2.C. DISTRIBUTION SYSTEM IMPACT SUMMARY

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TEAM: NUESS HUSKY POWER

USE CASE: NORTH CAROLINA STATE UNIVERSITY

Thermal and Voltage Constraints and Limitations on Solar-Plus-Storage on Distribution Networks:

The interconnection of solar-plus-storage systems can have a substantial effect on the distribution system, especially in terms of thermal and voltage constraints. The interconnection of these systems can cause increased power flows on the distribution network, leading to voltage fluctuations and thermal overloading of equipment.

Thermal constraints occur when the power flowing through a distribution line exceeds the line's thermal rating, causing the line to overheat and potentially leading to equipment failure. Voltage constraints occur when the voltage at a point in the distribution network deviates excessively from its nominal value, which can result in equipment damage and power quality issues. According to ANSI, the voltage of a feeder should remain in +/-5% of the nominal value.

The sensitivity of these effects to the magnitude of the PV system and the location of the interconnection can vary. Larger PV systems can cause greater power flow on the distribution network, thereby increasing the probability of thermal and voltage constraints. The location of the interconnection point can also affect the impact on the distribution system, as interconnecting at a point with existing thermal or voltage constraints can exacerbate the issue. In addition, the interconnection of DERs located further from the substation can cause thermal and voltage violations.

Factors Limiting PV Hosting Capacity on Distribution Network and Impact on Interconnection Cost:

In the North Carolina State University use case, the proposed design consists of nine rooftop buildings, a Ground Mount, and a Floating solar system with a nameplate capacity of 6.6 MW. The primary limitation of the existing electric grid at NCSU is that the excess electrical energy can’t be exported back to the utility. The secondary limitation is that the existing distribution network has a PV penetration capacity of 4.3 MW without any distribution system upgrades. These are the primary factors that limit our PV capacity without any substation or feeder upgrades. In order to interconnect a larger PV system, we need to use non-wire alternatives or upgrade the distribution system which wouldn’t make the project economically viable. The average cost of battery system is around $ 450/kWh and the cost of upgrading the distribution lines would be approximately $ 1,000,000/mi and would also require additional upgrade in the existing switchgear.

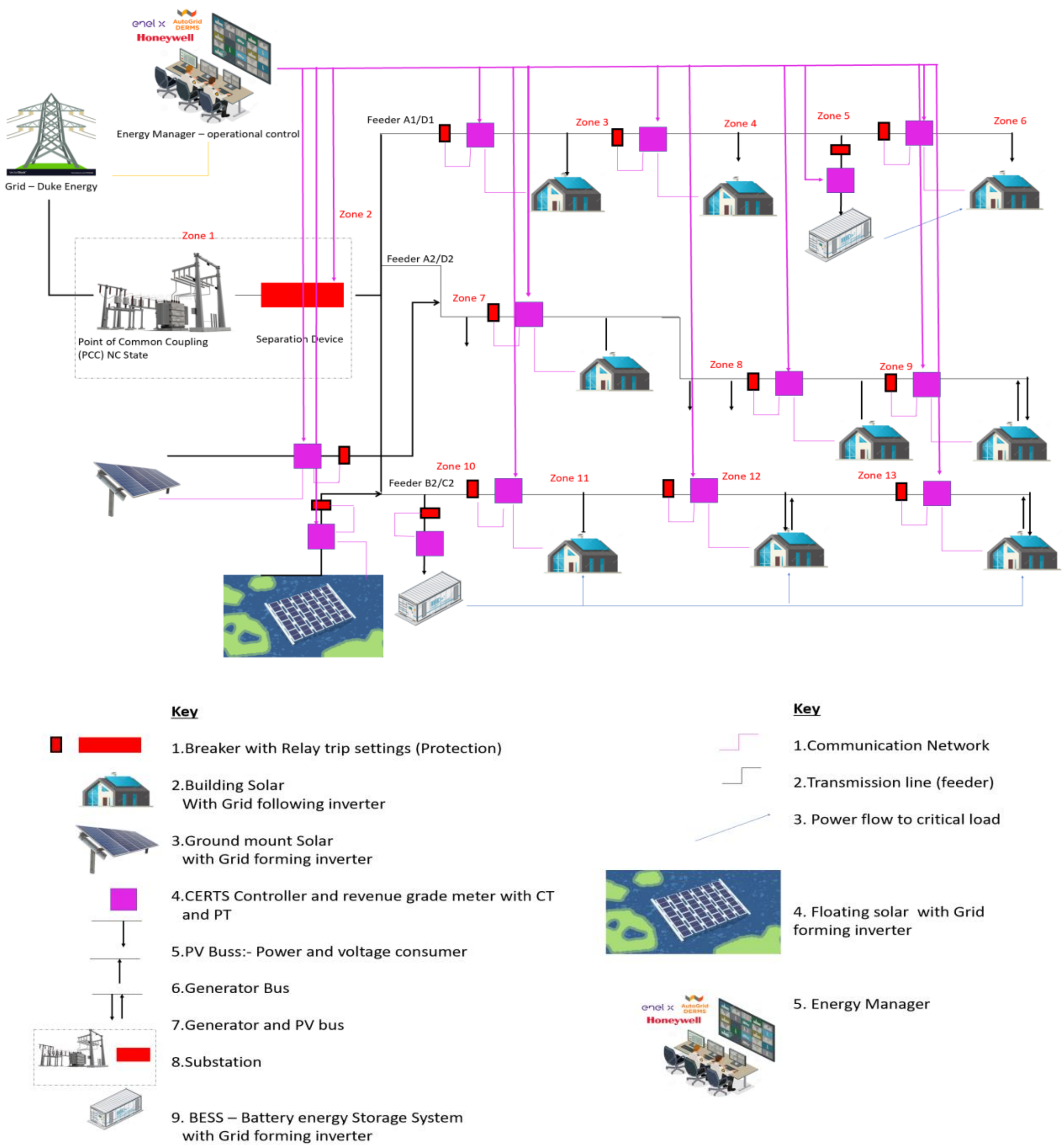
Improving PV Host Capacity with Battery Systems and Smart Inverter Control Mode:

When there is a presence of excess generation from DERs, we can alleviate the thermal and voltage constraints on the distribution system by using non-wire alternatives (i.e., batteries) or smart inverters. The batteries can be charged during the period of high generation and discharged during low generation, ensuring grid stability. Similarly, the implementation of smart inverters can regulate the amount of electricity being fed into the grid, which helps to stabilize the grid and prevent power outages. So, these components are crucial for interconnecting DERs and to maintain grid stability.

Consortium for Electric Reliability Technology Solutions (CERTS) Microgrid controller:

The monitoring and control of power flow from the distributed energy resources is vital as the grid is designed to operate with unidirectional power flow. The implementation of the distributed energy resources will affect this operation as would bidirectional power flow. So, to maintain reliability and stability of the grid the implementation of CERTS controller is vital as this would monitor the energy generated and curtail the remaining energy so that there wouldn’t be any impact on the system. The CERTS control allows communication between resources that are physically distributed over the area of

the "microgrid". In the CERTS Microgrid Concept, each microgrid source has a basic set of controls that allows the source to remain stable during both steady-state and transient electrical events. This is important for maintaining low-level stability inherent to each device and for avoiding the need for a master-level controller to serve this function. The basic controls are simple droop controls for frequency and voltage and a limiter function at the edges of the operating envelope. In the proposed solution, the implementation of the controller ensures grid stability and curtails the energy by less than 1% at instances where the energy production is greater than the PV penetration capacity.
Below is the schematic layout of the implementation of CERTS controller:

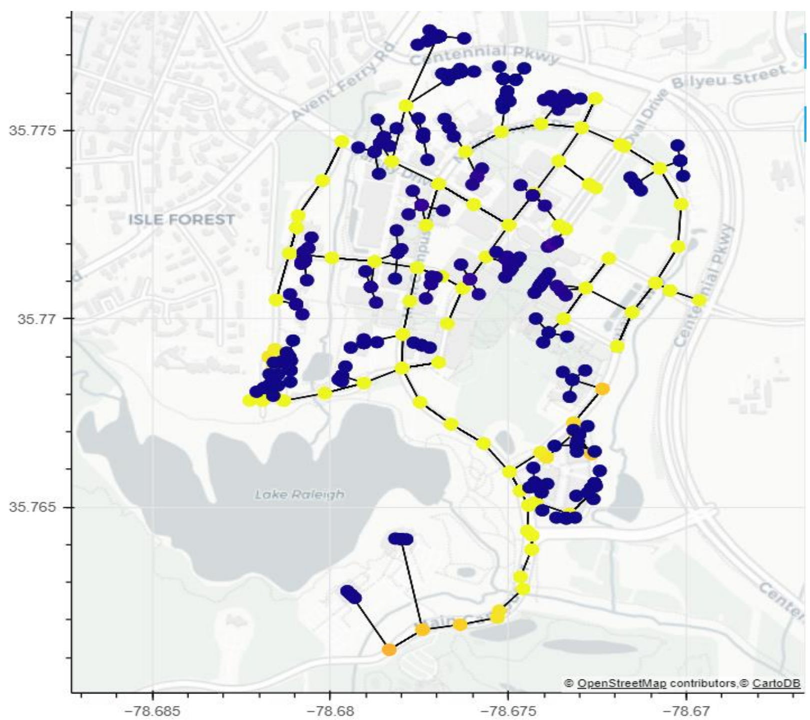


The crucial components and their functionality of the components in the above schematic is detailed below:

- **CERTS Controller and revenue grade meter with CT and PT:** Monitors the voltage and frequency of both source and DG generation. Provide fast response to disturbances and load changes without relying on communications for inbuilt PID loops programing.
- **Energy Manager (program):** Provides operational control though the dispatch of power and voltage or expected instances through energy projections.
- **Protection equipment (disconnects):** Protection of Microgrid in zones to prevent a blackout. This equipment is normally a Relay with trip settings set to certain setpoints of fault detection.

Distributed Impact Study using Heat Maps:

The use case document contains a heatmap of the electric grid, which provides essential information about the distribution system, including the voltage levels of different feeders, the extent of PV (photovoltaic) penetration at various nodes, and their distances from the substation. Upon analyzing the heatmap, we can observe that the blue nodes, which mainly represent load points, have lower PV penetration capacity. In contrast, the yellow nodes, located on the feeders or transformers, exhibit higher PV penetration capacity.



The rooftop PV system's interconnection analysis is done by comparing the hourly production data from Aurora solar to the minimum yearly load of the buildings. The PV system is connected to the AC panel of the building using the Behind the meter interconnection method only if the system production is lower than the load of the system. This interconnection method wouldn't affect the PV penetration of the feeder. So, six rooftop PV systems out of nine are interconnected and they are mentioned below:

Buildings	DC	Building Min Load	Distance
	KW	KW	Miles-Yellow Dot
College of Textiles Complex	345	407	0.981
Engineering Building I	284	474	0.850
Research I	26	171	1.425
Toxicology Building	89	137	1.363
Partners II	166	205	1.254
Partners III	77	294	1.363

The remaining five systems comprising of 3 rooftops, floating solar and ground mount solar systems will be interconnected to the nearest feeder/transformer. These systems are interconnected prioritizing the distance from the substation and the PV penetration of the circuit as shown in the table below. The hourly generation of the five PV systems are obtained from Aurora solar and the combined Energy at any hour wouldn't exceed the PV penetration limit of 4.3 MW although the name plate capacity of the system is higher. This constraint is also ensured by the implementation of CERTS controller which monitors the data from all the PV systems and regulates the generation of the ground mount system such that the combined PV system output wouldn't exceed the PV penetration constraint.

Buildings	DC	Max Energy	Combined Total Energy (Using CERT)	Distance from interconnecting node
	KWp	KWh	KWh	Miles
James B. Hunt Jr. Library	455	272	4300	0.851
Engineering Building II	584	305		0.962
Engineering Building III	385	170		1.974
Floating solar	2000	1540		1.958
Ground Mount	2190	2013		1.688

Grid Outage scenario:

In the event of a grid outage, the battery powers the critical loads to maintain resilience, while the grid-following inverters disengage the nine rooftop PV systems from the system. Floating and ground-mounted systems are equipped with grid-forming inverters, allowing them to continue operating in the event of a power outage. Using the CERTS controller and Energy Management System, the energy generated during the day can be directed to a sector of the electric grid by switching relays and circuit breakers in accordance with the generation and demand requirements of that section of the grid. The other buildings will be disconnected from the grid to ensure reliable power flow.