Oral Discussions on Session: "Dynamics and Control" – Part I

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Chair: Pete Sauer (University of Illinois)

Abstract

This paper contains the first part of the transcribed oral discussions of Session "Dynamics and Control" of the 2013 IREP Symposium-Bulk Power System Dynamics and Control, held on Monday morning, August 26, 2013. Papers [1]-[4] were presented.

Discussion

Patrick Panciatici (RTE): My question is to the first two papers (by Robin Preece [1] and Dionyssis Aliprantis [2]). Are you able to capture the correlations in the uncertainties in your method?

Robin Preece (University of Manchester): I'll go first. Yes very easily, if we use Monte Carlo to generate the probabilities of the distributions that can be done quite simply. If you are using other techniques to model the uncertainties, some more efficient estimation techniques, it is possible with some of these techniques, such as point estimation techniques or cumulative based approach, which uses the sensitivities. It is possible, it is more complicated, but it is definitely doable. But in a probabilistic approach I am not so sure about that.

Dionyssis Aliprantis (Purdue University): I think it is harder to do, to extract formulas for correlations to estimate these things.

Claudio Canizares (University of Waterloo): This is a question for the second paper (by Dionyssis Aliprantis [2]). Correct me if I am wrong, my understanding is that you are working with interval matrices. We have a linear system, the box you end up at the end is basically defined by the extremes of these variations. The problem when you move to nonlinear systems is that you multiply these boxes and basically this expands exponentially and gets very big. I haven't worked with this reachability analysis, and I wonder how this expands when you multiply these boxes in a nonlinear system. Thank you.

D. Aliprantis: Thank you. This is a good question. So, if I understood correctly, your question is related to your concern that these sets will blow up. So, there are mathematical proofs and theorems that discuss the convergence of these sets and there are ways to limit this phenomenon, which is undesirable. For example, you can take smaller time steps. Or, if the set becomes too large, you can split it in smaller sub-sets and then, you know, proceed with the analysis from there. And that kind of controls the blow-up phenomenon.

Misha Chertkov (Los Alamos National Labs): I have a question to the second speaker (Dionyssis Aliprantis [2]) on zonotopes. It reminds me a bit of the story of Lyapunov exponent in applied mathematics, where you have a dynamical process and there is expansion in many directions. My question is: usually it is not uniform. So some directions stretch and others contract. This dimensional reduction do you see it? There are very few directions, which are significant for analysis.

D. Aliprantis: The zonotope method does not really care what the shape that you get is. The result will show you which direction stretches more than the others. So it is not a theoretical method, where you compute eigenvectors. It is more of a numerical method.

M. Chertkov: Alright, but can you use it? If there is a separation, can you use it to enhance your method? Get rid of many unnecessary directions to enhance your method?

D. Aliprantis: Yes, so what we do is that at some point the order of the zonotope increases, when you do these operations, because you keep adding generators and periodically you get rid of the less important ones. So that's one of the ways you do that kind of thing. I am not sure if I answered your question.

M. Chertkov: That's good. Can I ask one more question to third paper author (Urban Rudez [3]). It's actually about waves. In your study they are related to impedance and other characteristics, but if I were to restate it in terms of how speed of an electromechanical wave depends on

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power. Am I right to say that for a lighter system, like New Mexico as opposed to California, It would be much faster, so speed of a wave would be much faster, in a lighter system. Am I right?

Urban Rudez (University of Ljubljana): By lighter you mean with lower inertia constant?

M. Chertkov: No, I mean really to translate from impedances to power flows to how much power flows do I have in a region.

U. Rudez: In my opinion, I think the amount of power flow in the system does not contribute much

M. Chertkov: I am referring to the work of my colleague from Los Alamos,…., and I think it is equivalent to what you said, if you translate from impedances to power flows.

U. Rudez: It's a different point of view actually.

Ian Hiskens (University, Michigan): So, my comment relates to Dionyssis Aliprantis' work [2] as well and is linked with Misha's comments. Well yes, when you think of Lyapunov exponents you see expansion, contraction in different directions and you can extract that information and do some reduction based on that. Looking back to the paper, there are two fundamental problems. We did some work some time ago. One is related to non-linear systems and the cases that are particularly interesting are those that are verging on instability and if you take your polytope idea, once a polytope crosses the boundary, or part of a polytope lies in the stable region and part lies in the unstable region, they separate and it is not a polytope from that point onwards. So, there is a limitation in nonlinear systems that is fundamental. You can always shrink the polytope down to an Infinitesimal small size, but you still need to think through some of those. The other aspect is that we are dealing with real power systems. We are dealing with hybrid dynamic systems and the switching is vitally important as well. In real cases often when the system goes unstable, something hits a limit and it might be a controller, saturation, so the techniques ought to map the polytopes through switching boundaries, as well.

D. Aliprantis: Very good questions. Should I reply or not?

(Laughter)

D. Aliprantis: In the case of instability, of course you are right; once you cross to that region we don't know what it's going to happen to the set. One of the ideas we are exploring is to define some boundaries in the state space. For example, these could be boundaries that define the safety and security of the system, which are clearly away from the instability region. And if the set crosses these boundaries, then this means that something is gonna trip. And you stop simulating there and you switch. So this is not meant to simulate all kinds of cases, including unstable systems and this also crosses your second question, the hybrid system. There are ways to expand numerical techniques to handle switching in the system. Of course the issue of intersecting a zonotope with, let's say a plane, that intersection is not a zonotope. However that intersection of an ellipsoid with a plane is an ellipsoid. So there are ways to come up with hybrid ways to model hybrid systems and continue on this line of research.

I. Hiskens: Can I have a follow up comment?

Chair: Of course! You are Chairman of the IREP Board…

I. Hiskens: Oh, thanks Pete. In terms of driving the system on to boundaries that determine bad things, there is lot of work in grazing bifurcations. So, you can set up a shooting method that would exactly establish exact conditions that would drive you exactly to the boundary of acceptable regions. And that's another way of exploring those ideas as well. Thank you.

Gregor Verbic (University of Sidney): I am basically following up on Claudio's question regarding the second paper [2]. I couldn't very well understand how you benchmark your method. So the solid line within the box was that for the midpoint for the uncertain intervals?

D. Aliprantis: Sorry about the uncertainty in my presentation about uncertainties. We ran a few deterministic simulations with arbitrarily generated inputs, initial conditions, to verify that these trajectories remain within the set that describes the reachability. So, did I answer your question? These black lines inside were deterministic classical simulations. Not a mean value or anything like that.

G. Verbic: This agrees with my understanding. Why didn't you use Monte Carlo simulations? You assume a certain probabilistic distribution over that interval, being either uniform or more realistic, probably normal distribution. It would be fairly easy to calculate Monte Carlo simulations to assess the performance and especially I am interested, as Claudio said, that it might happen that the box may possibly blow up which means that you tend to overestimate the trajectory. And my second question, what is the computational intensity of the method and especially if you compare it with the Monte Carlo simulation? Thank you.

D. Aliprantis: This is a different approach than Monte Carlo. We run one simulation that captures all different scenarios, which perhaps you might miss with the Monte Carlo simulation. I personally do not know how to assign probabilities to these events. Perhaps there are ways. Perhaps there is a lot of research done. This is a different technique. We run some Monte Carlo simulations for benchmark. We are over-approximating a little bit. But the over-approximation is kind of tight, we think. There is obviously an error there. And perhaps there is an input that might drive the trajectory closer to that boundary of the box which we might not be able to capture.

Thierry Van Cutsem (University of Liege): My question is for Miroslav Begovic [4]. You dealt in your presentation with margin estimation, which I guess is a case where the system doesn't collapse and you like to see how much margin it still has after a contingency. My question would be more about the case where we have a severe disturbance in the system and the system is going to collapse in one or two minutes after the event and I would like to ask you to comment on the possibility to do better than the standard protection systems, or the integrity protection schemes, do presently, which is to basically observe the effect instead of observing the cause of the instability. The problem in this case is of course to tune the threshold, which is not obvious in some systems. So, I would like to have your comment on the possibility of VIP in the future to give something better to beat the simple voltage criteria, V smaller than some threshold.

Miroslav Begovic (Georgia Tech): Thank you, Thierry. The purpose of the method we have entertained in this paper is more along the lines of doing an emergency control trying to steer the system away from what may be a straight hit into the maximum loading condition. It is quite true that the most common scenario is hitting a large disturbance and succumbing to the consequences of it. VIP hasn't been used much in that mode. VIP has been a commercial product for over a decade. And I think there is a limited potential to that, but it is plugged to some extent by the interaction with the system dynamics that happens in those several seconds and I wouldn't advise at this point with the knowledge I have of it that VIP be the one to be used for that purpose. But what we are trying to explore are methods that enable us to increase its accuracy in those moments, try to peel off the layers of dynamics that interact with assessments of VIP so that it could be used in that mode. Any information that can be obtained in addition to the local information could be cleverly used to design such improved algorithms and we are looking into that multi-port mode, flowgate mode and other modes. That is I think the best answer that I can give you honestly at the moment. I don't see it immediately as a fresh potential for a wide-area protection scheme. And I see that Damir is already raising hand probably to make a comment on my comment.

Bernie Lesieutre (University of Wisconsin): I have two questions. One for Urban Rudez [3] and one for Miroslav Begovic [4]. The first one: when we are looking at these electromechanical oscillations, the way they behave, and you look instead of a single dimension at two dimensions, it starts looking like a drum. I was reminded of this a couple of minutes ago when we were hearing the drums (Rethymnon Renaissance Festival Parade). There is an interesting paper a while back: Can you hear the shape of a drum? And what I would like to ask you with regard to your research is when you look at the disturbances, can you see the characteristics of a power grid just from these travelling waves and that may be not such an important question because we probably know the characteristics of a power grid. So I will take it one step further. If you know the characteristics of a power grid and you look at the travelling waves can you determine when it is working properly? Can you say when the control systems operate the way they should be by looking at that part?

U. Rudez: Yes. Actually the problem is the observability of the power system. So if we have only a few measuring points in the system we only determine the moment when the wave reaches that point. I assume I know the entire power system and try to check, for example, how the wave travelled to my direction, towards the measurement. It is difficult to figure out what the speed would be in the opposite direction because it is not the same. There was a paper I think about the Korean power system, they had measurements. The characteristics of the power system in my research were known actually. But it is very difficult to figure it out through the measurement of the speed.

Chair: I think the speed depends on the location of the disturbance.

U. Rudez: Yes, definitely. It is hard…

B. Lesieutre: We like hard. Hard is good. Easy is not very interesting. My question to Miroslav Begovic [4], it is more of an intuitional question. The question has to do with the placement of the sensors for doing the monitoring you want to do for voltage stability. It seems where you have voltage collapse is locational and obviously it is better to have measurements near there. My question is for flowgates, as flowgates are not typically defined necessarily where you expect the voltage problems to be. The flowgates are like path 15 in California, where there is major power transfer. The actual place where the disturbance might be greatest could be fairly distant from what would be a traditional flowgate. So are you proposing new types of flowgates that would enhance the ability to detect voltage stability or just trying to rely on the typical existing ones based on power flow?

Miroslav Begovic (Georgia Tech): Thanks, Bernie. We view flowgates mainly as a potential for increasing the transmission capacity under the circumstances when the system is challenged. As far as location of places that are most prone to causing problems, we do not have to go much further than what Jacque Carpentier said probably 30 years ago; that looking into short-circuit currents and locations with the strongest one that might be the best site for pilot points for voltage instabilities. If we have no other information, topological information, from which we can build. Part of the effort we are currently trying to do is how to synthesize information from multiple VIP measurements which are very inexpensive and very easily placed across the system, how to synthesize more accuracy out of a large number of relatively inaccurate measurements.

Damir Novosel (Quanta Technologies): This work is from the '90s, we then called it VIP, voltage instability predictor. Actually operators were complaining about this, as this is not really a prediction. Because prediction would be if we could see before the line trips what would have happened. Because if nothing is happening, it is not really prediction. So, I think the latest term is real-time voltage instability indicator just to get the prediction element out. But what I wanted to ask Miroslav [4] is firstly, do you see any benefits or differences in using SCADA measurements vs. PMU measurements? Because recently a lot of work has been done in looking into the corridor, into the flowgate, looking into the load centers and so on using information from the synchronized phasor measurements. What's your feedback on this? Second question is, and relates also to Bernie's question, if you have flowgates, there can be actually some changes in the flowgates while you are doing the measurements, so let's say the line would trip, so did you look into how the change in that flowgate would affect really the algorithm itself?

M. Begovic: What change in the flowgate are you referring to?

D. Novosel: Let's say you have a corridor that has three lines and you are doing your calculation. Now one line trips and you are doing your measurements, you are summing up measurements as you very well explained. Now you sum the measurements from three lines and you have actually now two lines and one line has a zero measurement as there is no flow in that line. So your calculation in the flowgate can be really inaccurate if you don't know that this line has tripped. So, these are some of the things I wanted to check if you had a chance to look into, because they are I think some of the very important aspects to be able to, to Bernie's point, to really identify instability. Because we know that this methodology, VIP, works very well with the radial systems, but now looking into the flowgates, looking into those transmission aspects creates some additional problems. So any way, some of your thoughts.

M. Begovic: Flowgates indicators are assumed to be strictly local. And the only difference from traditional voltage instability indicator, predictor, however you choose to call it, is that they are looking into the pass-through power rather than the power of the local load. So when a change occurs in the topology of the flowgates that is automatically reflected in the measurements of that indicator that is obtained in the other flowgates. And what simulations we have done are proposing that if in the future things like distributed control of the line impedance become available, small changes and disturbances that can be introduced that are not threatening to the system can actually be exploited to provide valuable information about the point when those flowgates (where the measurements are being taken) are taken out of service accidentally and estimate what margin might be of transmission capacity in such situations. So, it is embedded in the measurement. On account of your other question, which is a synthesis of SCADA and phasor measurement there is nothing in the concept of voltage instability indicator that is forcing it to be applied with phasor measurements. It could very well be done with SCADA measurements provided they are fast enough and updated enough and time-tagged enough and so those measurements across the system can be compared.

D. Novosel: My question is, do you see the benefits of phasor measurement?

M. Begovic: The benefits of using SCADA is that when we go into the multi-port model we can expand the information about system topology and enhance the quality of the voltage instability indicators using that information.

D. Novosel: I just thought I would make an additional comment. Use of system integrity protection schemes I think that is a very good suggestion. The other thing is that there are a lot of tools now implemented for contingency analysis, for voltage stability contingency analysis, and so on. A tool like VIP could be really a trigger, because you cannot do the contingency analysis constantly, so with VIP you have a chance now to say: oh, there is a problem. So now you can actually initiate a more detailed and more accurate contingency analysis.

Juan Carlo Munoz (University of Waterloo): My question goes to the second paper [2] (by D. Aliprantis). Is there a way to account for generator limits in the analysis you are proposing (reachability analysis)? And a second question is: how can you take into account the progress of contingencies and clearing process in this time-domain simulation?

D. Aliprantis: This relates to the question by Prof. Hiskens. So you are basically asking how we can modify the system equations to account for switching phenomena, like a limit of a generator and things like that. In this paper [2] we did not account for these things because it was the first paper we wrote, very simple, a lot of assumptions made. But it is possible to modify this technique to account for such nonlinearities. We did not develop this technique. Let me say this. This technique was developed by our esteemed colleagues in the control area in the last 3-4 years, so we are adopting those techniques.

Ian Dobson (Iowa State University): I have a question about electromechanical wave propagation [3]. You are interested at the time when the peak arrives at the predictable place to do the location and I wonder if there is a systematic enough relation between the time the peak arrives and the value of the peak to be able to correct the time of the peak arrival for the change in the system. If there is a systematic relationship between peak value and the time of the peak, then one would be able to correct the time for the change and the inertia. I guess I was just curious as whether this was a possible direction to pursue.

U. Rudez: The paper that I wrote for the Power Tech Conference this year was exactly about this problem which you now describe. I tried to find some relationship between the peak and the extension of the wave, how long it is, and perhaps there might be a correlation but I didn't find it yet. On that paper I saw indications that might point to a solution, but we are not quite there yet. Thank you.

Chair: This was the last question. I would like to thank all authors and discussers.

References

[1] R. Preece and J. Milanovic, "Assessing the Risk of Small Disturbance Instability in Mixed AC/DC Networks," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

[2] H. Villegas, D. Aliprantis and E. Hoff, "Reachability Analysis of Power System Frequency Dynamics with New High-Capacity HVAC and HVDC Transmission Lines," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

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