# Oral Discussions on Session: "Synchrophasor Applications" – Part II

Edited by Costas Vournas and Tasos Bakirtzis

Chair: Naoto Yorino (Hiroshima University, Japan)

## Abstract

This paper contains the second part of the transcribed oral discussions of Session "Synchrophasor Applications" of the 2013 IREP Symposium-Bulk Power System Dynamics and Control Sunday, held on Tuesday afternoon, August 27, 2013. Papers [1]-[3] were presented.

## Discussion

**Chair**:
I now open the floor to questions.

**Thierry Van Cutsem** (University of Liege)**:** I have two remarks and one question and they are directed to the second presentation by Glauco Taranto [2]. First of all, I would like to elaborate on the comment of Costas Vournas in the previous session [4]. I do believe that PMUs are most interesting to detect the situations where the system is going to evolve to instability after a large disturbance. I think Costas made a comment on this and I would like to just go in the same direction. Your work is basically showing this on the Nordic system, in your presentation. By the way, I would like to stress that there is an IEEE Task Force, that you mentioned I think, on test system for voltage stability. This is giving the details of this system and we plan to also provide trajectories in the form of time series of complex bus voltages, so the researchers can use this as input of realistic post disturbance instability scenario. A general comment, this is my second remark, measurement vs. model-based detection: So, model-based is generally more demanding. We need to concentrate data, we need to use a model to anticipate the system, but in our work using sensitivities (where by the way we just have to solve one sparse linear equation each time we want to compute these sensitivities), we found that anticipating the over-excitation limiter was giving a lot of information. It means that if you think that a machine is going to be limited, when you compute the sensitivities you already use the equation of the limited machine to carry out your small signal stability analysis. Measurement based detection, like your approach, is basically much less demanding in terms of calculation effort, but I have the feeling that you feel the effect after the fact. I mean, after generators are being limited. You have to wait for the generators to be limited in order to feel the effects through an increase of the Thevenin impedance. This is my understanding. So, finally to go to the question: referring to one of the last slides, in the Nordic system that you simulated the system was collapsing at 640 seconds. I'll check in the paper. Am I right that the detection point, where the two curves Thevenin impedance vs. load impedance cross, is something like a time equal 620 seconds, which is 20 seconds before the system collapse? Can you elaborate on the anticipation capability of the technique there?

**Glauco Taranto** (Federal University of Rio de Janeiro)**:** Thanks for your comments Thierry. Actually, you were one of the driving forces for us to try to test the algorithm for large disturbances. That's why we came up with the Nordic 32 system. We computed the impedances when things changed. That's correct. You cannot anticipate that. You could use other information, other measurements, like field current measurements, you could also use that. As soon as you cross that line, you could also issue some alarms, something like that, but it's true that we just can compute the impedances when things change, otherwise we cannot compute. There is no anticipation. The anticipation is that you are seeing the impedances are getting together, so you can have a threshold of this difference of the impedances and issue an alarm, so you decide what to do, you curtail load, you block the taps, so it's up to you what to do. You can also take into account, as I said, some other measurements to help you in this decision, like the measurements of the field currents. Sandro [2], do you want to add something?

**Sandro Corsi**: Thank you for the question Thierry. As you notice we use a very dynamic model when we analyze this indicator. Why? Because we are convinced that the dynamics of the process strongly impact the voltage instability when it happens and obviously the indicator that you have seen takes into account what is happening in the process and because this Thevenin equivalent, is an equivalent taking into account all the under-way process, including the effects of the over-excitation limiter and the

978-1-4799-0199-9/13/$31.00 ©2013 IEEE

on-load tap changer. But apart from that, I want to say that for many years and still now I also confirm the point that the information about the operation of the over-excitation limiter including the on-load tap changer is additional information to anticipate something about what is happening in the process. Answering your last question we all obviously agree an indicator is useful when it anticipates the instability. If the indicator gives information when the collapse has happened, it is not of interest from a practical point of view. So, obviously the tuning of the proposed algorithm can be made according to grid conditions, characteristics and so on, in a way to provide the information on time for what is needed to allow the timely operation of the protection.

**Anurag Srivastava** (Washington State University): My question goes to the second presentation, Professor Taranto [2]. It is good work. The only question I have is: have you compared your predictor-corrector with least squares and what benefit you get in terms of convergence and time?

**G. Taranto**: Yes, we did this comparison in this paper when we included the noise. So that was the comparison we have, but I didn't check convergence problems in the least square approach. You are going to have problems of convergence if things don't change and you still keep trying to identify. So you are going to have problems because your matrices will be not invertible. In our algorithm, we don't have any kind of matrix inversion, so you are just doing some logistics here. You are just tracking and there is no convergence problem in our algorithm. But I know that you can have that in the least square if things are not changing and if you are trying to continue to identify. Did I answer the question?

**A. Srivastava**: Yes. Thank you.

**Alex Papalexopoulos** (ECCO International): I see a lot of progress from this session and the previous one in the state estimation area. This is very, very good. The question I have is: why you think this progress has not propagated into the vendor community? ISOs are willing to spend hundreds of millions of dollars on market systems, I come from the market perspective, and state estimation and EMS has become so important because they drive the real-time markets: the 5-minute market that ISO is running in the US. The complexity of the market systems has increased substantially. There is a regulator out there, who is forcing ISOs to make changes and a lot of money is being spent to implement those changes. However the EMS, the state estimator, from the vendor community has not kept the pace of complexity to support the markets. So the gap of sophistication between markets and state estimation from the vendor community again is increasing. And this is a serious concern for us, from the market's perspective, because we really want the best possible state estimation to drive real-time markets. But this is not happening. So, the question is: why those good things that you guys produce don't find their way into the vendor community? I don't know if we have anybody from the vendor community here, to help us with this, but it is a serious issue. We don't see state estimation improvements propagated; find their way into an actual operating system in an ISO environment. And as a result we may be seeing in the future some impact on real-time markets, where lots of money change hands daily. Thank you.

**Antonio Simões Costa** (Federal University of Santa Catarina): Yes, actually I think there is some latency until those new concepts arrive at the power industry. I remember in the '80s when we started working on orthogonal state estimators, it took some time, but then later on this orthogonal state estimator came to the industry and they are one of the standards nowadays. One important thing is, I think (and our work was in that direction), try not to change the paradigm radically. So, if you notice, the proposals that we made try to keep unchanged the existing state estimator and then have just another estimation module that you can plug there to improve it. I think this is one way that we can maybe make those ideas more palatable, more easily to be accepted by the industry. Other than that, in my country, in Brazil (this is very fresh news) the National Operator just last week has decided as a new policy to install PMUs all over our network and at high voltage. As Joe Chow [4] commented before, at low voltage level we have nation-wide coverage with PMUs. This is a university project in my university, Federal University of Santa Catarina, and we have at low voltage complete coverage of all regions. We have, I think, 17 PMU installations in universities all over the country. And the National Operator became interested in that, for instance for disturbance analysis, and they are using these data for post mortem analysis and things like this. So one thing is, I think we have to strive to provide ideas that are not too revolutionary, but you can take advantage of the new technologies still without changing the paradigms too much. Maybe in another pace we should continue to work towards better algorithms, for instance, this tracking estimator that Mevludin Glavic [4] presented today. I think this would be a good idea for the future also. So this is what I can comment on your question.

**Costas Vournas** (NTUA): I have a question for Glauco Taranto and Sandro Corsi paper [2], but also it applies to all other papers that were presented up to now that use the impedance matching approach. We published a paper, two IREP conferences back, in 2007, in Charleston with my then graduate student, Dr. Sakellaridis, where it was clearly shown that impedance matching in one bus can only happen after the instability of the complete system, because it is actually monitoring the diagonal element of a matrix; only one load changing at a time. So I wonder if there is any comment or any indication that this result, which we had shown there, is wrong, so that you can have maybe impedance matching before system instability. Do you have an indication on this?

**G. Taranto**: I agree with you that monitoring just one bus is not a good thing to do. The problem is that - Alex Papalexopoulos just raised the question of state estimation - you have to have a good state estimation in order to have a good Jacobian matrix. Otherwise, you cannot get good sensitivities. So, we are trying here to use what the technology is bringing us so we may spread the PMUs along the buses that you think that could be the critical ones in some situations. You don't need to just plug in one place. You just spread the PMUs and the critical buses in that scenario will appear. And then you only need to go through the good state estimation and so on. I don't think we do a good Jacobian in Brazil. I ask them: do you rely on our Jacobian? No, they don't. So if you still fear, there is a technology that, even though it is approximate, can give you reasonable answers. So, that's my point of view. But I agree with you. If I have the models, of course I can do better than just measurements in one bus.

**S. Corsi**: The algorithm works according to the local measurement. And this is the starting point for any kind of wide-area application and, if you want, there are two points to be improved in the made proposal. First, what could be the best selection of the buses in the power system to locate PMU and the related wide area selection algorithm, so as to have good observability of the phenomena in the process? And second, as we published in another paper, we also showed that having some PMUs with the same algorithm working in different busses, you recognize whether the phenomena is growing, where are the buses that reveal the incoming instability and so on. When you have this kind of identification you can begin to alarm the operator and so on, you can see the voltage instability process trend and the points mostly affected. The trend can be towards recovery or not, but anyhow you can see what is happening in the power system up to reaching a given critical situation, which as I said before, is related to a given instability threshold for the operators, according to experience and can be defined for each grid and so on. But I want to say that in principle the starting point is the PMU use, those for WAMS but provided with an algorithm that will allow, when their information is centralized, to have a clear view of what is happening in the overall power system.

**Chair**: Time for a final question or comment.

**Claudio Cañizares** (University of Waterloo): Alex Papalexopoulos raised a very interesting question. And I like it because it is reason for discussion and not just discuss "how you did this or you did that", but how is this applied in industry. I fully agree with you that all of this should be making the way into markets, I fully agree with that. Antonio Simões Costa [1] mentioned that it takes latency. Yes, it took 20 years for the industry to take the PV curves into full operation. I have two particular personal experiences with this particular approach, working with ABB for the ISO of Ontario, trying to improve the dispatch of reactive power. We looked at the problem, we worked with them, ABB was waiting for the ISO to tell them: "Yes, let's take this to improve our energy management system". But the ISO had two problems. First, that it only saved about 2 million dollars a year, so they didn't consider that significant, because that would require from them to retrain the system operators to redo the management of the system again. So that was a major issue for them. The second problem came from the ISO. The ISO determined that they would lose about 10 million dollars per month in redispatching generator units because they don't compute properly the transfer capability of the system, since they ignore system dynamics. So what did they do? They set up a project, which is operational now, in which they basically run full contingency analysis dynamic simulations to actually compute the limits. Instead of off-line, on-line. So, it depends on the savings, the complexity of the problem and also the policies behind it. Who is willing to pay for this.

**Chair**: Thank you very much.

## References


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[3] G. Wang, C.-C. Liu, N. Bhatt, E. Farantatos and K. Sun, "Observability for PMU-Based Monitoring of Nonlinear Power System Dynamics," Bulk Power Systems Dynamics and Control – IX (IREP), August 25-30, 2013, Rethymnon, Crete, Greece.

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