G-PST/ESIG Webinar Series: Impedance Scan Tools for Stability Analysis of IBR Grids	
Question	**Answer**
Hi, have you seen oscillations where there is a coupling between negative and positive sequence?	Most oscillations involving IBRs at frequencies below 100 Hz will involve coupling between the positive and negative sequence impedances. Hence, we have seend this behavior and we need to consider that in the analysis. If you will see the sequence-domain impedance responses I presented for analyzing the 2.5 Hz mode during the webinar, it included full 2x2 matrix considering coupling between the positive and negative sequence impedances.
Just to clarify, does the tool inject frequency components individually, one at a time? or multiple frequency components at once?	Yes, currently the tool injects frequency components individually, one at a time. Injecting multiple components at a time is possible to reduce the scan time but that might reduce the scan accuracy because of coupling frequencies present in IBRs.
How could the impedance of negative damping be reliably measured? I suppose the equilibrium for linearization cannot be maintained in EMT simulation.	That is the reason we start scanning with a stable system. Because the tool scans the impedance response of both the IBR and the network at its terminal, it can estimate the damping of the system in the absence of the IBR, even if its negative.
Shahil- removal IBRs to get stability is a bit extreme? IBR in different control mode or operating point can be sufficient & impedance method should inform that	We are not talking about removal of IBR for grid stability. We are talking about approaching the problem from a different perspective - instead of asking a question how connection of all IBRs is impacting the stability, we are asking how removal of one IBR is impacting the stability. We are analyzing the same system in both case and will arrive at the same conclusion how different IBRs impact stability, but one approach is scalable and the other is not.
Does the method apply to an aggregation of a sub-network?	Yes, we can place the impedance scan block at any poin the network and there by achieve aggregation. For instace if we scan impedance at a feeder substation, we are aggregating the effect of all DERs in that feeder.
agree impedance scan tool focussing of EMT analysis= powerful approach-we do this also; important scan method needs to align mode with EMT time domain; did it?	We are able to accurately find modes observed in EMT time-domain using the impedance scan tool. It also shows how different IBRs are influencing a particular mode.

It is common that IBRs use switched capacitor banks to meet power factor requirements. Can your tool account for these impacts of various cap bank statuses?	Yes, if we perform scan with and without the capacitor banks, we can see how they impact system stability at different frequencies using the impedance scan tool.
How do you measure the impedance of a saturating transformer whose inductance is varying dynamically?	In such case we have to be careful that the perturbation magnitude is not very high and we are measuring the impedance of only a specific operation point. If the system behavior, for example of a transformer, is varying even for a fixed operation point depending on instataneous voltage level, the impedance scan tool will capture the average behavior.
How to select the magnitude of the perturbation signal when you say "high enough". How to consider the trade-off of nonlinear and SNR during measurement?	This is more of an engineering judgement. When we perform scans, we make sure that either voltage and current perturbation levels do not increase above 5 or 10%, but at the same time, at least one of them is not below 2%. Sometime, the IBR impedance is very low at certain frequencies we need to decrease the injected voltage perturbation to ensure that the current perturbation is not too high.
Can you provide more details on modal impedances?	Modal impedances are basically eigenvalues of the second-order bus impedance matrix measured at different frequency points. They are obtained from the impedance scan responses of the IBR and the network.
what is the criteria to model the grid? I mean, how detail or how many buses away from the IBR?	We are not addressing this question here although it can be evaluated using the impedance scan tool. We simply take the whole system model either in PSCAD or PSCAD-PSSE cosimulation platform and perfrom the impedance scan.
Does the scan function apply to a converter with non-standard structures of outer loops in addition to current loops?	The scan does not care about the control structure. It can operate with even black-box models of IBRs. We aim to look at the behavior of IBR at different frequency from the outside, independent of the internal control structure of the IBR.
The impedance scan tool is currently in simulation. Is incorporating this measurement capability in real life field deployed ibrs feasible or desirable?	We do measure impedance of real wind turbines and inverter at our lab facility using a multimegawatt grid simulator. It is desirable to have a portable grid simulator type device that can be taken to wind and PV power plants to scan their impedance responses, but that is a big undertaking and we might have to wait until the point when such investment is justified.
Have you tried scanning a grid impedance with the grid source system?	In simulations we do scan impedance of the grid as well as IBR. In the impedance measurement system at NREL, we have not yet scanned the impedance of the grid that supplies us. This is because we generally perform stability experiments with a controlled grid simulated inside RTDS for PHIL experiments.

Slide 22 - how do these compare with assuming the impedance is a function of the electrical characteristics (ie filters, transformers etc)	Above 200 Hz or so, the impedance is a function of electrical characteristics, below 200 Hz, it is function of control parameters, topology, and mode.
Nice talk. Thank you. I have following quaries 1) what is the prefered sampling time for impedace measurement	We use 0.1 Hz resolution below 10 Hz, 1 Hz resolution between 1 to 60 Hz, and more than 5 Hz, above that frequency. The sampling time of our measurements is 50 microseconds, but one can use higher sampling time for getting impedance scan at low frequencies.
Do we get an confirmation of resonance identified from impedance scan from time domain simulation?	Yes, we can create some transient and see the identified oscillation modes. The tool give extra information on how each IBRs is impacting the identified oscillation modes.
Under highlyy unbalance system, positive sequence and negative sequence important right, then positive sequence analysis still give accurate assesment ?	Positive sequence and negative sequence dynamics are coupled throuh frequency cross-coupling even in balanced conditions. This is different from the steady-state coupling. We need to conider second-order impedance matrix that considers coupling for the analysis for oscillations problems at low frequencies, below 100 Hz. High frequency resoannce problems can be analyzed using positive-sequence impedances without considering coupling with the negative sequence impedance.
Could the measurement be done to an IBR in real operation connected to the grid? And is it possible to take the frequency response separately for IBR and grid?	Yes, if we can build a portable perturabtion injection device that can inject small perturbation current at a POI of an IBR, we can obtain impedance responses of a real IBR during operation. It is possible to perfrom scan for IBR and grid seperately in simulations, but we need to make sure that when IBR is removed, it is replaced by an ideal current source to preserve the operation condition of the grid.