for the case 672). Finally, running a new LF with this new generation power provides the

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[5] Table 1 shows that t_{c4} is smaller than CCT in 6 out of the 20 cases; but the maximum discrepancy in these 6 cases is of 5 ms.

TABLE 2: ITERATIVE RESCHEDULING PROCEDURE

Iteration #1			
1	2	3	4
Cont. #	η_1 (rad/s)^2	ΔP_1 (MW)	CM (gap (°); ΔP (MW))
687	-23.9	-70	2707(53;-42); 2706(41;-28);
656	-17.1	-71	2707(112;-31); 2706(101;-24); *2705(90;-11);* *2704(56;-5);*
686	-12.4	-38	2707(53;-20); 2706(48;-18);
672	-14.7	-82	*2712(89;-82)*
630	-15.6	-45	*2707(31;-45)*
680	- 9.7	-52	2712(94;-52)
708	- 9.4	-50	2712(96;-50)
598	-9.4	-50	2712(95;-50)
629	-16.5	-31	*2706(21;-31)*
463	-8.0	-43	2712(94;-43)
692	-14.7	-19	2706(43;-7); 2705(40,-4); 2707(38,-8)
707	-6.7	-35	2712(95;-35)
690	-2.4	-10	2705(46;-3); 2706(41;-4); 2707(27;-3)
437	-1.1	-2	*2573(103;-2);*

Iteration #2				
1	2	3	4	5
Cont. #	η_2 (rad/s)^2	ΔP_2 (MW)	η_3 (rad/s)^2	ΔP_3 (MW)
687	-2.2	-7	0.3	1
656	2.3	8		
686	-1.3	-4	0.09	~ 0
672	-0.5	-3	0.07	~ 0
630	2.2	6		
680	-0.2	-1	-0.01	~ 0
708	-0.7	-4	-0.04	~ 0
598	-0.6	-3	-0.04	~ 0
629	1.1	2		
463	-0.09	-1		
692	0.9	1		
707	-0.09	-1		
690	0.5	2		
437	1.7	1		

actual generation power limit for stabilizing the contingency, i.e. for increasing its CCT to 167 ms.

Thus, Iteration #2 requires 2 LFs and 1 stability margin computation per contingency.

Observe that this iteration is also the final one : columns 4 and 5 indicate that attempting to improve the stabilization of contingencies with negative values for η_2 , ΔP_2 provides negligible corrections.

Remark. The main concern of the above procedure is to show that the CS of Section 4 works, indeed, satisfactorily (i.e. provides proper ΔP_1 values). From a practical point of view, however, the concern should be how to stabilize all contingencies simultaneously rather than individually. This latter question is addressed in [5,7].

CONCLUSION

Two types of compensation schemes have been proposed. The one aims at improving existing approaches to fast transient stability assessment. The other intends to design automatic means of control, non-existent so far. This is of paramount importance not only for deciding preventive control actions but also for emergency control. The development of such tools has been made possible thanks to the ability of the SIME method to provide margins, critical machines identification, and straightforward answers to the questions of "how", "how much" and "where" to control. They will contribute to add to the existing approaches to transient stability assessment, real-time control tools.

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