IEEE PES Presentation _ Battery Energy Storage and Applications

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Jeff Zwijack
Manager, Application Engineering & Proposal Development

IHI terrasun SOLUTIONS

AGENDA

1. Battery Energy Storage System (BESS) - The Equipment
2. Applications of Energy Storage
3. Solar + Storage
4. Commercial and Industrial Storage (C&I)
5. Augmentations

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1. **Battery Energy Storage System (BESS) - The Equipment**
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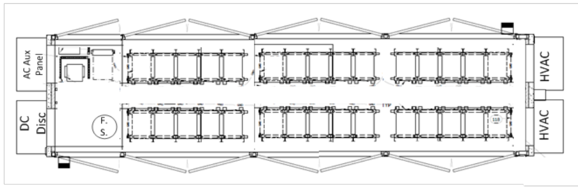
BESS – The Equipment – Battery (Li-ion)

Battery Cell

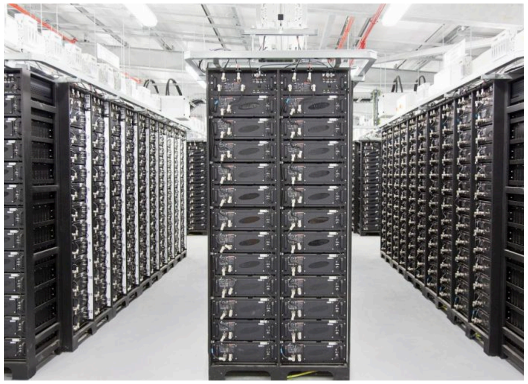
Battery Module

Battery Rack

Battery Container



Battery Building



BESS – The Equipment – Battery (Li-ion)

Advantages

•High energy density - potential for yet higher capacities.

•Relatively low self-discharge - self-discharge is less than half that of nickel-based batteries.

•Low Maintenance - no periodic discharge is needed; there is no memory.

Limitations

•Requires protection circuit to maintain voltage and current within safe limits. (BMS or Battery Management System)

•Subject to aging, even if not in use – Storage Degradation

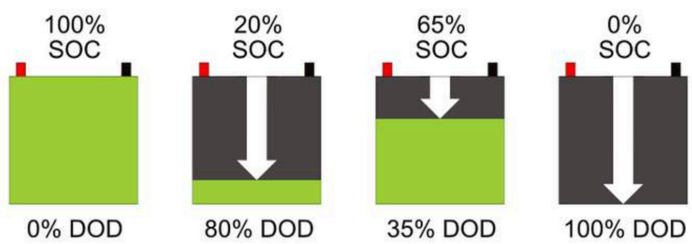
•Transportation restrictions - shipment of larger quantities may be subject to regulatory control. Special UN38.3 Certification is required to meet transportation regulations.

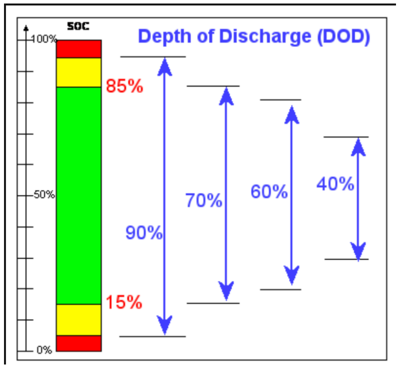
•Sensitivity to high temperature - Lithium-ion battery is susceptible to heat caused by overheating of the device or overcharging. Heat causes the cells of the battery to degrade faster than they normally would. Over-heating or internal short circuit can also ignite the electrolyte and cause fire.

BESS – The Equipment – Battery (Li-ion) – Common Terms

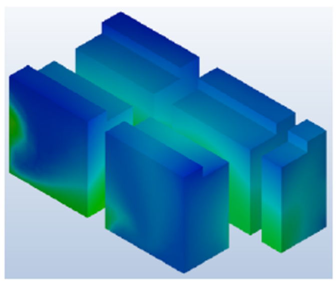
DoD - A battery's depth of discharge (DoD) indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery. Depth of Discharge is defined as the capacity that is discharged from a fully charged battery, divided by battery nominal capacity.

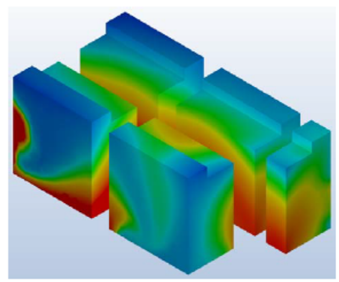
SOC - State of charge (SoC) is the level of charge of relative to its capacity. The units of SoC are a percentage (0% = empty; 100% = full). SoC is normally used when discussing the current state of a battery in use, while DoD is most often seen when discussing the lifetime of the battery after repeated use.

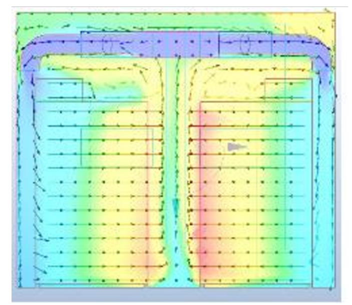


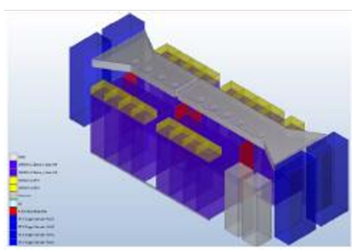


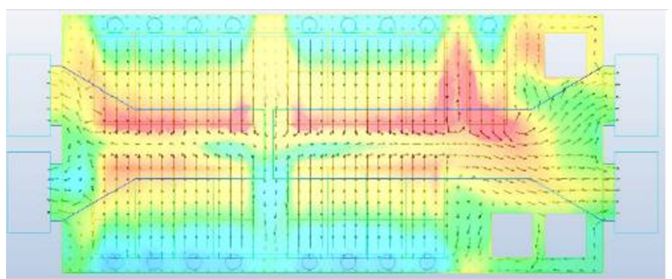
BESS – The Equipment – Heat Mitigation and Temp Control

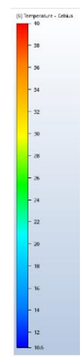


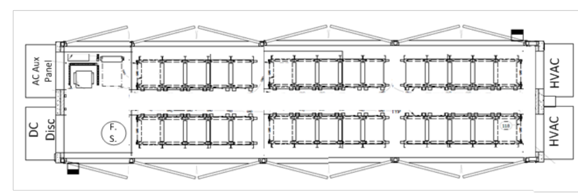




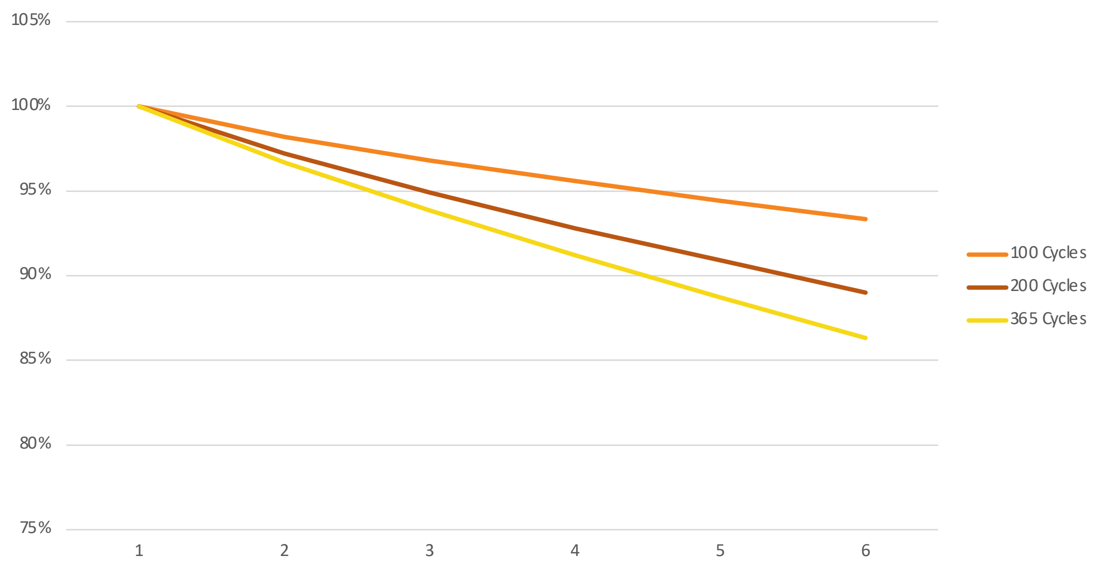




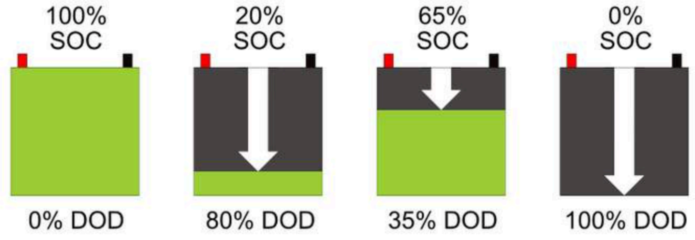




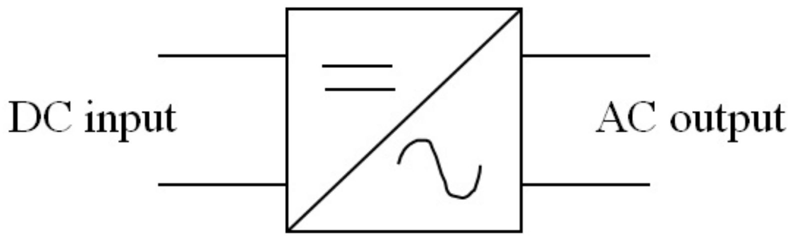
BESS – Battery Degradation



What is a Cycle? 100% SOC to 0% SOC



BESS – The Equipment – Inverter



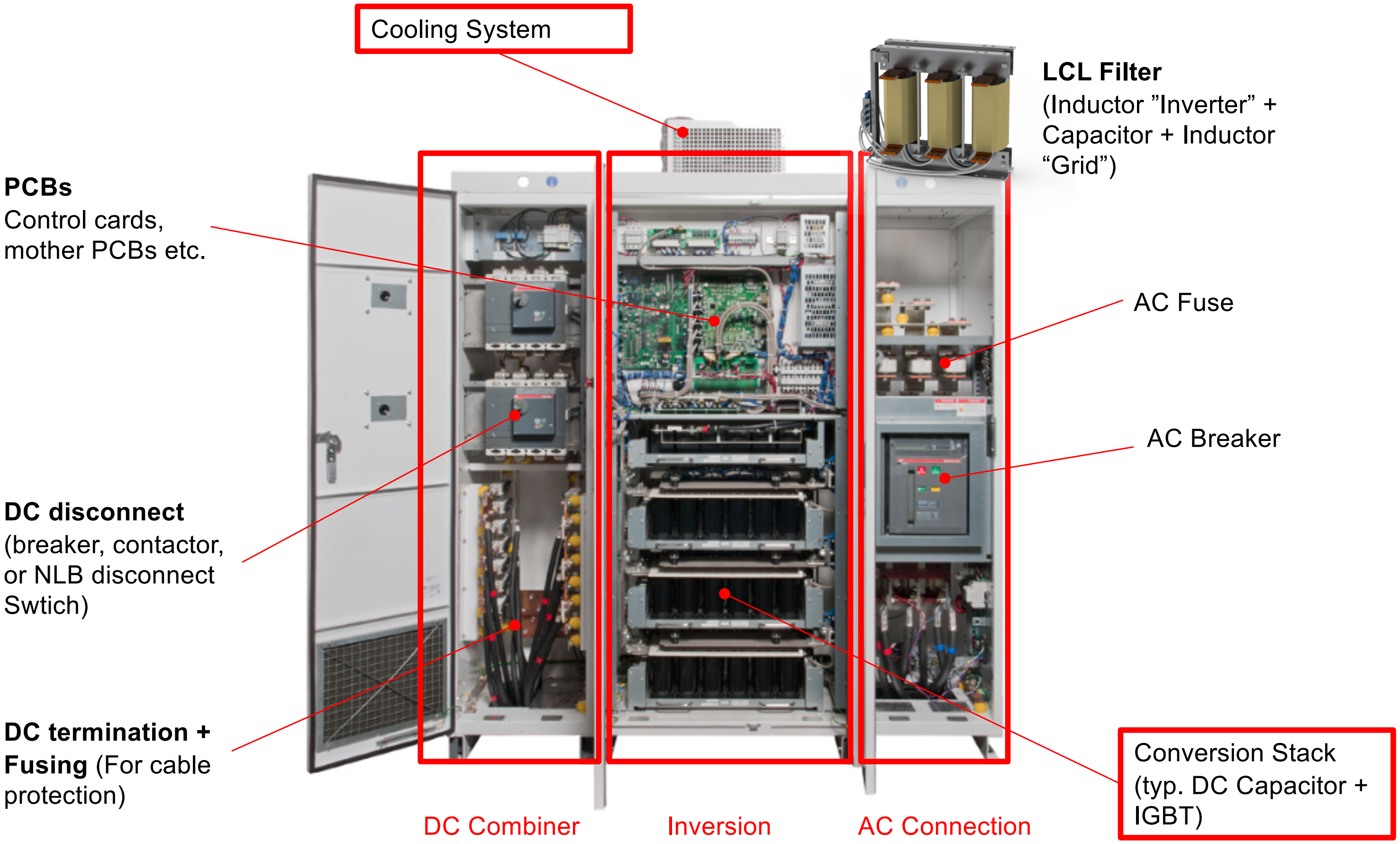
Taken one form of power source (DC/AC)
and transform to another form (DC/AC)
Provides system protection

DC/AC Inverter => Transforms DC (Direct Current) to AC (Alternating Current)

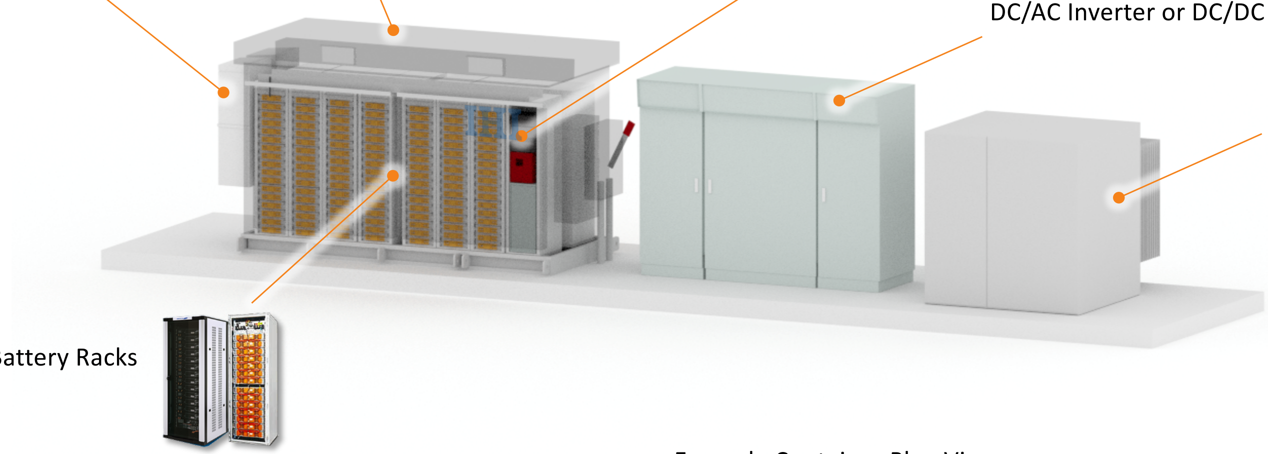
AC/DC Rectifier => Transforms AC to DC

DC/DC Converter => Transforms DC to DC

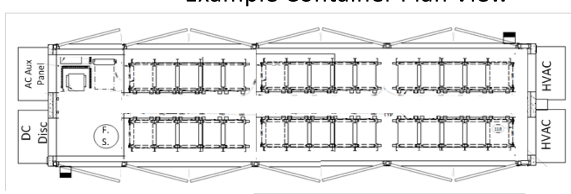
What is in the Inverter?



Put it all together - BESS



Example Container Plan View



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1. Battery Energy Storage System (BESS) - The Equipment
2. **Applications of Energy Storage**
3. Solar + Storage
4. Commercial and Industrial Storage (C&I)
5. Augmentations

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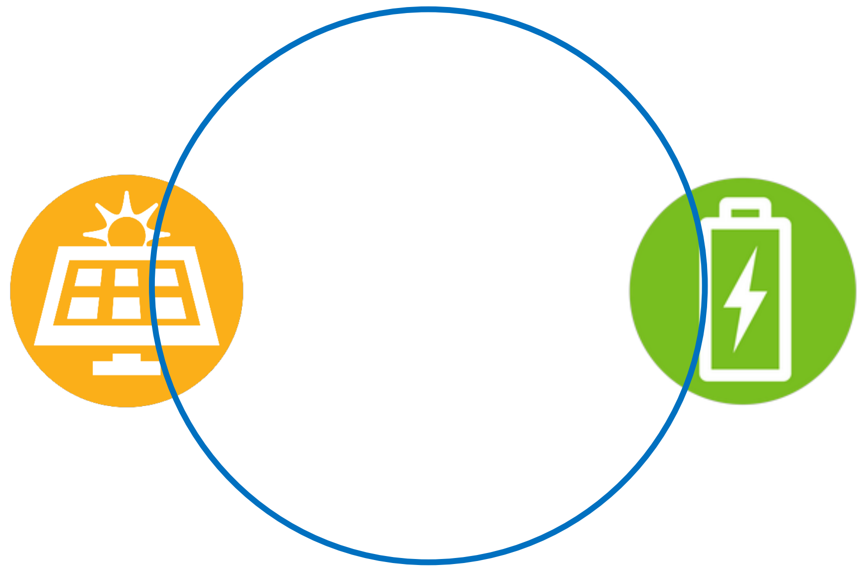
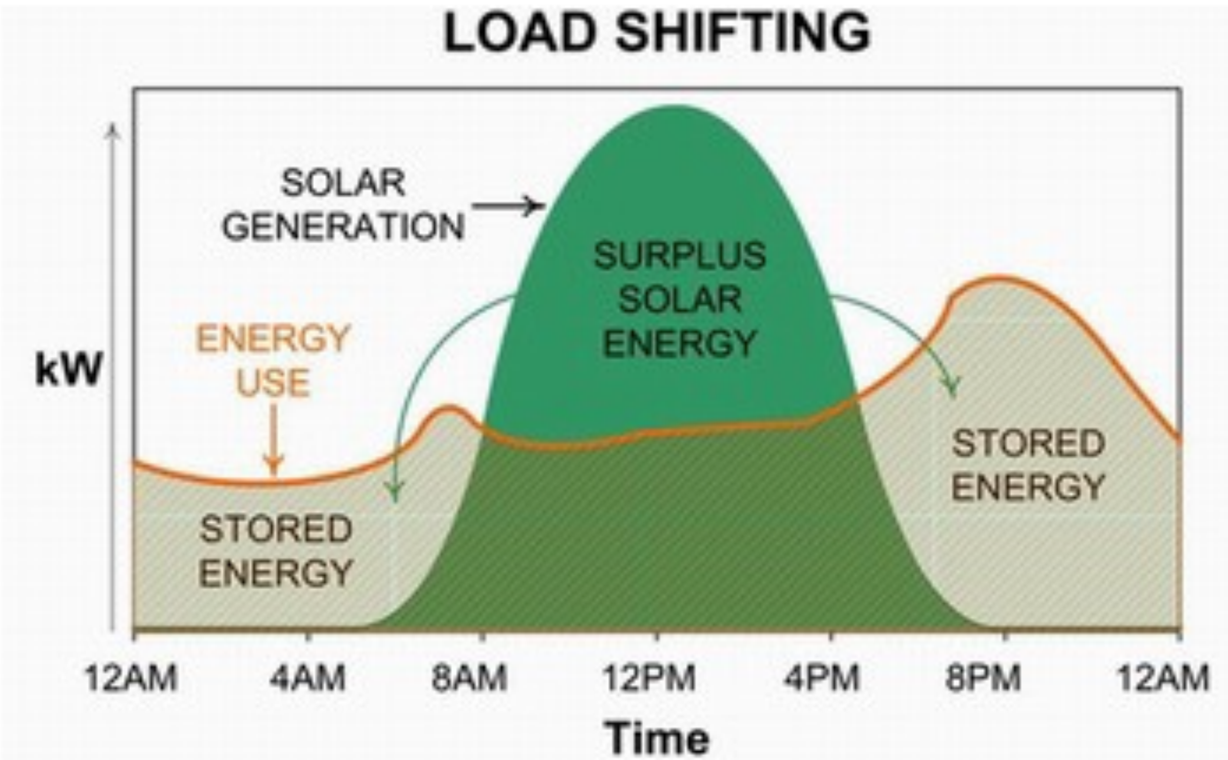
Solar + Energy Storage Convergence

Solar + Storage PPA
Added Value & Incentives with Solar + Storage



PV System Design with Storage

Simple Load Shifting

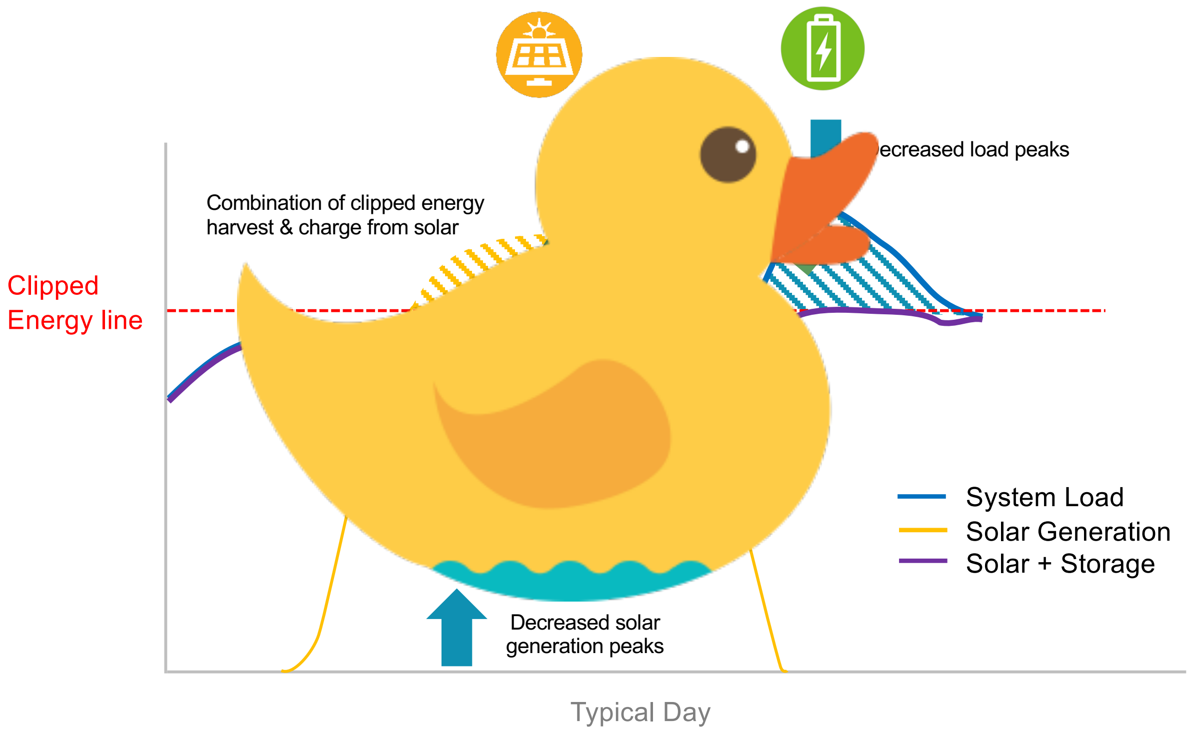


Charging the Battery from Solar vs Charging from the Grid

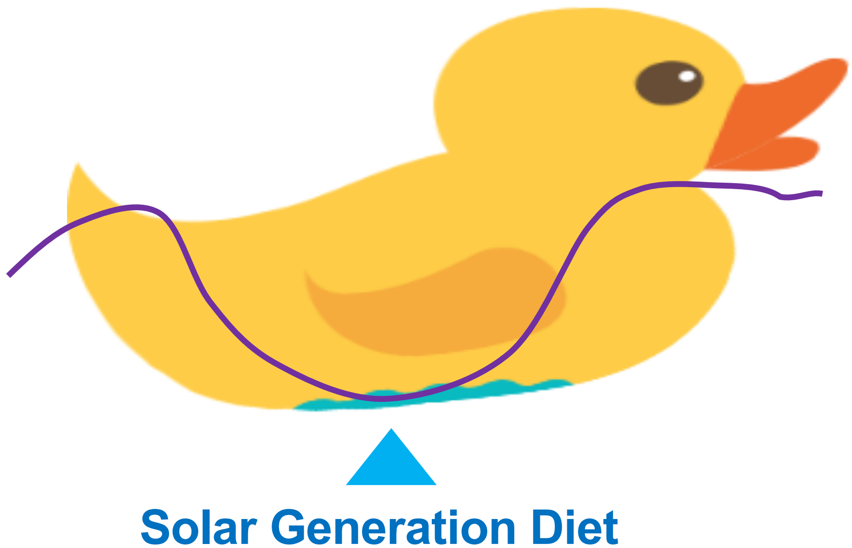
Energy Arbitrage

- Charge when Pricing is Low
- Discharge when Pricing is High

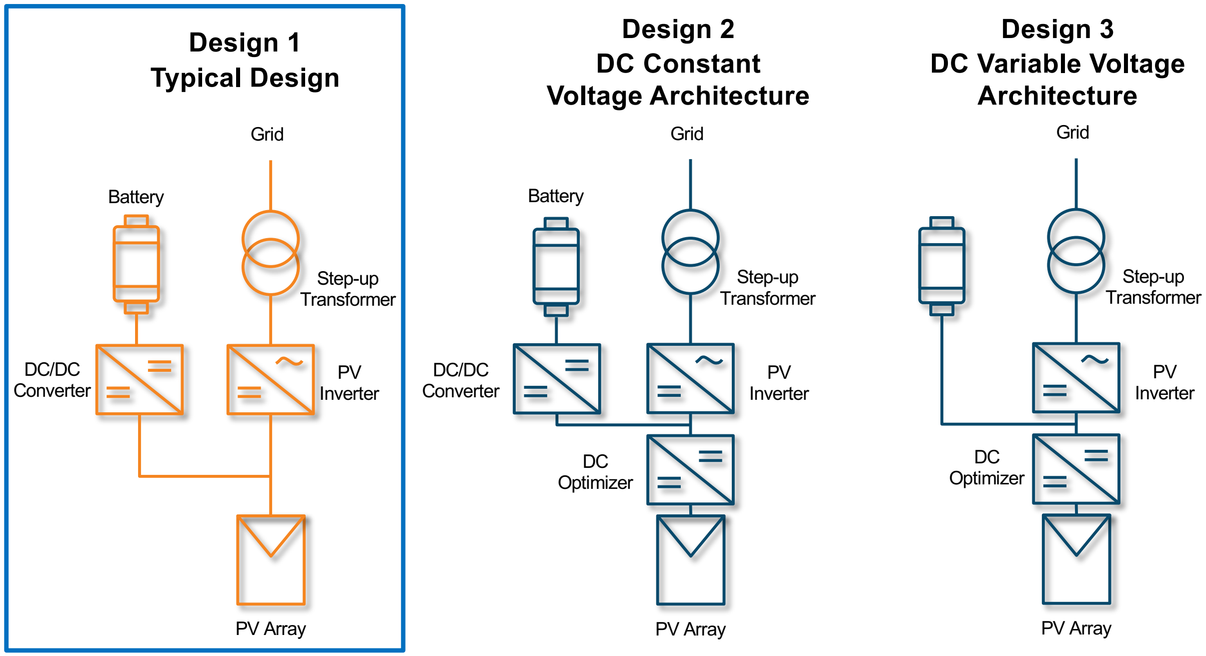
Solar + Storage Value with DC Coupling



Let's make the duck healthy…

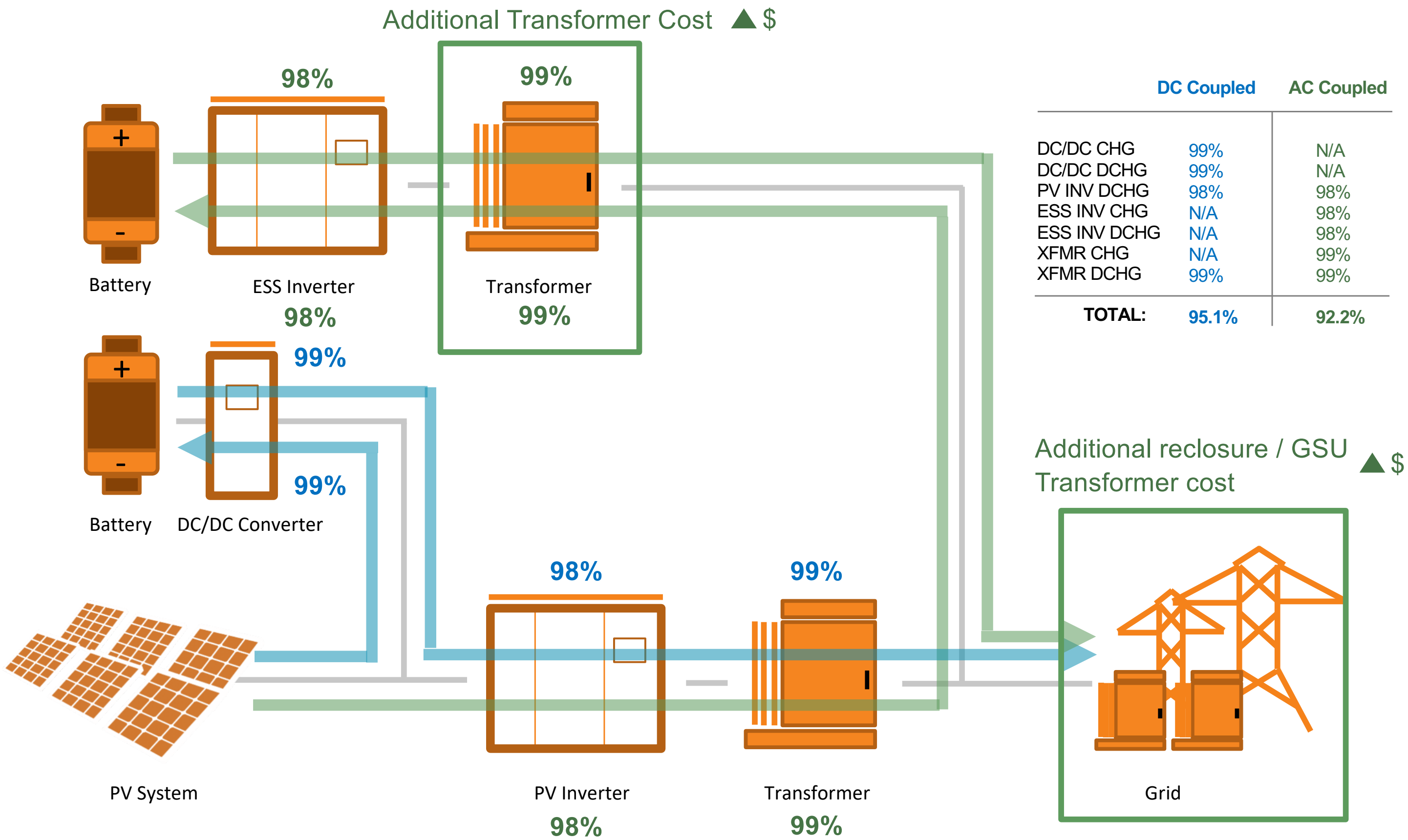


DC Coupled System Differences in Architecture



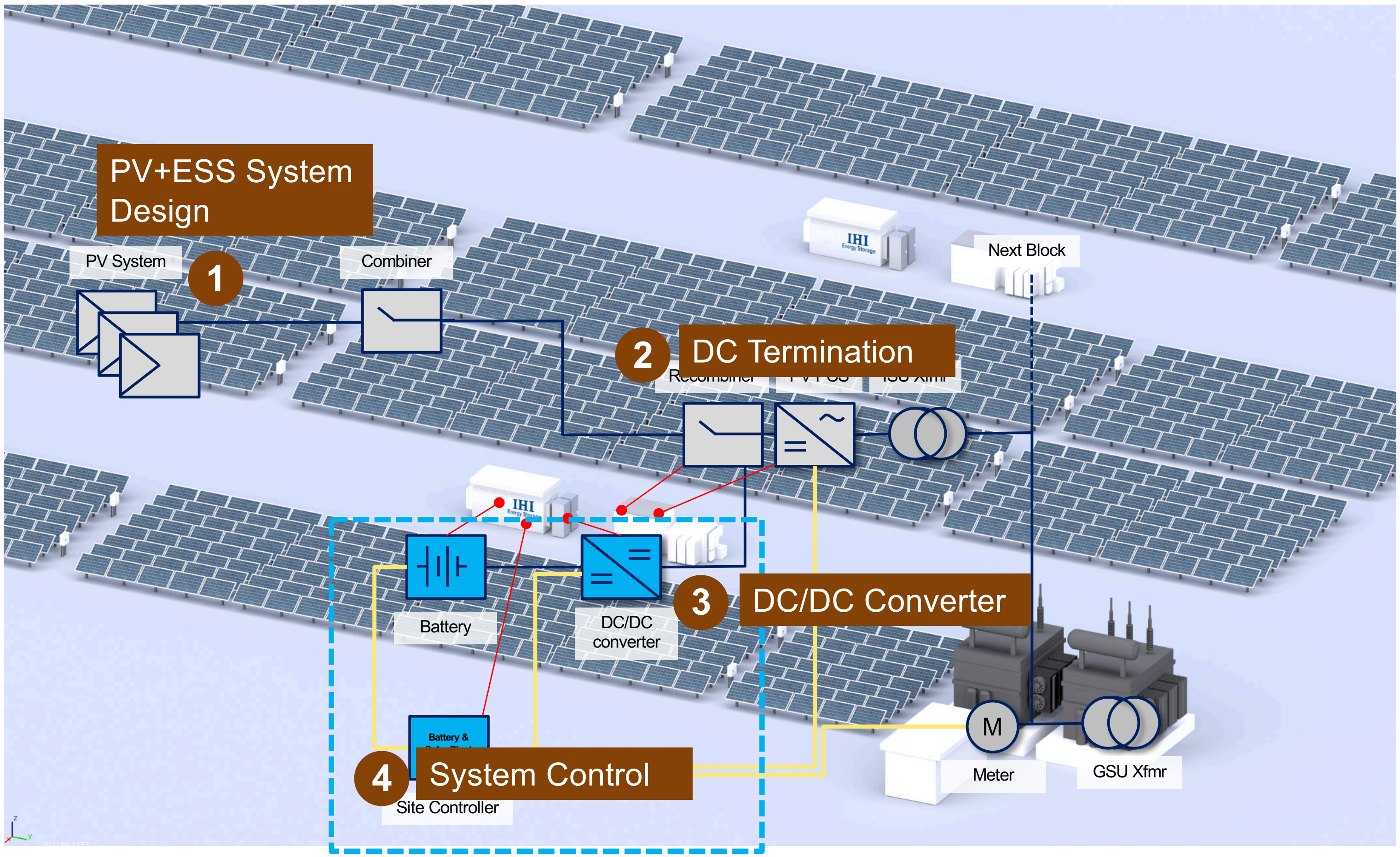
DC/DC Converter	High Cost	Medium Cost	No Cost
DC Optimizer	No Cost	Medium Cost (Simpler charger)	High Cost
DC Voltage Control	Centralized MPP Control	Distributed MPP / Constant Voltage	Distributed MPP / Variable Voltage
PV Inverter	Standard PV inverter cost	20-30% inverter cost reduction	Standard “ESS Inverter” Cost
PV Inverter Power-flow	Single direction (to grid)	Bidirectional	Bidirectional
System Controls	DC/DC & DC/AC Inverter Control	DC/DC & DC/AC Inverter Control	DC/AC Inverter Control
ESS Availability	Medium	Medium-Low	High

DC Coupled Solar + Storage Value: RTE & Cost

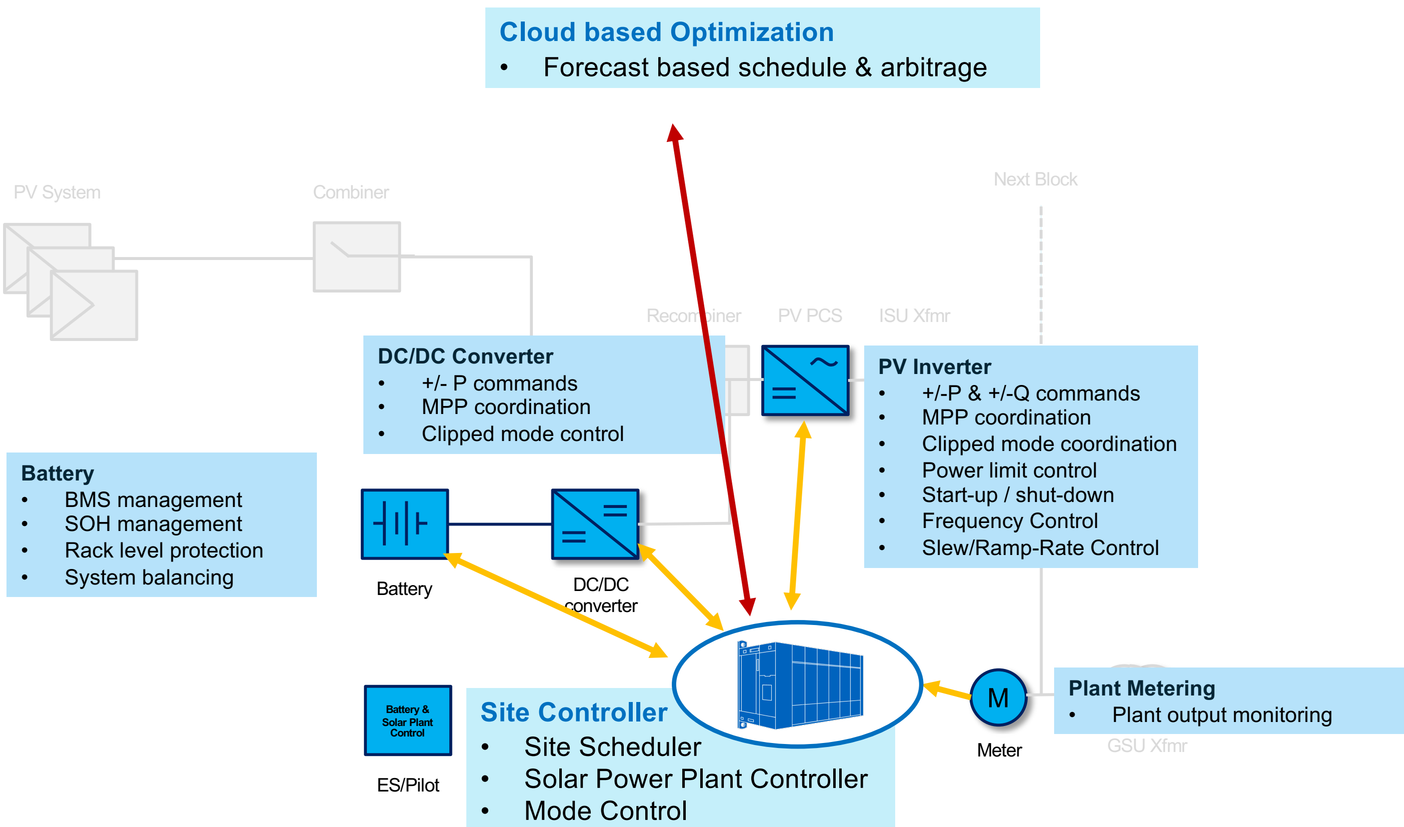


	DC Coupled	AC Coupled
DC/DC CHG	99%	N/A
DC/DC DCHG	99%	N/A
PV INV DCHG	98%	98%
ESS INV CHG	N/A	98%
ESS INV DCHG	N/A	98%
XFMR CHG	N/A	99%
XFMR DCHG	99%	99%
TOTAL:	**95.1%**	**92.2%**

DC Coupled System Design – Hardware Overview



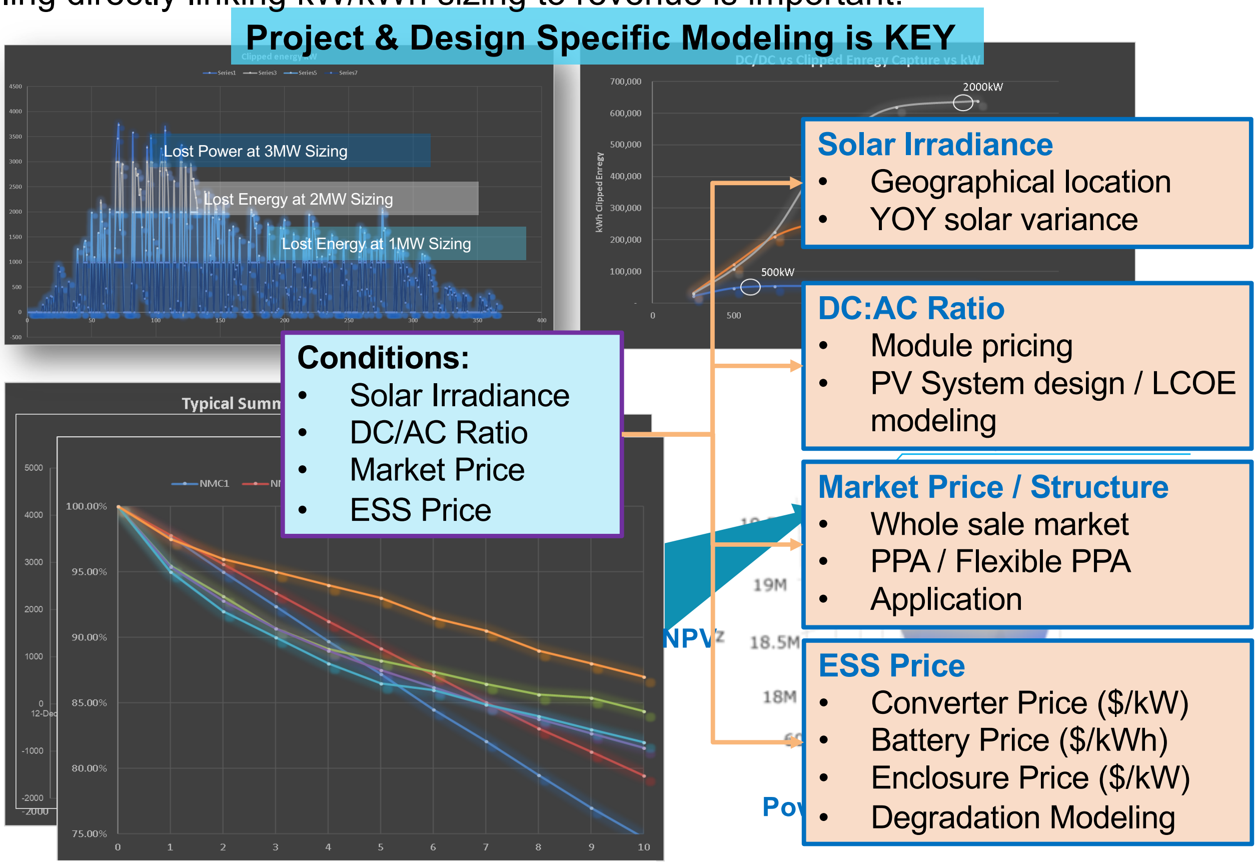
DC Coupled System Design - Controls Architecture Overview



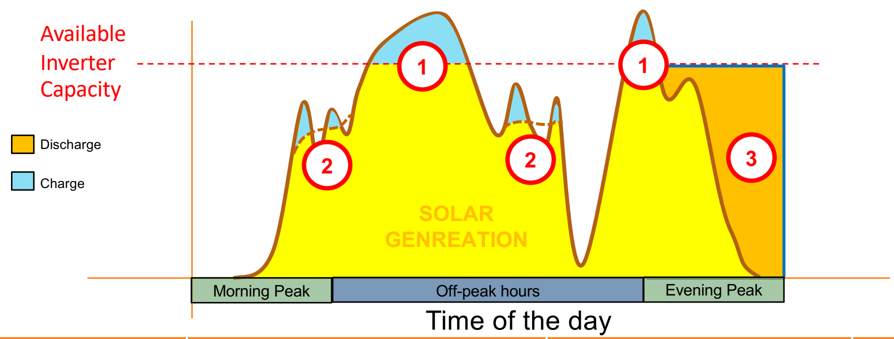
System Design - Optimal ESS Power & Energy

ESS Power & Energy Sizing

- System modeling directly linking kW/kWh sizing to revenue is important.



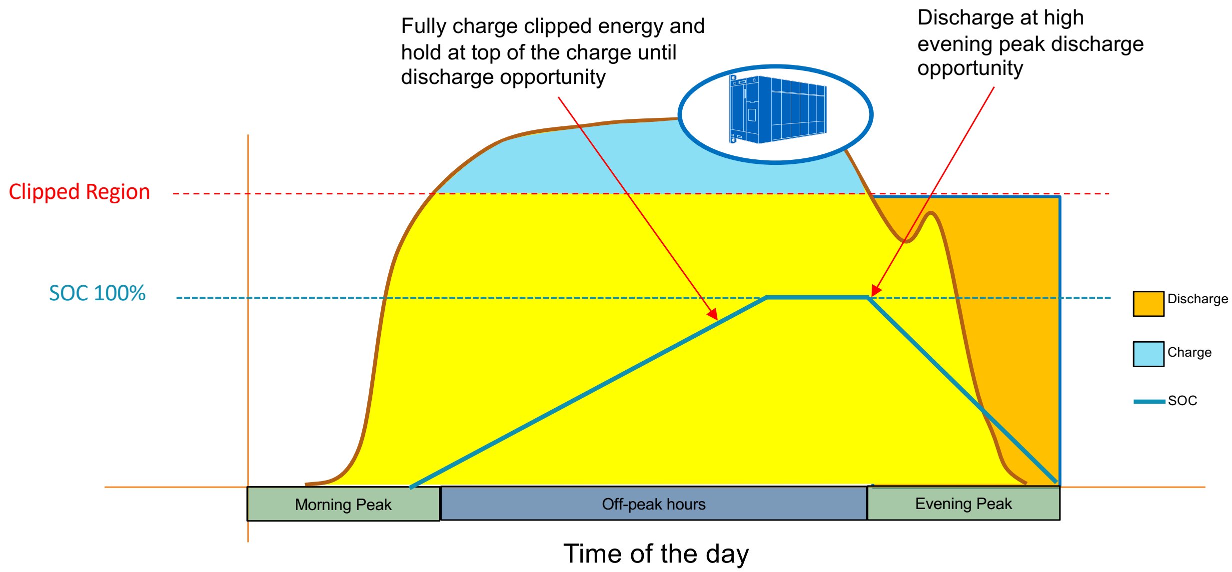
Controls - Clipped Energy Harvest & Time Shift



	Modes of Operation	Controller	DC/DC Converter	DC/AC Inverter
1	**Solar Charge During Clipping** Charge ESS when DC energy is clipped due to maximum power capacity of the PV inverter	• Controller charges DC/DC converter while monitoring DC/AC inverter status during power limit	• DC/DC converter follows voltage dictated by DC/AC inverter • Dynamically control current and charge based on commands	• Operate at power limit • Operate at nominal MPP during night discharge
2	**Solar Charge During MPPT** **Solar Discharge During MPPT** Forced ESS charge during the time when the plant is not clipped. Discharge during On-peak time	• Controller dynamically charges the ESS when DC/AC inverter is in MPP state. • Rule based optimal discharge during on-peak hours.	• Dynamically charge ESS during MPP operation and follow array voltage.	• Operate at nominal MPP during charge.
3	**Solar Discharge During Night** Discharge during On-peak time	• Optimal discharge during evening peak hours (Scheduled dispatch)	• Break open for PV during night or use RBD • Switch to IV-Mode	• Operate at nominal MPP during night discharge

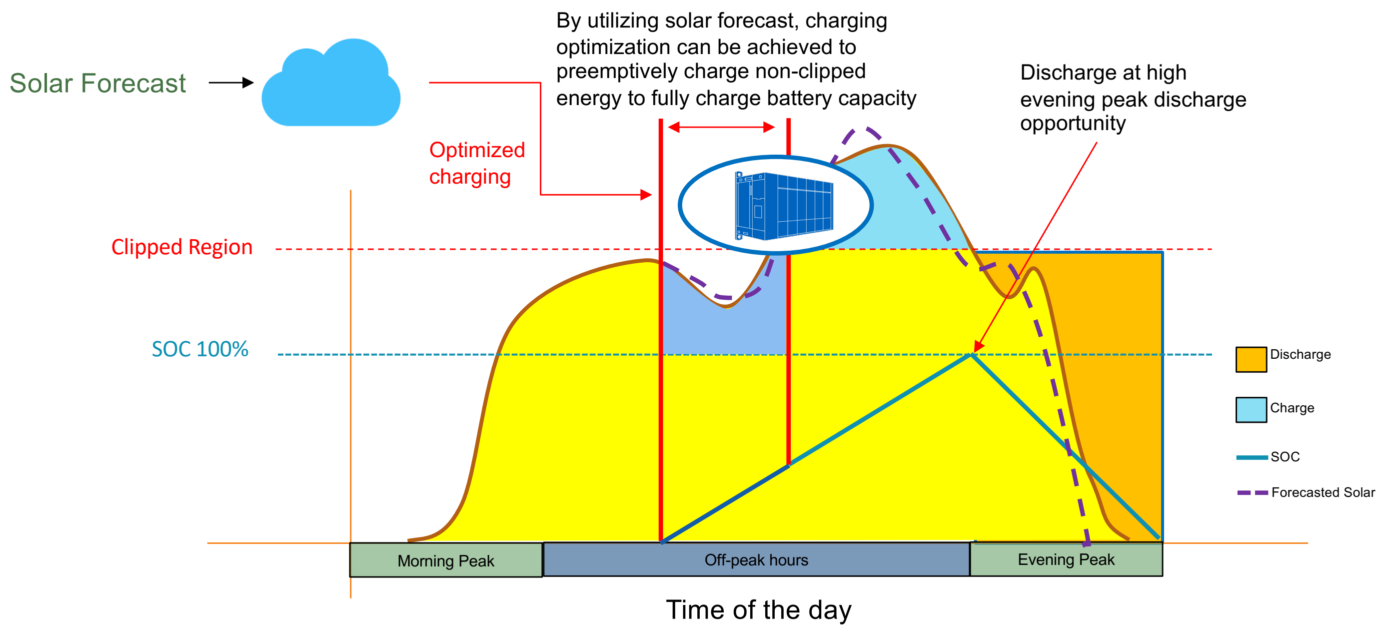
Controls – Full Sun

Days with full sun having ample amount of charging opportunity = “Scheduled Dispatch”

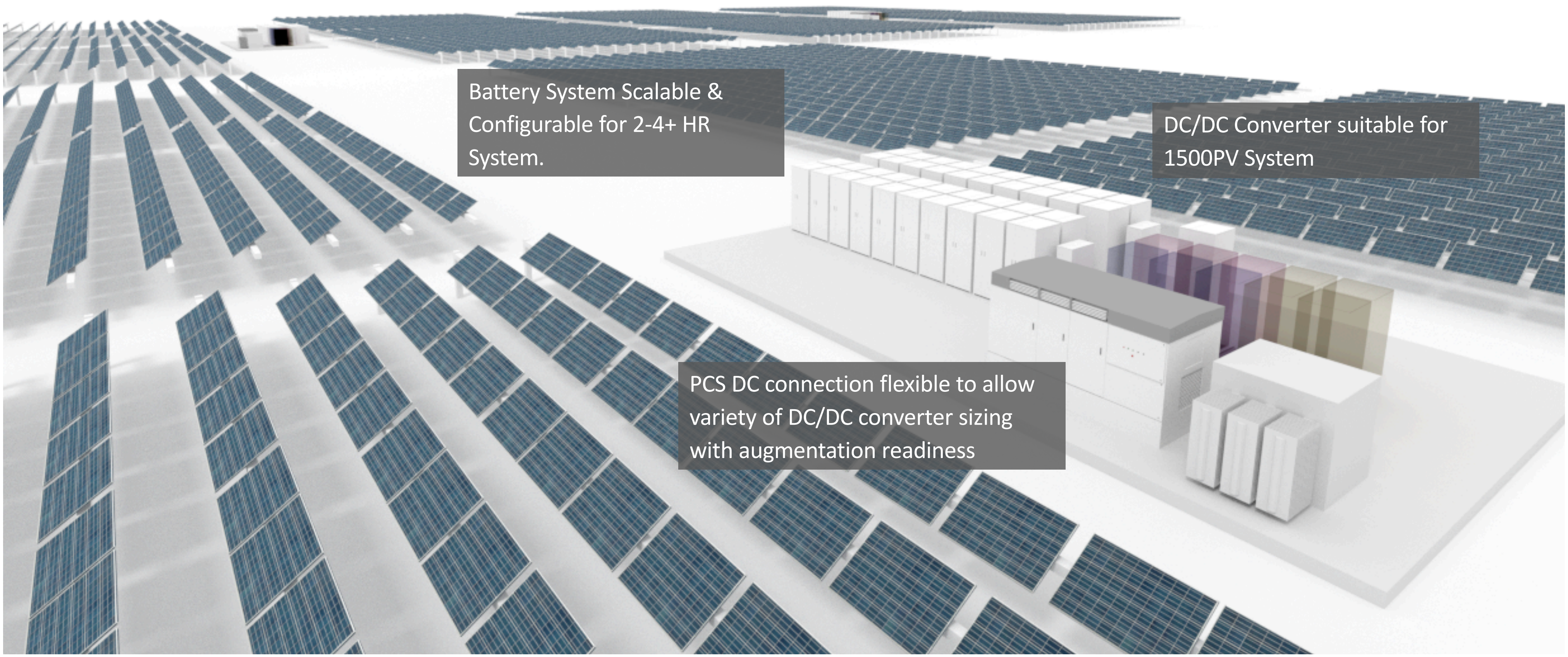


Controls – Partial Sun (Charging using forecast)

Days with partial sun having partial clipped charging opportunity = "Dynamic Optimization" based on Solar Forecast



DC-Coupled System - Overview



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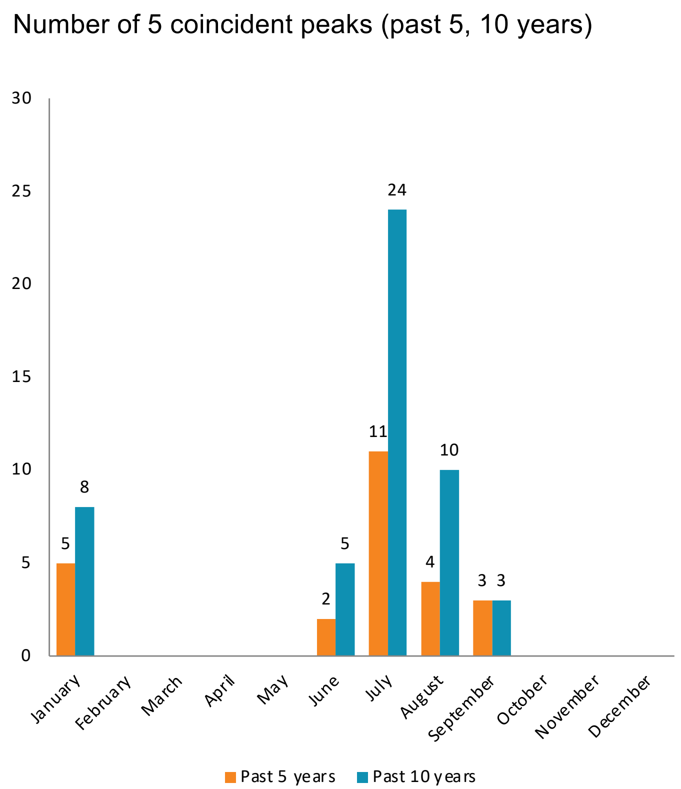
Commercial & Industrial Systems - Ontario Market Background

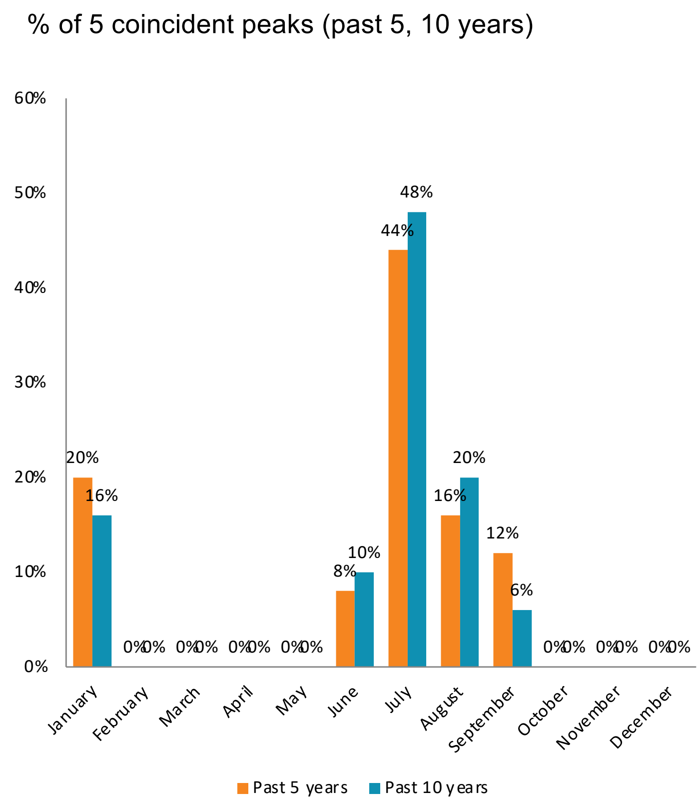
The Global Adjustment (GA) charge is a line-item charge for customers in Ontario IESO territory which supports the sustained deployment of energy in Ontario, even during unexpected peak events

Any customer participating in the ICI (Industrial Conservation Initiative) is charged a GA fee proportional to their energy usage during the five highest system peaks of the year.

- Save CAD400K – CAD430K/MW/yr by reducing your energy usage during these peak hours

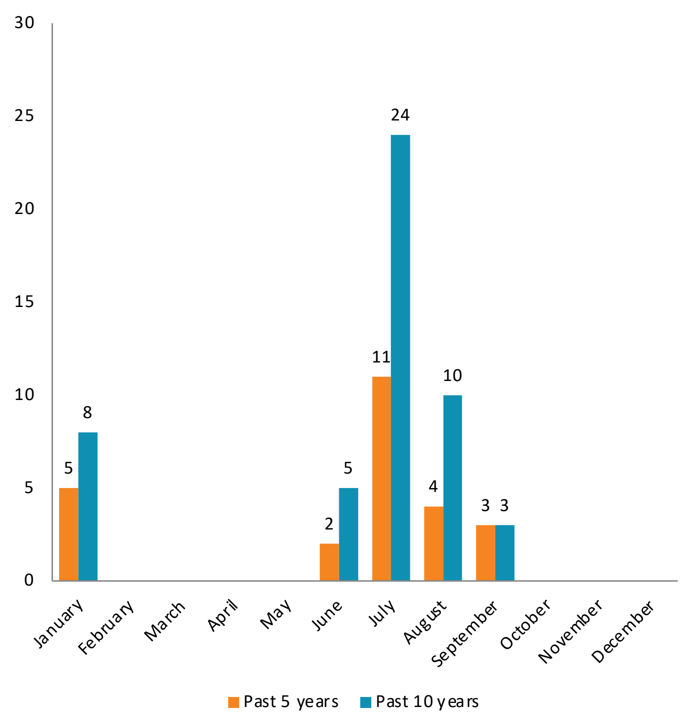
Commercial & Industrial Systems - 5 System Coincident Peak Patterns





Other Participation Strategies

Global adjustment reduction (~80%)



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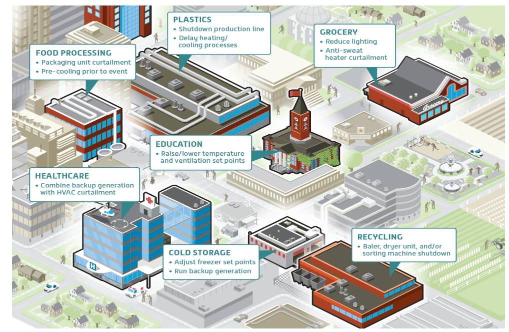
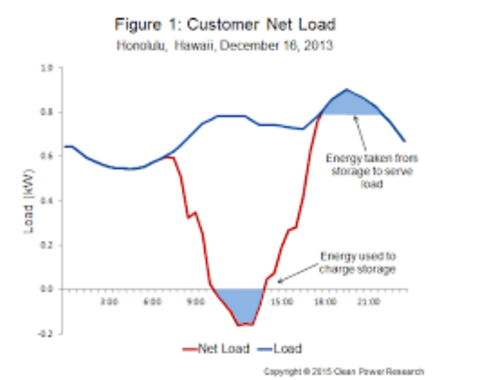
Demand response (~15%)



Energy arbitrage (~5%)



Commercial & Industrial Systems - Reducing your GA with Energy Storage

- Reduce your electricity usage without disrupting operations
- Maintain energy usage reduction with technology that can be used up to 10+ years
- Participate demand response programs without operational disruptions for generating revenue
- Reduce your electricity bill by energy arbitrage

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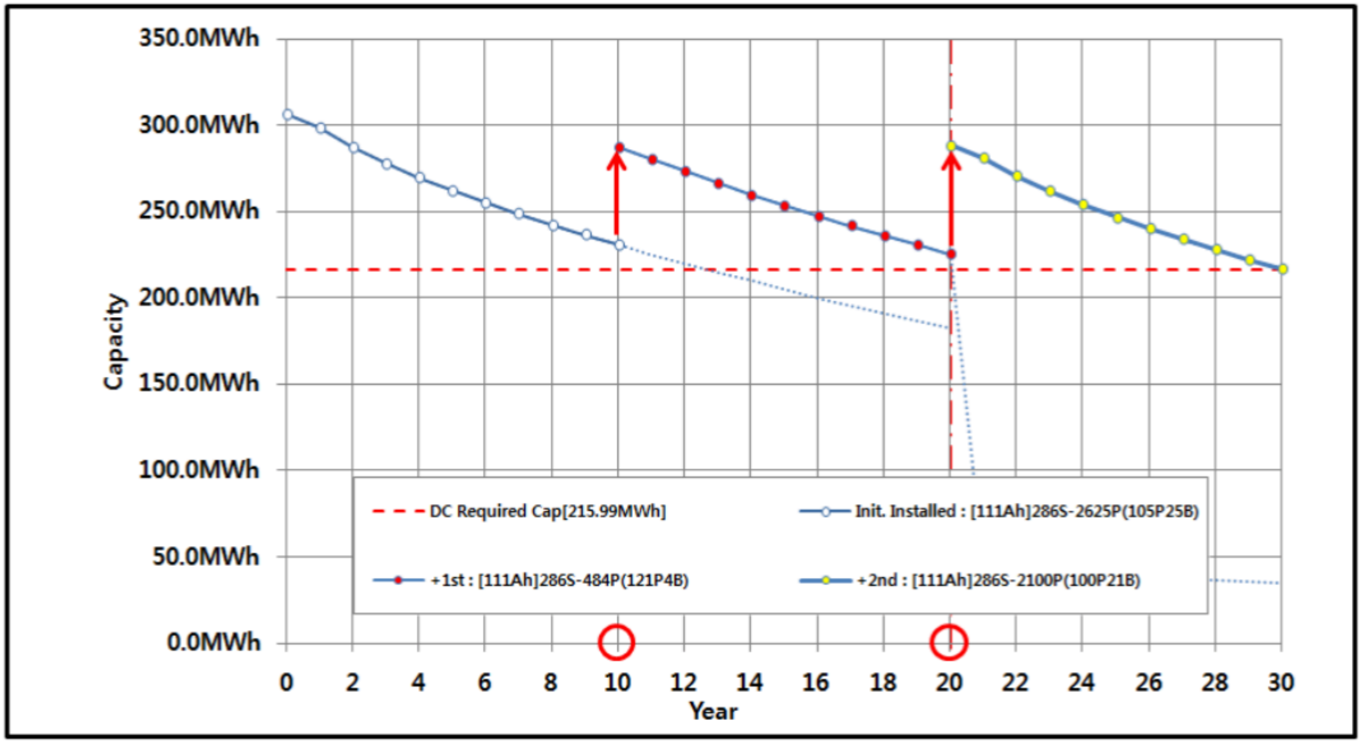
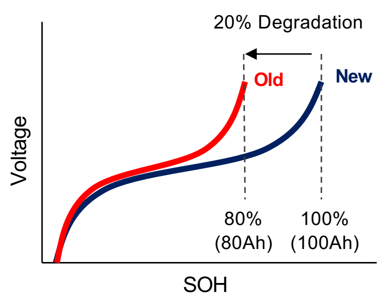
Battery Augmentation

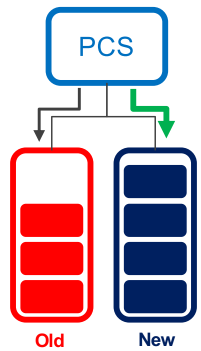


· Cell : 111Ah · Ambient Temperature: 23℃±5 · Pattern : 7Days' Profile · Rest : SOC60%

Battery Augmentation

New & Old Batteries Mix



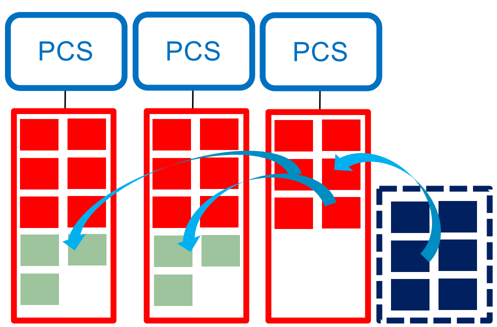


- With higher internal resistance on the old racks, the current will flow more to the newer racks potentially causing over current issues
- Old and new racks will charge/discharge unevenly and rack to rack balancing will be disturbed

Solution

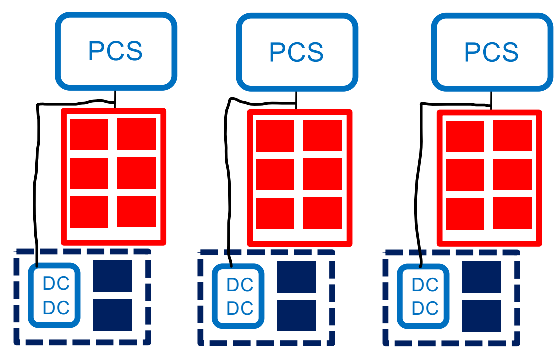
❖ Distribution Augmentation

Design increased footprint with empty space at Yr0. Empty one of the PCS blocks and distribute to older PCS blocks. Replace the emptied block with new battery racks



❖ DC/DC Converter Augmentation

Fully maximize initial design with fully populated battery container at Yr0. Utilize DC/DC converter during augmentation to control DC Bus voltage.



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AGENDA

Bonus Slides

Video - Adjust your volume as necessary

Video