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Breakout Session #1 – Defining "Hybrid"?

These notes are from the three breakout groups compiled by Jenn, Kaushik, and Matt.

Sub breakout group 1

1. Agreement on defining a taxonomy of hybrid systems
   - Generically and globally applied
   - Including all the possible variations of hybrid systems
     - Gen+Gen, Gen+Storage, Gen+Energy conversion…
   - Then focusing on the scope of IEA Wind TCP Task 50
   - Focus on both on-grid and off-grid
2. Important keywords:
   - Co-located
     - Behind single substation
     - Same PoC vs PCC
   - Co-operation / Management of the assets together
3. Cost saving/value maximization
   - Functionalities, fit for purpose
4. Microgrid vs HPP
   - Scale (microgrid is very small)

Sub breakout group 2

1. Florin: Transmission systems have different definitions in different countries >> use voltage level instead.
2. Asma: Australia defines hybrids based on whether BTM or not. Majority of Australian HPPs are off-grid in order of megawatts (eg, 300 MW).
3. Das: Whether we should develop a global and generic definition or specific for our TF.
4. Lev(?): Talking about BTM ownership and coordination should be defined.
5. Dominic: It's better to have a generic definition and we can define different types for HPP
6. Florin: Agree with Dominic about having a higher level look. Looking from AS point of view, we can differentiate from VP. Co-located should mean being connected from the same substation.
7. Kaushik: From the previous PW, how about an off-grid one?
8. Richard: First define the hybrid system which has a coordinated management. HPS can be co-located or virtual but will go on co-located, later on, we can talk about coupling. Ownership is irrelevant as long as we can have agreement.
9. Das: Having reduction of cost should not be considered as a feature for HPP BESS is expensive.
10. Florin: Everything smaller than 1 kw is Microgrid, otherwise its hybrid system.

Sub breakout group 3

5. What size of hybrid plants should be included?
   - Looking at the utility scale. Not sure if 20 MW is the right side but the grid should be connected as well.
   - Should be a combination of one or more generations with storage and or H2 production. Different technologies.
   - Josina - more than 5 MW project because regulations are different for over or under. Utility scale is 5 mw and over.
     - Wind power plants under 5 mw are "micro" and considered distributed if under 5.
   - Antonia - I think from a size point of view, I don't really think we are talking about small scale. We are talking about really larger systems in 10-100 MWs. Importance of discussion of co-location. Main

added value of hybrid plants is you reduce requirements of the electricity grid. If storage on one side and production on the other then you do not win a lot. Co-location!
- Joanne - From project POV we wouldn't go lower than 50 MW. Turbines are getting bigger 5-6 MW each so if we use 10 then we are already at 50MW.
- Paolino - number would be lower for utility scale. Higher than micro grids but lower than 50 mw in some cases. Difference is very big with the utility scale but grid codes could be very different. Consider islands. Less than 50 but more than 20

6. What does co-located mean?
   - What or when do you consider it to be co-located?
   - Alin - might be integrated in the same point of connection. That's what we are taking into account because we can operate together. Co-location and operation is according to the point of connection. If you speak of different points of connection then operation becomes more complicated because of regulation.
     - Would you consider ownership of asset co-location? Ownership is very important. One thing to build a plant and another to make it commercial. If it's commercial then it's about trading! Ownership is an important aspect as well. Asset management is one thing, but the other is also energy trading! This can be challenging if you have different owners.
   - Antonio - also consider that you do not always have the same owner. Also important is the point of view of the grid. Electrically two points are different.
   - Luis - In the sense that mentions of two different generators is not a hybrid. In order to be hybrid systems, there needs to be a common management. Not necessarily physical but it's maybe electrically constraints and common management is to work with constraints. In my opinion its physical, perhaps its point of connection that makes it a constraint for generation technologies.
   - Chris B - sounds like so far we are thinking from grid perspective, behind the meter, there is use of similar equipment.
     - **Maybe have a follow up survey for different regulations of all countries?**
   - Oskar & Alin - questions related to the guy at Vattenfall. They don't have to be physically located but electrically located. How far apart does this need to be? Electrically needs to be the same point of connection. How far apart? This is a business case question. Can be 10 km distance but also has to be with regulation and business case
7. What can we learn from microgrids?
   - Paolino - We can learn energy management techniques
   - Luis - Other points we could learn from capability of splitting in particular times of grid forming capability. In the microgrid world, this has been done for quite some time. At bigger scale it has not been done
     - Islanding to support critical resources or profit maximization.
8. How are microgrids different from hybrid power plants considered in this task?
   - Paolino - one point is H2. From microgrid POV, you have a genset and use a generator as a backup for the H2 production at higher level. Energy management systems work more or less the same way of scaling of a system.
9. What are the opportunities for cost savings in hybrid plants?
   - Use the same equipment? Behind one grid connection?
   - Antonio - Did a small study of hybrids in US and India and found you have grid connection is one, then equipment such as transformers you do not have to size grid connection so high and ended up coming with reducing rent of land. Have a team to check PV and wind parks and cut costs. You can economic viability by sharing resource and cut costs
   - Alin - O&m costs can be reduced and done together at the same time.
   - Joanne - We optimize hybrid systems for h2 production. We see a lot of complementary characteristics in the production profile on an hourly basis. For us it's maximizing energy production profile for use-case. Smooth load profile and this is the least cost solution in most of our configurations
   - Paolino - With wave energy while niche, you can see if you put base load of wave energy and baseload of wind energy, it is more than sum of the two. Reducing variability of production is the most important benefit to hybrid plants. Providing more firm power.
   - Luis - Technical viability. Many wind farms are installed in complex terrain. Some distance might be good. But the benefits of co-locating in Spain are not ideal because of the topography. Hybrid solution

is more robust to connection of the grid. Hybrid solutions bring more robust solutions to the grid for the future when demand will be more difficult to fulfill. Hybrid systems are better prepared to handle grid constraints.

- Oskar - Complimentary forecasting from this perspective smoothing effect also improves forecast as well. This is another aspect as these parts are motivated so forecasting is also a given aspect.
- Caity - Ancillary service, storage consultant have clients that want profit maximization and compensation not just for bulk energy production, they are looking for other services they can provide in different markets and tax minimization. Hybrids have a key role to play in this space with different policies and incentive
- Michaela - Solar power is not our strong side but we have so much wind in Denmark. Storage part is very key to how to maximize output from wind. Little bit of surplus for solar too but not too key.

10. What about black start capability of a hybrid plant?
    - Antonio - this would be a very important value add for hybrid plants. One point we should think about. This plays into design optimization control of hybrid plants.

Breakout Session #2 – What Technologies?

Sub breakout group 1

1. What type of services should hybrid Power plants provide?
   - May vary from country to country on the basis of preferred services required
   - To play in different markets (energy, balancing, ancillary services), that will also vary from country to country
   - Services have different values based on the location
   - It will depend on the type of technology used in a plant
   - Is it optimal to design HPP for a resiliency market?
   - Energy capacity
   - Ancillary services: Black-start capability, power balancing, frequency regulation reserves, operating reserves, reactive power/ voltage control
   - To maintain power quality
2. What type of end uses/business cases should be considered?
   - Power to users (electricity)
   - Thermal energy (Power to heat)
   - Power to Gas
   - Fit-for-purpose (baseload, peak-load)
   - Energy storage (time shifting is aided by energy storage)
   - Power system damping
   - Carbon capture (use cases)
3. How many types of storage should we include?
   - Depends on the time scale of storage (short, medium, long term), capacity
   - Technology of storage
   - Storage to meet the energy production use case that HPP is expected to provide
4. Should hydrogen as storage and as an end use be considered?
   - The cost of electrolyzer will be the major concern to make this decision
   - Hydrogen can be considered as a chemical storage or as a product
5. What technologies should be excluded for now (Highest vs lowest priority)?
   - Maturity of technology will define the priority
6. Services
   - May vary from country to country on the basis of preferred services required as well as types of technology used in a plant
   - Depends on purpose of design/value proposition
   - Energy production, energy capacity, Operating reserves, Power quality, Blackstart, Power system damping
   - We should keep the scopes broad considering the future opportunities
   - Use cases
   - Electricity, P2X (hydrogen) production, thermal energy (power to heat), fit-for-purpose (peak, baseloads…), carbon capture
   - Types of storage
   - Timescale (very short, short, medium- and long-term) and capacity of the storages will be decided by the use case / business case
   - Storage to meet the energy production use case that the Hybrid is expected to provide
   - Hydrogen can be considered either as chemical storage or as a product
   - Priority of technologies
   - Consider maturity and interest for prioritizing
7. What size of hybrid plants should be included?
   - 20+ MW? 100+ MW?
   - Hard to define technology based solutions around size because it's really about control. Instead define control or technology rather than size-based.
   - It should connect to the transmission system (voltage/control requirement) – some agreement here

- Controls may be different because you're connected to transmission system and have to respond to provider
- If number, maybe not absolute, could depend on other factors, need guidelines
- Economics may decide on its own
- Is there a minimum? Why limit?
- On vs off-grid – defer off-grid?

8. What does co-located mean?
   - Interconnected at the same point and controlled together – agreement on this
   - Common control/owner
   - Connections among generation/storage are not public
   - Physical interactions are important? It depends…
   - A possible numerical criterion on collocation could be with overall average plant energy output greater than (say) 5MW/km^2 (where area is calculated as the square of the largest distance between units).
9. What can we learn from microgrids?
10. How are microgrids different from hybrid power plants considered in this task?
    - Microgrid is a group of consumers, HPP is a group of producers
11. What are the opportunities for cost savings in hybrid plants?
    - Complimentary generations
    - Directly coupling technologies
    - Shared power electronics, controls, BOS, inverters, DC bus
    - Can hybridize existing generation and use same grid resources
    - Shared land use
    - Paper work, admin, etc.
    - Cross-training O&M, optimization and development of O&M
    - Installation timelines, solar faster than wind
    - Ability to provide different "loads" (base, peaking, etc.)
    - Firmness? Less variability
    - Policies requiring renewables?
12. What type of services will hybrid plants be asked to do? What end products will they serve?
    - Part of energy market
    - Part of ancillary services market – frequency, blackout, reactive power, black start, inertia, fault current
    - Power to hydrogen (or other) to market or storage
    - Resiliency?
    - Value to owners, behind the meter use
    - Grid compliance
    - Build out a microgrid/island?

<u>Sub breakout group 2</u>

13. What type of services should hybrid plants provide?
    - Demand response
14. What type of end uses should be considered?
    - Has to produce electricity for the grid
    - Should electricity production be the primary purpose?
15. How many types of storage should we include?
    - consider duration, frequency support abilities
    - Thermo-mechanical: pumped heat, compressed air, liquid air
    - Batteries
    - Hydrogen (storage/end-use)
    - Multiple types in one plant (different time scales?)
    - Synchronous condensers
    - Flywheels
    - Repurposing existing infrastructure (coal to storage)
16. What types of generation?
    - Wind

- Solar
- Geothermal
- Wave (with floating wind?)
- Small modular reactors? Too baseload, so not complimentary? But can be integrated
- or other uses (hydrogen, etc.)

17. Hydrogen as storage and an end use?
    - Is this feasible or does it need to be a dedicated use?
    - Is hydrogen production the primary or secondary goal?
18. What technologies should we exclude, for now? Maybe put another way, what is highest priority vs. lower priority?
    A. Wind+solarPV+(generic) storage (tied)
    B. Wind+wave+storage (offshore?) (tied)
    C. Wind+hydrogen+storage
    D. Wind+solarPV+hydro-pumped storage (salt with desalination or fresh)
    E. Wind+geothermal
19. Does there need to be terminology/consensus around the policy/market portions of hybrids? If so, what does that look like?
    - Where electricity originates matters for tax credits
    - Restrictions on over-building because of cyber security concerns
    - “first take” laws/rules for using renewables
    - What if HPP is a mix of renewable/non-renewable?
    - What's the best metric? Not LCOE? Instead of the cost of valued energy (more holistic view including market)?
    - Interconnection queues
    - Decarbonization value
    - Grid congestion
20. Services expected from HPP differ from one region to another
21. Services have different values in different places.
22. Grid codes and different markets alongside included technologies defines the probable services.
23. Das: Specification are not aim of this task force, but final result will be good start for standards, test guidelines, and certification
24. Lev: Power industries already defined services for us such as blackstart, balancing, operating reserve, power quality.
25. P2X Using power from within the HPP or from the grid is the point of distinction.
26. Dominic: Primary market of HPP defines the value of HPP. Power system decoupling is a hot topic as a service. We should start the use cases first, then define the service accordingly.
27. Hydrogen can be considered either as chemical storage or as a product.
28. Maturity of the technology defines the priority of technology.

Sub breakout group 3

29. What type of services should hybrid plants provide?
    - Stoyan - Vattenfall, in my perspective to provide the ability to participate in energy markets wholesale and balancing markets. To produce energy and sell to the market. Another application is ancillary services, frequency control related services, markets FFR FCR FRR and all different kinds of markets and frequency control services. Reactive power control services. Not all of it but also power shifting and solar and wind power that cannot be exported and if there is a storage capacity, then to store excess power based on resources and sources.
        - Power shifting!
    - Michalea - Actually you covered it very well. System protection as well. Key areas
    - Antonio - two things to add - good with everything above. First functionality typical for HPP is the ramp rate control. Since we have combined storage and generation, we can reduce the rate of change in power production. Second part is, more on the black start capability, since we have storage it is important to participate in bringing up the system. Possibility to bring the system up again, quickly.
        - Grid forming and be able to island different parts of the grid and be a service that can be provided

- Stoyan - basically, ancillary services but also grid code compliant. Interconnection needs to comply with regulations. Grid code compliant! You must comply with this regardless if you are participating in diff markets of asset management strategies. Ramp rate limitations, voltage control, diff things to make sure your power plant is compliant.
- CB - another consideration, is anyone looking at hybrid power plants providing either equity services or social justice service? Talk about this in the US but what about everywhere else?
    - Palino - not really, can you make an example?
    - CB - considering social economic status of those receiving services of power plants and who is getting what power at what rate? Not just maximizing profits but also providing equitable resource for folks
    - Caity - work with that a lot in distributed space.

30. What type of end uses should be considered?
    - Luis - if we limit scope to transmission hybrid plants then end uses are quite limited. Only one can think about the electricity market in PPA. For example, we could think of, if not at transmission level, production of large industries in islands or smaller grids. Large industries? Steel production and think of physical connection to industry
    - Antonio - I think Luis said it perfectly . If we do not only look at transmission, the level of functionality is the topic of resilience. What happens if one section of the grid is not working? Scheduling possibilities is also a functionality we need. What happens if we have cut in lines, how can we compensate with HPP?
    - Stoyan - I do want to underline it does not need to be HPP to offer black start capability. Not quite sure, the wind farm producing h2 does not have grid connection.
    - Paolino - isnt plant making H2 a microgrid?
31. How many types of storage should we include?
    - Storage technology vs storage purpose and use
    - Stoyan - Batteries and electrolyzers to cover electrification to h2, als hydro power. Hydro power could be a possible combination with other sources of electricity.
    - Luis - I think the other and don't need to limit ourselves but mechanical storage, flys wheels, thermal storage as well via solar thermal which comes together with solar thermal storage (molten salt)
    - Paolin - are there torah storage types used in wave energy? Would be the same as offshore wind. Electrolyzer is a power transformer and has h2 storage. With HPP, power production and batteries, and electricity, this becomes something difficult to manage and control properly.
    - CB - control of diff technologies and balancing different objectives and end-use production is within the interest of the group.
32. Hydrogen as storage and an end use?
    - Any further view points? Is this the most important topic for HPP right now or anything else?
    - Stoyan - is not the most important right now but will be in years. Looking at applications. Currently HPP applications are wind connected to solar and batteries.
        - Looking at what is happening now and the sizes and challenges. Maybe in 2030 but not sure if this will be in large-clae. Looking at GW developments. Development of tech side and pipelines, electrolytes, and everything. Very long development I think. Not the most important right now though.
    - Luis - some hybrid systems in h2 but not for storage. For just h2 production, there seems to be. Industry is using the h2 for chemical industries and fertilizer, as well as ammonia. Most HPP systems do not include storage because there is no market currently. If there is no way to pay for storage then it is not compulsory.
33. What technologies should we exclude, for now? Maybe put another way, what is highest priority vs. lower priority?
    - Luis - Solar thermal, waves and tidal, wave energy converter technologies
    - Stoyan - Hydropower.
    - Antonio - biogas generation could also be another part to help reduce the amount of storage you need.
    - Stoyan - Heat, to generate heat such as district heating or manufacturing.
    - Solar and Wind

34. Does there need to be terminology/consensus around the policy/market portions of hybrids? If so, what does that look like?
    - Is there a need to have common terminology and consensus and would this be useful output from this workshop?
    - Michaela - Yes this would be a useful output!
    - Stoyan - yes it is useful. When we see HPP we imagine certain things. Multiple technologies connected at one point to the grid. Wind farm producing electricity and h2, and is this still a HPP? If we say HPP, do we include or exclude grid connection or not.
    - CB - Are there specific parts of terminology that you all would find useful? So having specifications based on end use or grid connection?
    - Luis - reminds me of technical communities in IEC in wind and solar PV, they both have working groups on terminology. Perhaps take a look at their definition for a hybrid system? And compare them and maybe have more than one or two definitions based on size.