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Oral Discussions on Session: "Synchrophasor Applications" – Part I

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Abstract

This paper contains the first part of the transcribed oral discussions of Session "Synchrophasor Applications" of the 2013 IREP Symposium-Bulk Power System Dynamics and Control, held on Tuesday afternoon, August 27, 2013. Papers [1]-[4] were presented.

Discussion

Chair: Are there any questions and comments from the group?

Fernando Alvarado (Consultant): I have three questions for Mevludin Glavic [1] and a couple of questions for Joe Chow [3]. Question 1: In your paper you say that you use measurements as and when they are received. It is possible that a newly received measurement may be bad, or that once you receive a new measurement you may realize that it is bad. How do you filter out bad data? Question 2: It is also possible to have synchronized sampling even though the sampling of the measurements may not arrive at the same time; it's perfectly possible, especially with PMU that you sample in a synchronous manner all over the system. That would eliminate one of your biases. Is this something you are doing or something you consider doing? And my third question is that the accuracy of the measurements can be related to how recent an event is. And at some point if you don't receive measurements from a certain substation, you have to kind of phase it out. How do you remove measurements that become stale, older?

Mevludin Glavic (University of Liege): Thank you, as for bad measurements, at the last slide (unfortunately I was taking too much time), and actually in several of the slides we used an index J to identify abnormally reconstructed measurements. For the measurements we are receiving, we didn't do any special bad data processing for now. So, the point is that it is the first time we present this methodology and we use J index just to detect abnormally reconstructed values but for the measurements that are coming, let's say that we still rely on that the last exact state estimation is doing the bad data processing.

F. Alvarado: OK. Two quick questions for Joe Chow [3]: One is why do you say that we can't put a PMU in every substation? And the second question is: you are talking about angle bias as a parameter, you are kind of estimating, and I somehow expect angle bias to be a little more complicated than just a fixed parameter deviation at every given substation. I somehow expect it to be somewhat load-dependent, condition-dependent, maybe that's wrong, but I expect it to be that way.

Joe Chow (RPL): Regarding the first question, of course, you can put a PMU at every substation if you want. But the companies just don't want to do that. In New York City the situation gets to be pretty tricky because there's no space in the substation to put new instrumentation, even though putting a PMU means you just slide another box into a rack or something. And also, in some power systems you have to wait six months for even to hook a current channel. All these things will cause reliability issues. The second question that you have is that the bias actually changes every sampling time, and referring to the earlier question that you had for Mevludin Glavic [1], all the PMU data are time tagged so they may arrive out of sequence but you can still just line them up at the phasor data concentrator. So, you can use all the data with the same time tag together. In some sense it is easier to just use synchrophasor data because you know that they are all measured at the same time point. And if you try to work with SCADA data, the RTU data come every 5 seconds and may be stale, or have other issues. That is a much more difficult problem because you have to find a backspace or whatever. It would be nice if all these RTU data, the SCADA data, would be also time tagged…

M. Glavic: I would like to comment about the time tagging of the SCADA measurements. We have information that some SCADA, some recent solutions, provide time tag. Not time synchronization but time tagging. And in the list of our future extensions, we intend also to explore the possibility of having the time-tagged SCADA measurements.

Antonio Simões Costa (Federal University of Santa Catarina): My question is for Mevludin Glavic [1]. Congratulations for a very interesting approach for actually revisiting the tracking state estimator concept in the presence of PMUs. My question is about the weighting factor that you use in your approach. I couldn't read your paper in detail, but I understand you use Cartesian rectangular coordinates, right? And then, even so, you use a diagonal W matrix of weighting factors. My concern is that, as professor Chow [3] has shown us, even PMUs may generate bad data, so at some time you have to use some statistical tests to detect that and so we have to be very careful with the statistical properties. And since what you actually measure is the magnitude and phase, when you translate that into rectangular coordinates, actually it is sort of a not trivial assumption to consider that the measurement errors are decoupled. Actually there is correlation. So, in that case your W matrix would be block-diagonal instead of diagonal. Would you comment on the impact of that? I think this is really an important issue.

M. Glavic: Regarding measurement weights, as I pointed out in the presentation, for the moment we are not doing any systematic tuning … We are really trying to test the algorithm to see if the algorithm works and provides meaningful results, using some heuristic weights for the SCADA vs. PMUs. And I fully agree with another point that you raised: in these formulas and the results that we presented we are using measurements that are last recorded PMU values. However, there is certain number of PMUs that are collected in between state reconstruction and one of the possibilities that we exploit all these measurements in some systematic way, possibly to tune weights for the PMUs. But for the general tuning of the weights, it's work to be done.

J. Chow: May I add a clarification? Antonio, the original data in the PMU, the FFT process, actually calculates the rectangular coordinates quantity. So, people can get phasor quantity or the rectangular quantity from the PMU. You either have one or the other

Louis Wehenkel (University of Liege):_I also have a question for Mevludin Glavic [1]. In your presentation and in the paper you use refreshing time of one second and I was wondering, because with PMU measurements you can get much higher rates. So, I was wondering if you use smaller refreshing delays, whether this input would increase the accuracy of your estimator and how much, how far can you go in that direction?

M. Glavic: Actually what we are doing every second is that we perform state reconstruction every second. But in our simulation, we assume that we collect PMU measurements every 0.1 second. So, of course there is a computational issue that could be associated with this methodology, regarding its application to a large scale system. In this stage what we are thinking is that it is not necessary to apply our methodology to the whole large system. We can use it for part of the system and running that at a faster rate. So, of course, this dilemma of running the state estimation more frequently also requires that we have a faster algorithm to do that. So, in this stage we are thinking of applying that for a particular part of the system and to run it at faster rate. But PMU data are collected at a rate of 100 milliseconds in our simulation. And we expect some improvement in that respect.

Sandro Corsi (Italy) I refer to the second paper [2] on the instantaneous computing of the voltage instability indicator. I really enjoyed your introduction, because you stressed the point to reduce the computing time. In our common paper with Glauco Taranto [5] we studied the problem and stressed the point to minimize the time interval, in which to identify the Thevenin equivalent; otherwise this identification is not good. Probably I was not able to follow well your presentation to well understand the conclusion. One thing is to minimize the identification interval in a way to produce the minimum interval. That was our effort. But the step to move from this interval to the instantaneous computing is a big not understandable step. So, probably I don't get something of your paper, or probably your assumptions about the output of the PMU are different from what are assumed in an iterative procedure for identifying the voltage instability indicator. Something is not clear to me. Thank you for clarifying.

Anurag Srivastava (Washington State University)_In distributed voltage stability algorithm the assumption was $\Delta ts=0$ and we are not saying that it would be very accurate, but in the disturbance our results show that Thevenin equivalent with estimation will not give you a good result anyway. So maybe you follow the $\Delta ts=0$ and then calculate, which is OK, still producing some result. For a wide area, there is no assumption here, so the only thing we are doing is get the PMU data and then use the network information Jacobian matrix to compute, or generate pseudo-measurement. And that pseudo-measurement can be used with enough measurement and we then can again calculate the Thevenin equivalent directly. So, these two are basically the procedures to do that.

Costas Vournas (NTUA): My question is also for Professor Anurag Srivastava [2]. First, I saw in your presentation some statements that I would like to challenge. You say that for large disturbances we cannot do much and that power flow based approaches are not efficient. I know of instances where you have on-line voltage security assessment based on a detailed system description that is operating. So, I think this is not a problem that is out of reach. I mean, it can be easily solved. Of course I understand that you follow a different approach, but I should make this clear. Thank you.

A. Srivastava: Thank you for your comment. My statement was mainly for PMU. We performed very comprehensive PMU testing in our lab and we know that in the presence of large disturbance the PMU will not give you a good performance. So, if the phasor estimation is not correct, anything based on that will also be not correct. So, basically, voltage stability will not be good based on phasor, that was our statement about that. And for power flow I said that right now we have quite good computation and we can really calculate very fast but again, if you are using the power flow approach, you have to do a state estimation, you have to get the data and then apply the power flow and then the iteration technique. So, it will work, but can we do better than that? So, that's what my comment was.

Elizabeth Ratman (University of Newcastle): My question is for Mevludin Glavic [1]. Have you considered the SCADA measurement accuracy relating to transducer accuracy, sampling rate, data compression like deadbanding? I suppose this is necessary when you are going with the state estimation.

M. Glavic: At this stage not. But of course we are planning to do that.

Ian Hiskens (University of Michigan): First question is for Dr. Glavic [1]. In the algorithm that you are proposing, it seems that you are using older estimates to compute new estimates, along with new data of course as well. Is there any guarantee that you do not introduce some bias? So, if you had bad data that biased an estimate that you then used in the subsequent time step, you could get some propagation of that bias into later estimates. Or is there a guarantee that it does not occur?

M. Glavic: There is no guarantee, except that we have some simulation evidence that with this recursive computation of the pseudo measurements (that are replacing SCADA for some time), they show somehow a Kalman Filter effect, so if the bias is present in the measurement, it somehow dies out. Of course in the four steps it will not completely die out, but we certainly have at some stage to compare our algorithm with the extended Kalman filter, which is more natural formulation for this. So let's say my short answer is that there is no guarantee, but we have some simulation evidence that it has some Kalman filter effect on the bias, if it is present in the SCADA.

I. Hiskens: Thanks. And may I ask another question for Joe Chow [3]? I don't work in PMU stuff, but working with colleagues in industry in the west coast, it seems that the ability to obtain PMUs is straightforward because every digital relay these days has that capability. The issue becomes one of cyber security; that they are not willing to have digital protection connected to a communications network that is vulnerable in the sense of passing information across the substation fence. So, you mentioned in your presentation that it is difficult to install PMUs. It seems it is easy to install PMUs but it is difficult to get the data available from PMUs. Could you comment on that?

J. Chow: If you have certain kind of digital relays it is easy to put PMUs on it. Now the general comment on the cyber security issues of PMU data is that most of the companies already figured out how they upload PMU data from the substations to a central data concentrator. Normally, they have their own company network to do that. This is just like any other data that you have. There are firewalls, and so on. So, those data entirely stays within the company. On the other hand, once the data is collected, then it will be sent to the ISO or DSO. And this is the part where the data is exposed to the wide world, basically the internet. But they typically use EPN, they have T1 lines and so on, they have not gone to encryption yet, but I suspect it may be coming soon.

Rodrigo Ramos (University of Sao Paolo): My question is to the last presenter [4]. I have paid attention to your conclusions mainly, and one of them has struck me as very important. The fact that the delays introduced by the PSS and PODs can make the system unstable, if you add them into a control loop using PMU measurements. It's a well-known fact from control theory that depending on the amount of the delay of the control architecture, the optimal control can be a decentralized one. So, I would like to hear your comments on that. From your experience in these cases what would be the best solution for that? To have a hybrid set-up, or to try and reduce the delays in the communication links to make the centralized control possible?

Muhammad Almas (KTH)**:** Thank you for the comment. Well, there is one installation of a POD somewhere in the Northern Norway and what they are using is fall-away logic. So, if there is a large delay in one of the wide area measurements, they simply switch over to the local measurement. So I would say that could be the answer that if there is a relatively large delay in one particular measurement coming from the WAM system, then you should simply switch over to the local measurements, because they are always available.

R. Ramos: OK. Just a quick follow up. If you switch to the local control, as some type of back-up control, are you sure that you tested all possibilities of switching and these interactions will be stable? Would render a stable system? Because, that of course can be a major problem.

M. Almas: That is true, because when you are changing to another measurement, another signal, you need to re-tune your PSS or POD, for sure. But an optimal solution to it would be to use a mixture of the two signals all the time, to the PSS and tune it in that way because in that case, even if you lose a wider area measurement, you can still get a best effort service from the PSS, from the local measurement at least.

R. Ramos: Thank you.

Glauco Taranto (Federal University of Rio de Janeiro): My question is to Professor Srivastava [2]. I just want to bring back the point that was raised by Sandro Corsi. We may be overlooking something here, but looking at the paper, you have a two-bus system in the Thevenin equivalent, so the Y_{bus} is a 2x2 matrix and you are assuming that you know the Y_{bus}. And then you compute the Thevenin voltage. Is that correct?

A. Srivastava: That's correct.

G. Taranto: So you can compute that. Thank you.

Thanos Koronidis (IPTO): All the papers and the presenters are to be congratulated. The topic is also very interesting. Unfortunately in Greece we have only two PMUs installed. One in the area of Athens and the other in the area of Thessaloniki in the North, where we have all the interconnections. Fortunately, I got the information this morning that they are going to hook this information from the PMUs to the SCADA, I do not know how they will do that. Unfortunately again we cannot use them in the state estimator, because the state estimator is 20 years old, so we cannot make use of this. But anyway, the system of PMUs in Europe, including those two, are being monitored, observed I would say, centrally in Switzerland, by Swissgrid. So, from time to time we get a phone call from a guy named Walter Sattinger from Swissgrid that says: "have seen that the angle between North and South in your country has been increased. It is typically six degrees and now it is twenty something. What is going on?" And then we detect and we tell him that one of the 400 or two of the 400 kV circuits between North and South have been switched off and this is an explanation. And then I come to my question. One of the very basic uses of the state estimator is to provide a sound starting point for running first load flow, which will allow you to run the contingency analysis after that. If you don't do that,, if the state estimator blows, you cannot start the contingency analysis. I am not talking about exotic things, area oscillations and staff like that. And sometimes our state estimator blows because of a topology error. So, my question is if you are aware of algorithms, or if it is already solved, ways of using the PMUs in the state estimator, in the topology processor, and detect status circuit-breaker errors? "On" Instead of "off" and "off" instead of "on". This is my question to all [1]-[4].

M. Glavic: Let me be the first to answer your question. I am aware of some publications, some works on using PMUs to detect topology errors. And we can be in touch and I can provide it to you. But it is not directly related to our work. In our work we assume that the topology is known. But another point that you raised is that you have only two PMUs. And of course you will not change your existing WLS estimator. What we propose is that we need the change to be introduced in the WLS formulation. But actually you just confirmed that we were right, on the good track, saying that not enough PMUs are available…. And by the way we believe and we will test a so-called "extreme case" where we have no PMU and in principle this should only work with the SCADA. Or with one PMU, two PMUs, etc.… The more PMUs, the more accuracy we expect. And this is one of the objectives that we said: That you have a scalable method able to accommodate different PMU configurations, but also different SCADA.

J. Chow: Just to add something to the answer. Topology processor is truly a challenge in the weighted least squares state estimation process. I have seen, I have actually played with these things, commercial products in real control room and when you know that there is a line that already switched out, the operator has to acknowledge that the line is out before you upload it to the state estimator data processor. So the natural thing is, I was sitting in the back and I was thinking: OK, let's push the topology processor and it just won't converge. Now, how do we go around it? I am of course talking only about the phasor data, only state estimation. A state estimator like that you can always count on about 1% error. Anything more than that, something is wrong. Either line switched out or data were no longer available. And this will be only limited to the high voltage system. Because when you get everything, when data estimator has everything, and there are lots of these inconsistencies in the low voltage, this can create all kinds of silly things that if you apply a topology processor all the time, the state estimator will run for ever, it will not converge.

A. Srivastava: Just a quick comment. If you have enough PMU, you can send switch status. If the state estimator is giving you high error, you can send a switch status. IEEE standard allows to send a user defined input. Of course you need a flexible design for communication, and also for PMU. I am working on that project right now.

M. Glavic: Just one more piece of information that just came to my mind is that I could refer to recent work by Overbye that is very interesting and practical in my view about detecting the topology change with limited number of PMUs.

John Kabouris (IPTO): I am not an expert. I have some experience in monitoring the oscillations in Europe by the PMUs. I think it is really a break-through. I think that with this technology we will have a lot of such devices everywhere, so a lot of procedures will change in protection, in estimation, maybe it will be state confirmation in the future. My question is why do we go so slowly in that process? I think the problem is in the telecommunications and standardization of these devices. And I would like to know to your opinion, to your knowledge, if there are any activities to standardize the PMUs. I think it's a very important step.

Chair: Unfortunately, we have already exceeded the time allocated for questions and discussion. Let's thank the authors

References

[1] M. Glavic and T. Van Cutsem, "Tracking network state from combined SCADA and synchronized phasor measurements," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

[2] S. Biswas and A. Srivastava, "A Novel Method for Distributed Real Time Voltage Stability Monitoring using Synchrophasor Measurements," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

[3] S. Ghiocel, D. Dotta and J. Chow, "Applications of Synchrophasor Data to Power System State Estimation and Control," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

[4] M. Danielson, L. Vanfretti, M. S. Almas, Y. Chompoobutrgool, J.O. Gjerde, Analysis of Communication Network Challenges for Synchrophasor-Based Wide-Area Applications," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

[5] G. Taranto, C. Oyarce and S. Corsi, "Further Investigations on a Phasor Measurement-Based Algorithm Utilized for Voltage Instability Awareness," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.