Question Text	Answer Text
Would the dMW/df value also depends on available headroom, in slow active power service category?	In this framework, the available headroom should be considered for all resource types for the slow active power service characterization. For example, a synchronous machine might be able to transiently exceed its maximum active power rating, but would be brought within a normal range over time. An inverter-based resource such as a BESS connected via power electronic interface would have a maximum power rating that would be applied in fast and slow timeframes.
How would a VSC-HVDC line/converter be considered with respect to the stability service? What about an LCC-HVDC?	The framework should be able to handle HVDC. Especially in the context of a single terminal. Details, including VSC vs LCC, as well as bespoke controls would be important in the characterization. We have not thought about the active power coupling between rectifier and inverter, which will complicate things.
Did the study look into how the GFM-BESS can help improve the system frequency response for NERC PRC-006 UFLS requirements?	The study did not consider UFLS requirements per-se, but such requirements can be a part of the acceptability criteria that determine the need for services. Increasing levels of active power services would result in the system having more margin from triggering UFLS.
Why are GFBs providing more services than GFLs if both are rated for the same apparent power? Is it because there are more GFBs in the network?	This is a key point. For the same apparent power rating of resources (for instances, GFL and GFM), it can (and often will) have different levels of grid stability services, depending on the controls and configuration of the resources. In the study the two kinds of IBRs added to the network were selected to be 'bookends', where the GFLs were considered to be legacy units that do not provide any active power/frequency or reactive power/voltage services. With proper control pathways enabled and proper control settings, it may be possible to obtain similar levels of services with different IBR control architectures. The framework developed does not need to 'know' what kind of IBR it is apriory, and in fact some of the existing GFL units in the network did provide some active/reactive power services (and were captured in the characterization)
Based on your studies, what is the optimal headroom for Regulation services?	We did not attempt to define this. However, (as was recommended in some recent work for ERCOT), only the headroom necessary to allow full response for a 1% frequency excursion buys primary reliability benefits. For resources with conventional 5% frequency droop, more than 20% headroom is wasted in our context.
When the unit is operating near its minimal output, what is the recommended range at which the headroom requirement should be discontinued?	If the notion here is that at minimal output the full capacity of the unit is available, then a headroom requirement per se may not play a role, but a headroom limit would still apply. Here, especially for BESS, the available SOC may need to be considered.

How do solar plants maintain headroom without overbuilding or utilizing storage, given their operational differences compared to wind systems?	Solar plants can operate in a derated or curtailed mode if desired (or economically viable). This operation mode would bring about headroom, as long as the available irradiance does not change (similar to wind plants whose headroom is determined by available wind speed).
The mismatch in the need and provision of services amongst groups makes me wonder if "groups" are defined correctly - can you remind how groups were defined?	The groups are defined using a hierarchical clustering method based on the measured voltage deviation during short circuit fault analysis. The goal of the grouping method is to identify buses that we expect to exhibit similar dynamics. It's important to note that the individual groups are not treated as 'islands' when it comes to services. There can be a mismatch in need & provision of services within a group that is resolved by the transfer of services from another group. This is an area we would like to explore in future work in order to better quantify the services contributions between groups.
in slide 16 why the Rocof was calculated over a long time frame? it should be calculated over the first 0.5 to 1 second	After a significant disturbance like a sudden loss of generation, the response of the system is very complex, having fast (~0.1s) local dynamics and slower (seconds) system-wide dynamics. The RoCoF and frequency deviations for each time-frame (local v. common-mode) are different. The red-dashed line on the plot indicates an estimation of the common mode, whose RoCoF has been evaluated, and it still considers the linear part of the frequency devitation signal, as you would expect from a RoCoF metric.
Regarding Fast Active Power Services, SM was better than GFM. Why do you think this was the case? Does GFM control (say, amount of virtual inertia) affect this?	One aspect in the fast timeframe are the power and current limits that constrain the response from IBRs (including GFMs), whereas the SM response does not have such hard limits in the fast timeframe and is governed by appropriate impedances. Though, the IBR control parameters relevant to the faster response do also play a role in what that IBR would provide in the fast timeframe.
Could this provision/need ratio be used to quantify the cost of the stability services, such as in ancillary service markets? If yes or no, why or why not?	This is definitely a potential application of the services framework. However, the framework is not yet at that stage and more work is to be done, especially from the perspective of identifying the absolute quantity of services that are needed/essential.
Have you considered incorporating insights from model-based studies on frequency response coordination to complement your simulation-based findings?	If by model based studies the reference is to analytical frameworks of the entire network, a comparison with such a framework can be future work. A potential aspect to consider here would be the incorporation of blackbox models, which is presently handled in our framework through the use of data.
Would it be correct to say that this method won't replace the need to do detailed stability analysis for each generator specifically?	Yes. This is addressing a broader systemic need: The requirement to assess the need and availability of an increasingly heterogenous and constantly changing set of resources to provide services. It is not a substitute for focused stability analysis.

What kind of GFM control methodology do you apply, and which one do you think is more reliable for providing these services?	We had used droop-based GFM control in the study, but similar level of services would be possible from different IBR control architectures.
Synchronous machines provide higher fault current and higher inertia. Does it have any advantage over GFM resources ?	The higher fault current and higher inertia from synchronous machines are reflected in (typically) higher active power services in the faster timeframe, and in that sense, they are advantageous. Though, when selecting between what resource to install, GFMs (and GFLs also) may have other advantages, and it may be possible from particular devices to achieve a higher active power depending on aspects such as using higher capacity switches, short term higher rating. This aspect was not studied separately in this study but could be added in future work.
There have been instances where IBR's provide FFR followed by a cool-off period that could harm the grid. How does this framework address this issue?	If this question is referring to the inertia-like response offered by some wind turbine vendors, where there is a brief increase in power (under the banner of FFR) that persists for several seconds, during which the wind turbine drivetrain is slowed, and after the initial boost in power, there is a dip in active power output from the wind turbine as the energy is returned to the wind turbine drivetrain, then yes -- this framework would capture that response. It would have the effect of shifting energy contribution from the slower time-frames to the medium or faster timeframe. This would be captured in the resource characterization by having a higher active power service provision in the medium time frame and a reduced (or possibly negative) active power service provision in the slow timeframe.