ARDA™ power

DC-connected energy

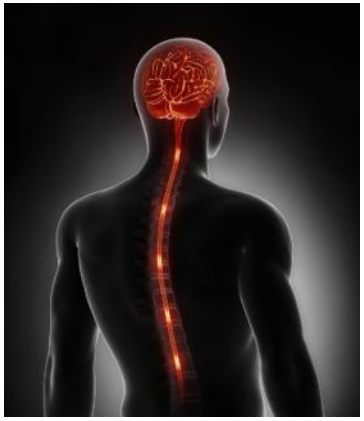
ARDA Power presentation at LBNL seminar

September 26, 2017

Berkeley, California

ARDA Power

Microgrid Power System Innovator and Integrator



We provide the **intelligence and central nervous system of a microgrid,** using proprietary battery centric plug-and-play ARDA DC Microgrid Platform:

- ✓ **Microgrid Controls**
- ✓ **Power Converters** including grid-tie/decoupling converter
- ✓ **Core Protection and Distribution**

ARDA Power's fully integrated package of **services, software and hardware** allows our customers to:

- **simplify** design and implementation of microgrids,
- **lower** component and system cost and **increase** efficiency,
- **eliminate** complexities of a microgrid's interconnection to the utility grid and islanding,
- **focus** on economics and performance while sourcing the right mix of distributed resources,
- **future proof** microgrids by offering the best available third party power converters, and by accommodating emerging building level DC distribution systems in addition to existing AC systems.

We **focus on >100kW microgrids**, standalone single/multi meter, or sub-system of large AC microgrids.

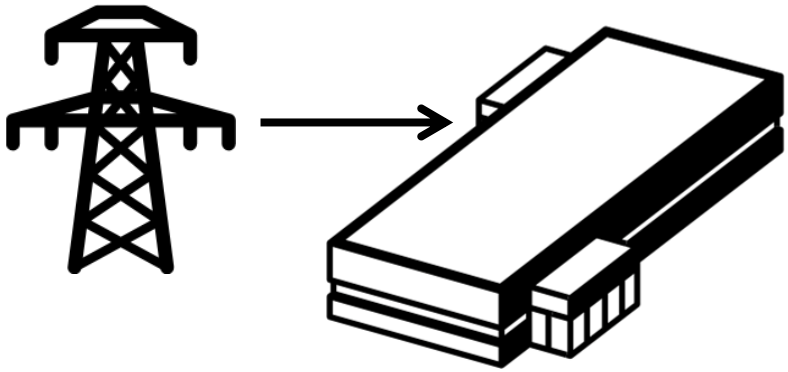
Global Electricity Mega Trend

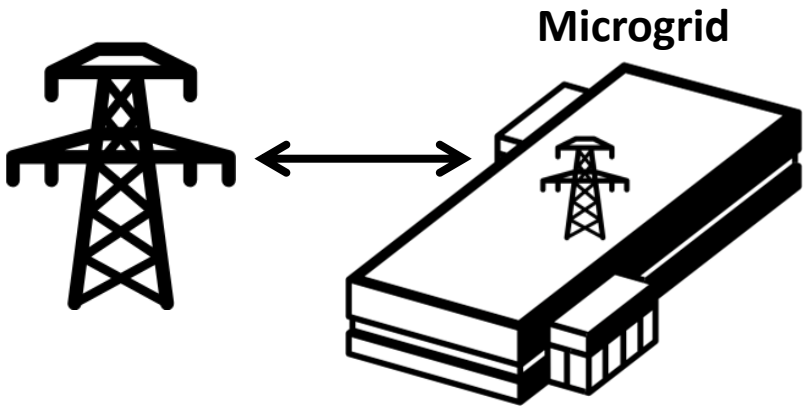
recent past
Centralized

near future
Decentralized

- ✓ Utility Grid manages Power and Energy
- ✓ **Consumers**

- ✓ Microgrid also manages Power and Energy
- ✓ **Prosumers** (Produce and Consume)





Explosive Growth Market

"Market undergoing transformation from a niche application intended for military bases and remote communities to a grid modernization tool." – GreenTech Media

Navigant in 2014:

$23 billion by 2024

Total Capacity 14GW

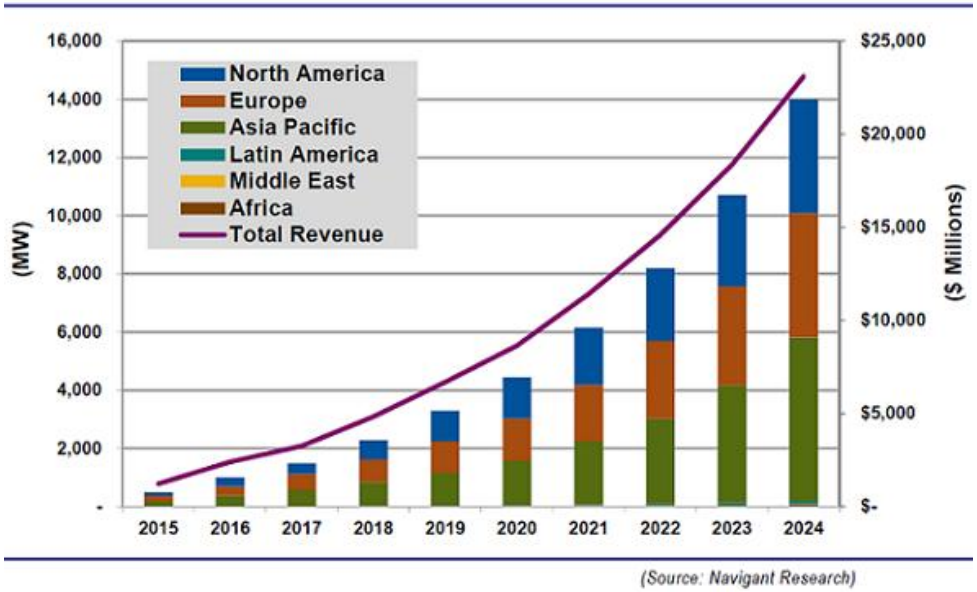
Solar PV plus Energy Storage Nanogrids

Navigant in 2017:

$49 billion by 2026

Annual Market 27GW

Distributed Solar PV plus Energy Storage



Per Navigant the sweet spot is C&I Microgrids

Main Focus of ARDA Power

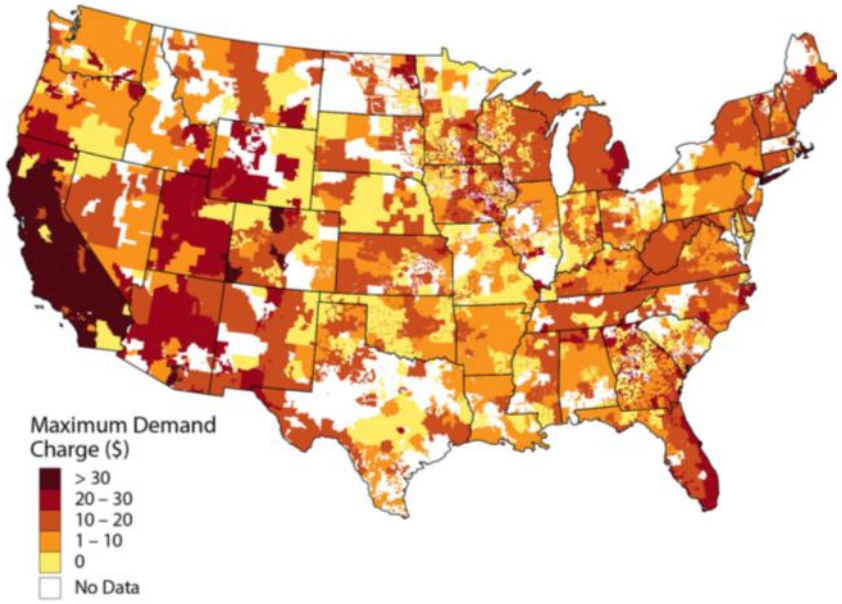
Customer Opportunity Pool: millions by 2021

Battery Storage economic justification – the main driver for Microgrids proliferation.

USA alone forms a tremendous opportunity pool. August 2017 NREL study:

3 million (of total 18 million) commercial customers will have a great economic case for Battery Storage based on just one value stream (demand charges) by 2021.

In addition to well known "storage case" states like CA and NY, there is a diverse set of qualifying states like CO, NE, AZ, GA, AL, MI, IA, NM and TX.



	Number of Customers Eligible for Demand Charge >$20/kW
California	1,081,000
New York	648,000
Georgia	216,000
Michigan	205,000
Massachusetts	180,000
Kentucky	41,000
New Mexico	24,000
Alabama	23,000
Texas	23,000
Iowa	23,000

Solar PV and other DERs, especially in a Microgrid arrangement, maximize value streams from Battery Storage.

Resiliency: $$$, not just Energy Security

Significant value stream for C&I applications. On average >1 major event per year with average 1-7 hours interruption event. Value in manufacturing sub-segment is doubled.

Jan 2015 L. Berkeley National Lab study, and U.S. Energy Information Administration Form EIA-861

Interruption Cost	Interruption Duration					
	Momentary	30 Minutes	1 Hour	4 Hours	8 Hours	16 Hours
Medium and Large C&I (Over 50,000 Annual kWh)						
Cost per Event	$12,952	$15,241	$17,804	$39,458	$84,083	$165,482
Cost per Average kW	$15.9	$18.7	$21.8	$48.4	$103.2	$203.0
Cost per Unserved kWh	$190.7	$37.4	$21.8	$12.1	$12.9	$12.7
Small C&I (Under 50,000 Annual kWh)						
Cost per Event	$412	$520	$647	$1,880	$4,690	$9,055
Cost per Average kW	$187.9	$237.0	$295.0	$857.1	$2,138.1	$4,128.3
Cost per Unserved kWh	$2,254.6	$474.1	$295.0	$214.3	$267.3	$258.0
Residential						
Cost per Event	$3.9	$4.5	$5.1	$9.5	$17.2	$32.4
Cost per Average kW	$2.6	$2.9	$3.3	$6.2	$11.3	$21.2
Cost per Unserved kWh	$30.9	$5.9	$3.3	$1.6	$1.4	$1.3

Note: the interruption costs are for the average-sized customer. The average annual kWh usages are 7,140,501 kWh for medium and large C&I customers, 19,214 kWh for small C&I customers and 13,351 kWh for residential customers. The average for medium and large C&I represents the most typical size of ARDA's target customer.

The Core of a Microgrid

Power and Energy Management System
(Software and Hardware)

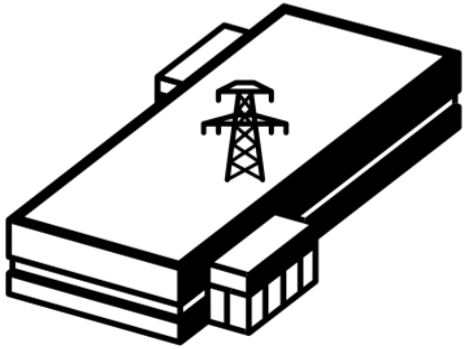
✓ **Power "Format"**
for AC (Voltage, Frequency, Phase), for DC (Voltage)

✓ **Energy Balance and Optimization**
to Utility Grid Pricing, Fuel Cost, Weather Forecast, etc.

✓ **Export and Import**
of Energy and Services

✓ **Islanding**
from the Utility Grid

Microgrid



C&I has the Largest Gap

Power and Energy Management System
(Software and Hardware)

TRADITIONAL	NEEDED
Complex	Plug-and-Play
Engineering Heavy	Productized
Utility Grid conflicting	Utility Grid friendly
$$$ AC	$$$ DC

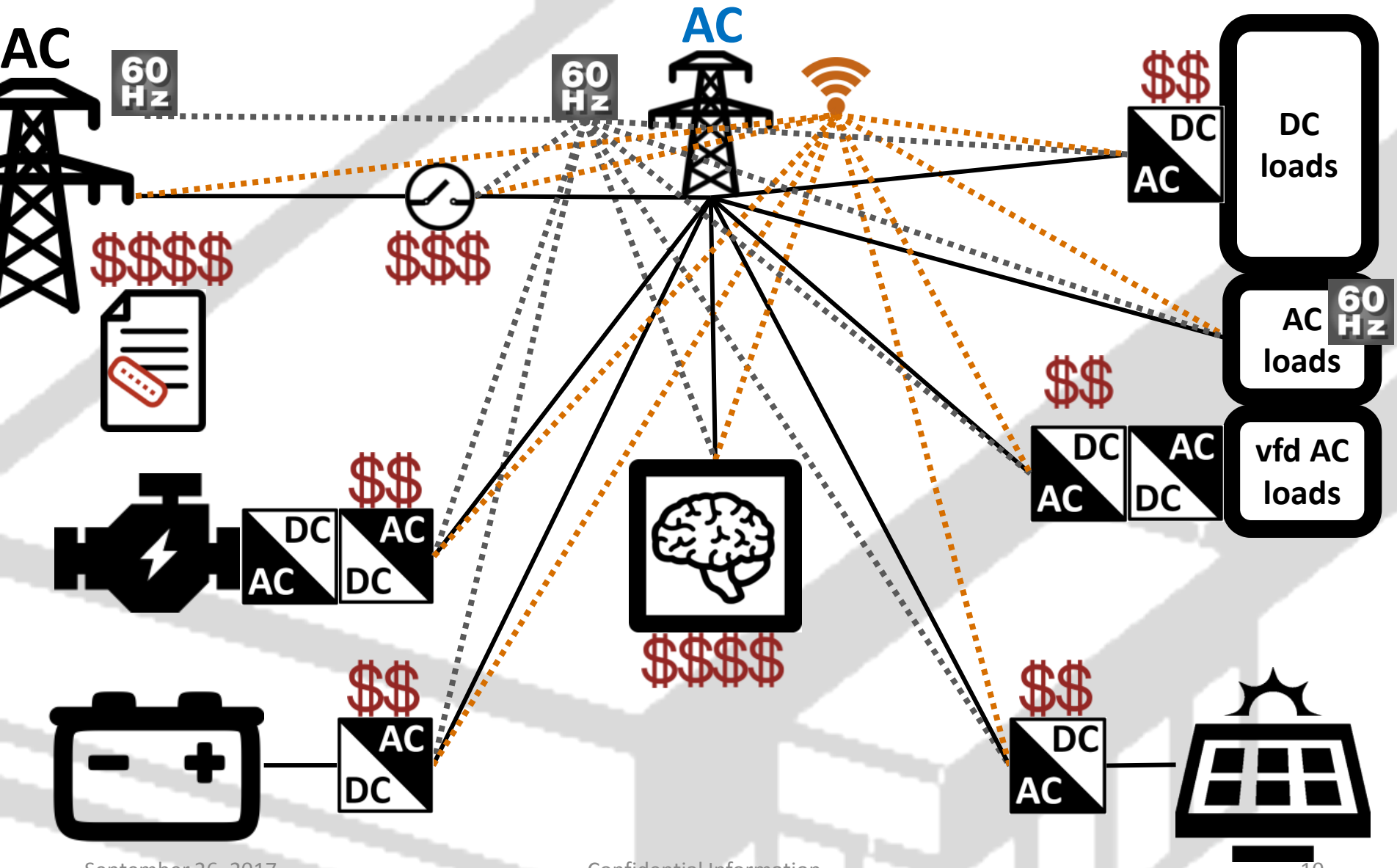
SECONDARY reasons for “Why DC?”

I generate DC

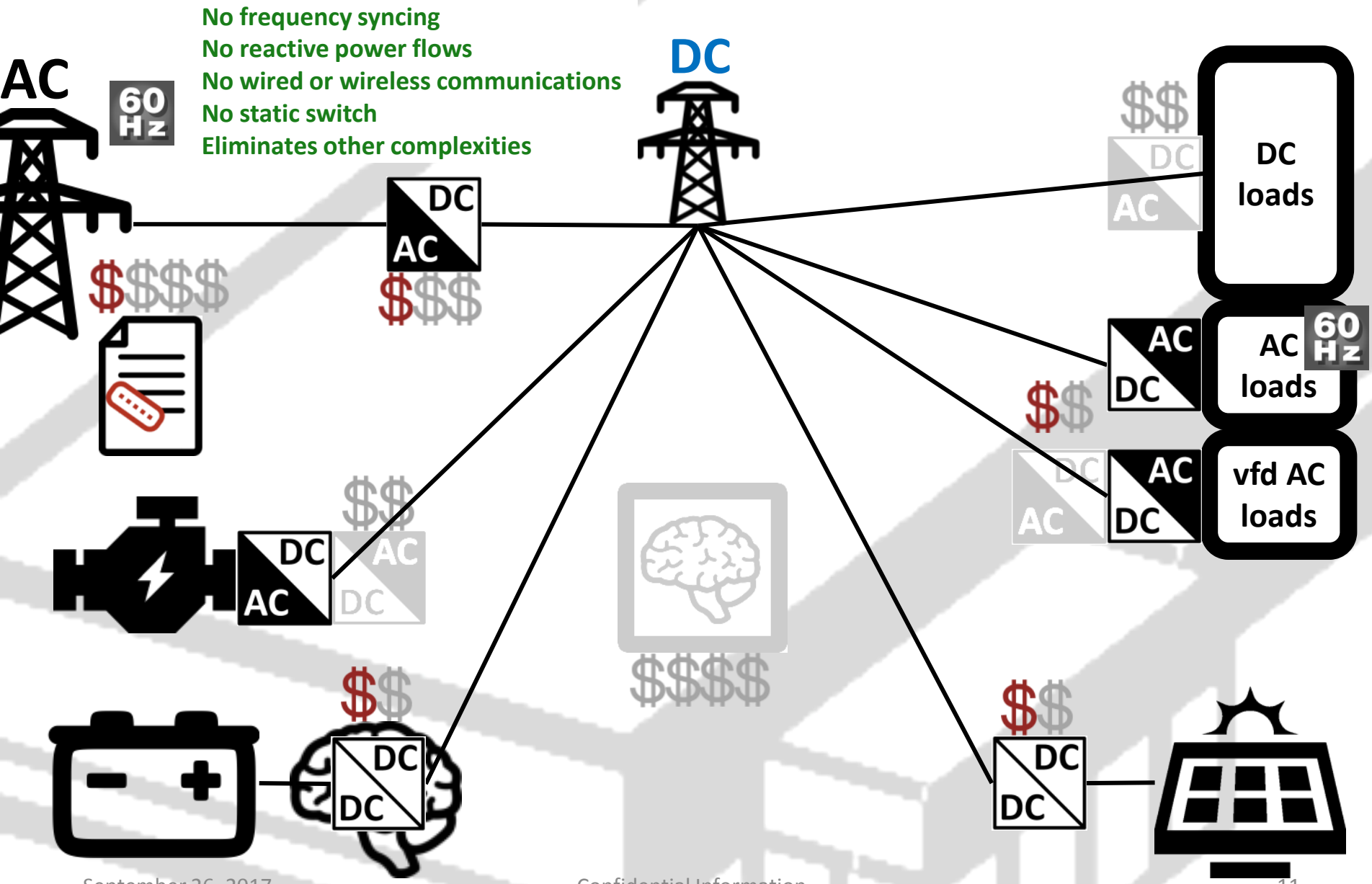
I store DC

I consume DC

Traditional Solutions: Natural Complexity



ARDA DC Platform: Inherent Simplicity



Simplicity enabled by Proprietary Controls

Microgrid Management Controls are performed from the Battery's DCDC converters

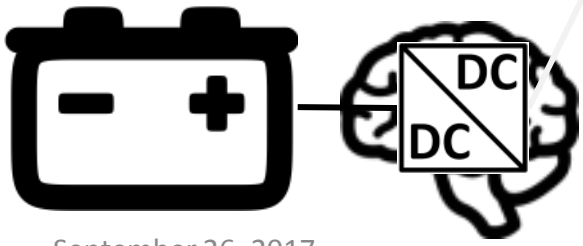
The Controls maintain Nominal DC Bus voltage, e.g. 760VDC, using exclusively the Battery's resources

The Controls follows the Battery's State of Charge, which changes when the microgrid's energy becomes imbalanced

The Controls change the nominal voltage to broadcast an expectation of change leading the system back to Energy Balance

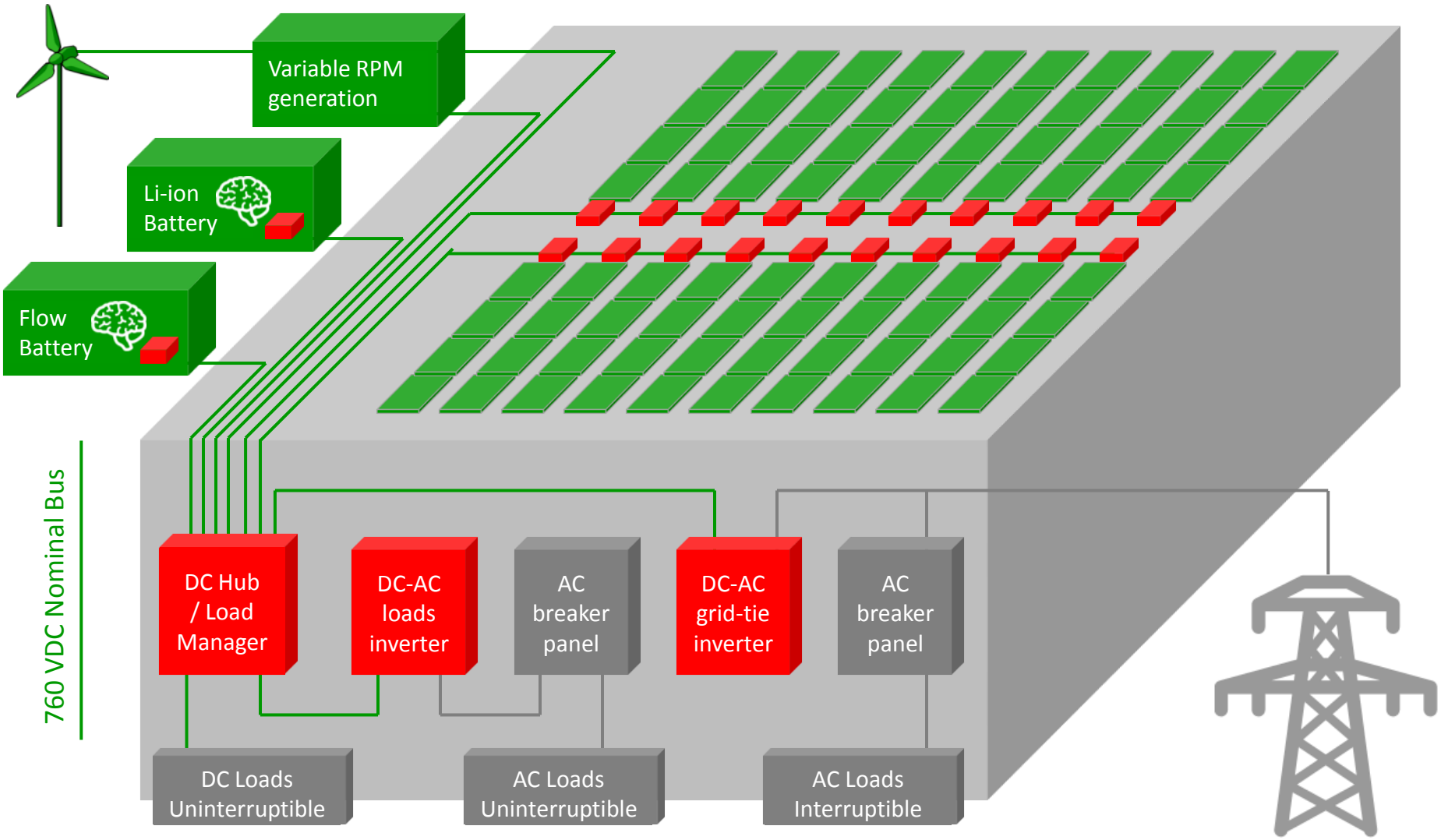
Each microgrid's generation and load elements have their individual response algorithms of reaction or lack of reaction programmed to respond to multiple levels of change in nominal voltage

There is only one mode of operation independently on the status of the utility grid



Resilience and Always Seamless Islanding

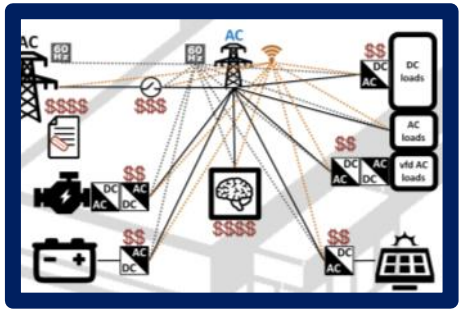
Small Footprint: in the Building, on the Grid



Can it Get More Disruptive?

ARDA power DC-connected energy

Grid CONFLICTING



$$$$ **Traditional** $$$

Group 1: power converters, protection, distribution HW	Group 2: microgrid controller (controls, design, HW)	Group 3: static switch

islanding with interruption of loads

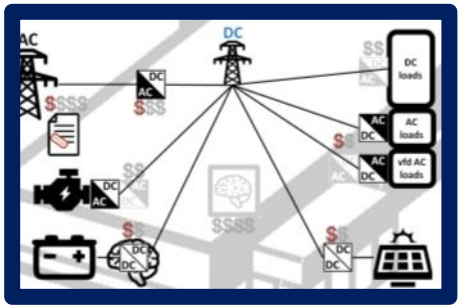
seamless islanding

Example: 1MW (DGs + Energy Storage) grid connected Microgrid

$$$$ **ARDA** $$$

ALWAYS seamless islanding

Grid FRIENDLY



Group 1 + Group 2 (embedded)	~~Group 2: microgrid controller (controls, design, HW)~~	~~Group 3: static switch~~

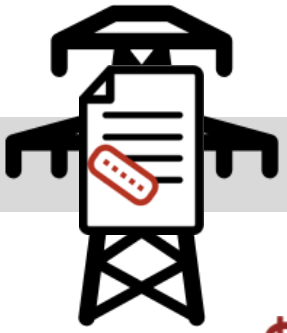
Can it Get More Disruptive?

✓ at a cost comparable to primitive non-microgrid power conversion + EMS solution

ARDA customers double or triple the value streams from the same DER resources

✓ in comparison with traditional microgrid architectures

ARDA provides a better solution at a third of the cost



Example: 1MW (DGs + Energy Storage) grid connected Microgrid

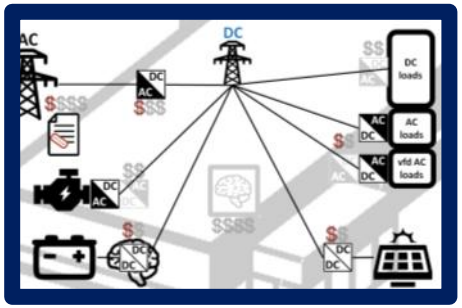
$$$$

ARDA

$$$

ALWAYS seamless islanding

Grid FRIENDLY



Group 1 + Group 2 (embedded)	~~Group 2: microgrid controller (controls, design, HW)~~	~~Group 3: static switch~~

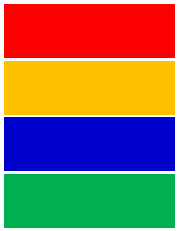
Controls + 3 HW modular Building Blocks

ARDA Microgrid Package satisfies any System Mix and Size with the same set of:

- ✓ Microgrid Controls (SW)
- ✓ DC Hub (breaker panel with Holistic Protections and Load Management)
- ✓ 3x modular Power Converter Building Blocks (2x types of DC-DC and 1x type of DC-AC)

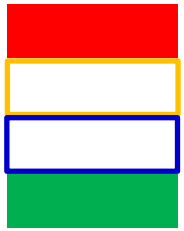
2017

DC Hub + 1 SW + Project Engineering + 3 x ARDA Blocks



as of 2018

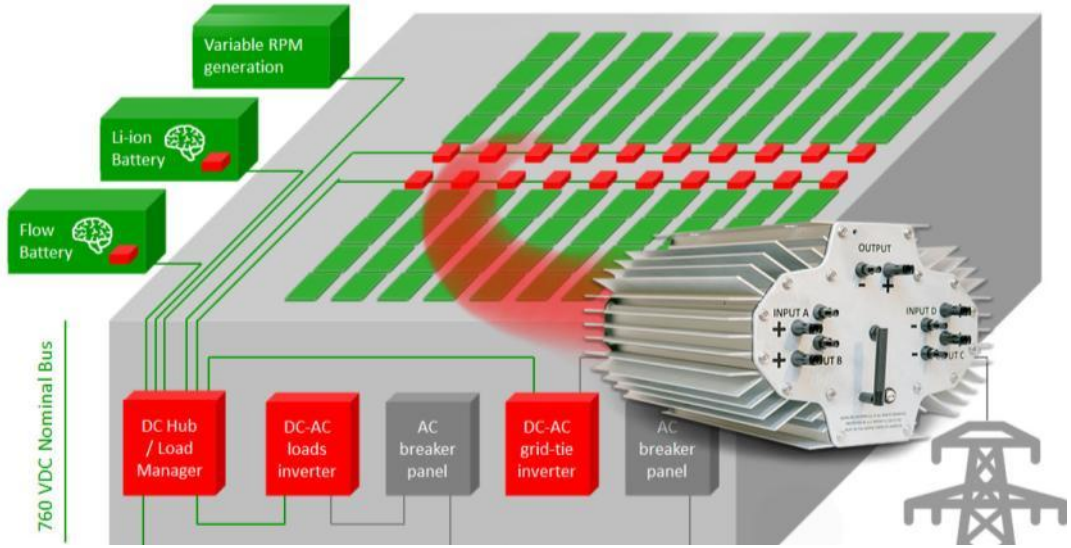
DC Hub + 1 SW + Project Engineering + 1 x ARDA Block + 2 x 3rd party Blocks



3rd Party Blocks Bet: Modular, Mass Produced

Solar DC/DC Converter with MPPT

Contracted Alencon Systems for their isolated converter (SPOT) in July 2017



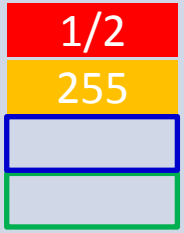
ALENCON

DC/AC Inverter

In 2017 large manufacturers are starting to introduce storage (bi-directional) versions of their mass produced, low cost trasnformerless solar string inverters. Most of these versions fit ARDA solution. Partner selection is in progress.

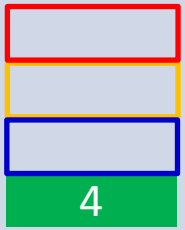
TABUCHI ELECTRIC SMA CPS REFUsol SUNGROW

Blocks: first used in non-Microgrid projects

Project	Status	Blocks
Solar PV plant, Sault Ste. Marie ON, Canada	Commissioned in Q2 2014	
2MW of Solar PV as extension to existing 30MW		

BLACK & VEATCH
Building a world of difference.

ESS Inc.
Energy Storage Systems

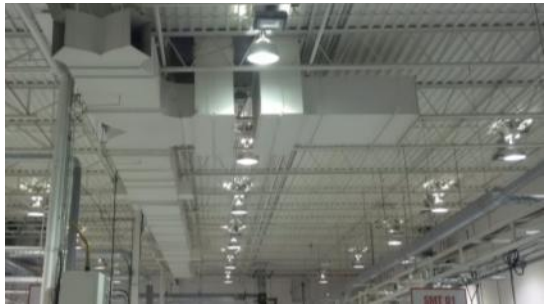
Project	Status	Blocks
US Army microgrid demo, Fort Leonard Wood MO, USA	Delivered in Q1 2017	
Battery DCDC converters for 2x ESS flow batteries		

Blocks: then used in the 1st Microgrid project

Project	Status	Blocks
Burlington DC Microgrid, Burlington ON, Canada	Commissioning Q2, 2017	1 3 2 1
16 kW Solar PV, 10 kW Natural Gas Generator, 20 kW/100kWh Flow Battery, 15 kW Grid Inverter (IMPORT/EXPORT), LED lights, DC air conditioner, DC refrigerator		

TINY "Grid Footprint":

Interconnection to the Grid follows the process for Rooftop Solar PV interconnection !!!

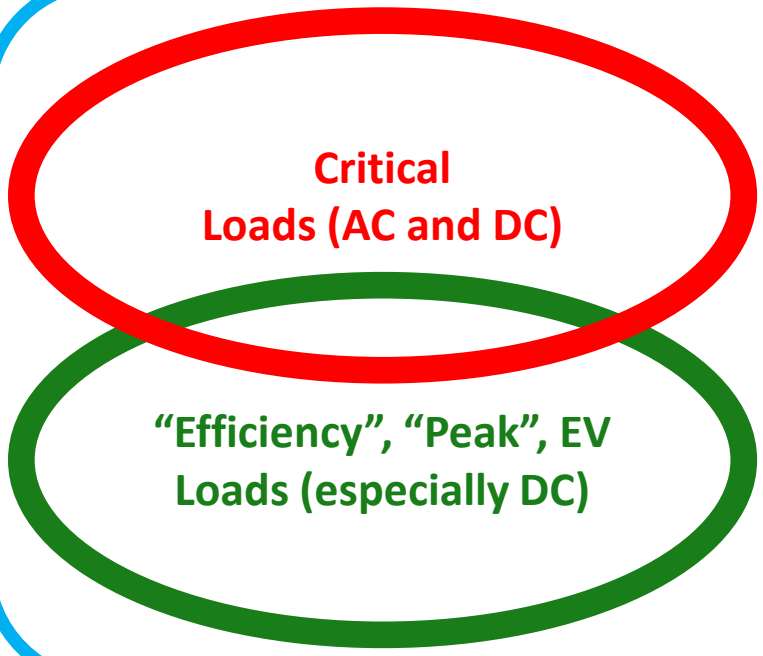


Blocks: hypothetical Microgrid examples

Microgrid Example	Description	Blocks
Office Building	Solar + Storage/DC Connected Loads	1 13 4 5
100 kW Solar, 100 kW/500kWh Flow Battery, 50 kW Grid Connect, LED Lights, DC Connected High Efficiency HVAC System – 50% of building loads		

Microgrid Example	Description	Blocks
Industrial Building	Solar + CHP + Storage/DC & AC Connected Loads	1 75 30 14
600 kW Solar, 400 kW CHP, 500 kW/1000 kWh Lithium Battery, 300 kW Grid Connect, LED Lights, DC Connected High Efficiency HVAC System, DC Connected Refrigerator, Critical AC Loads – 70% of building loads		

Single Meter applications

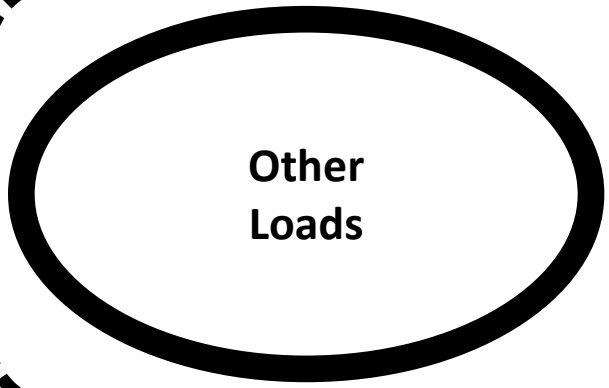


Target Loads

✓ Loads are covered by DC Microgrid and not directly connected to the utility grid

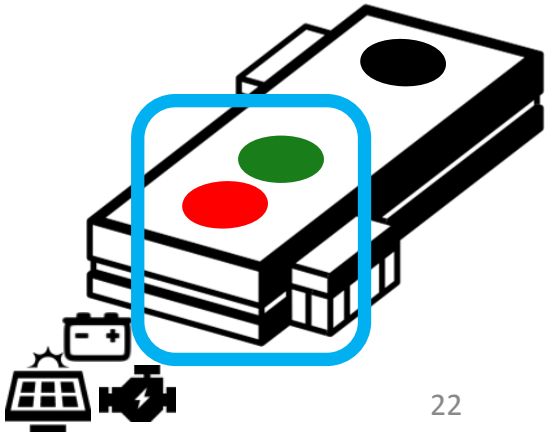
✓ Changes to the loads distribution infrastructure are not necessary

✓ Deployment in phases will be preferred if no penalty/cost derives from microgrid expansion



✓ Loads stay connected directly to the utility grid

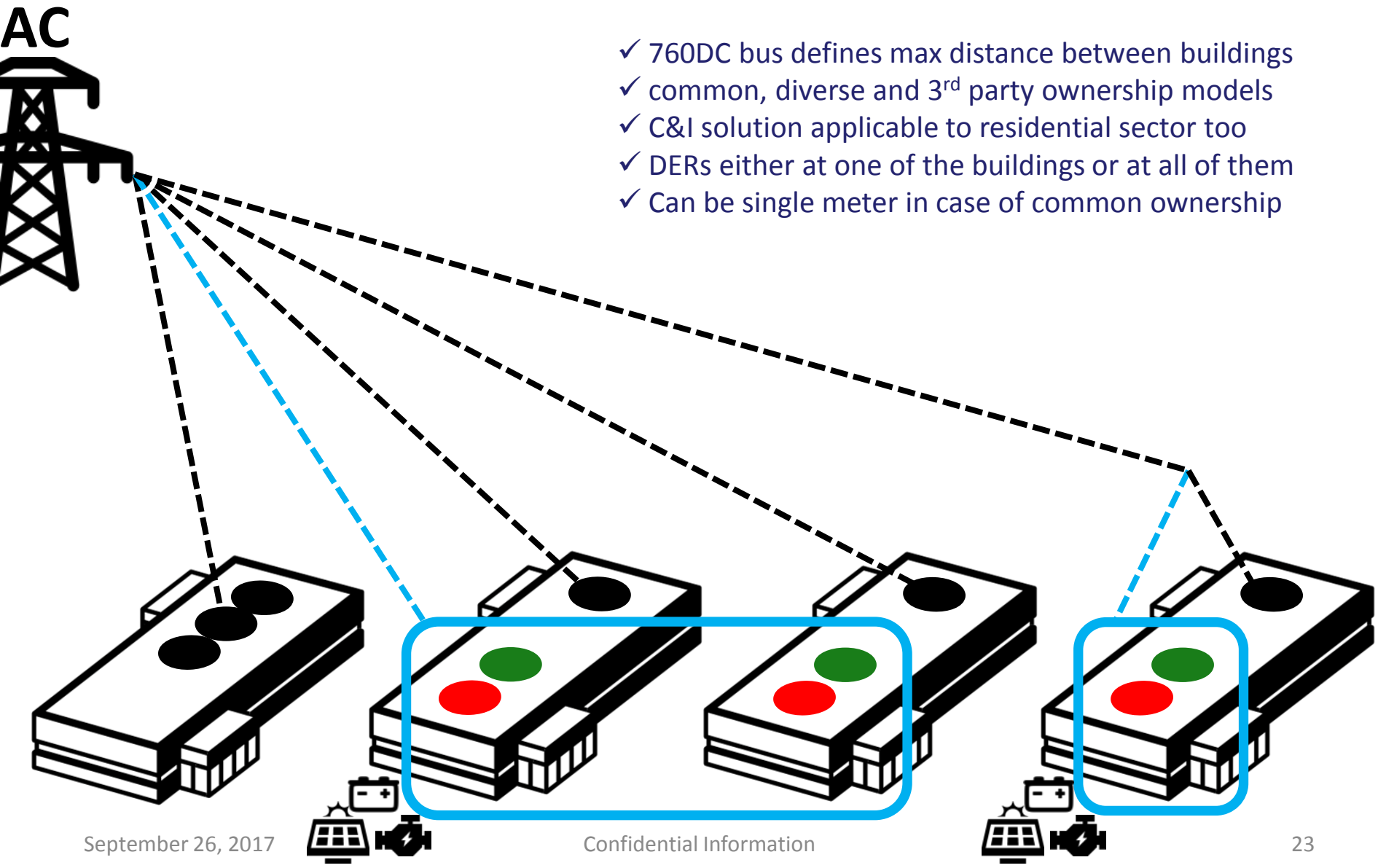
✓ No changes to the loads distribution infrastructure



Multi Meter applications

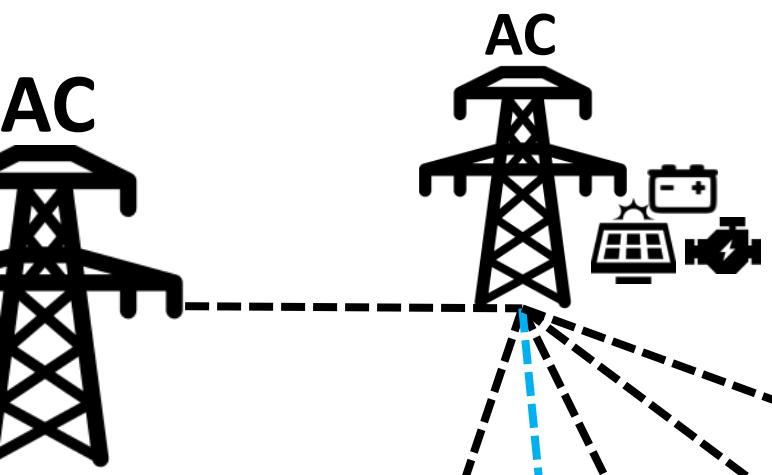
Several buildings covered by one DC Microgrid

- ✓ 760DC bus defines max distance between buildings
- ✓ common, diverse and 3rd party ownership models
- ✓ C&I solution applicable to residential sector too
- ✓ DERs either at one of the buildings or at all of them
- ✓ Can be single meter in case of common ownership



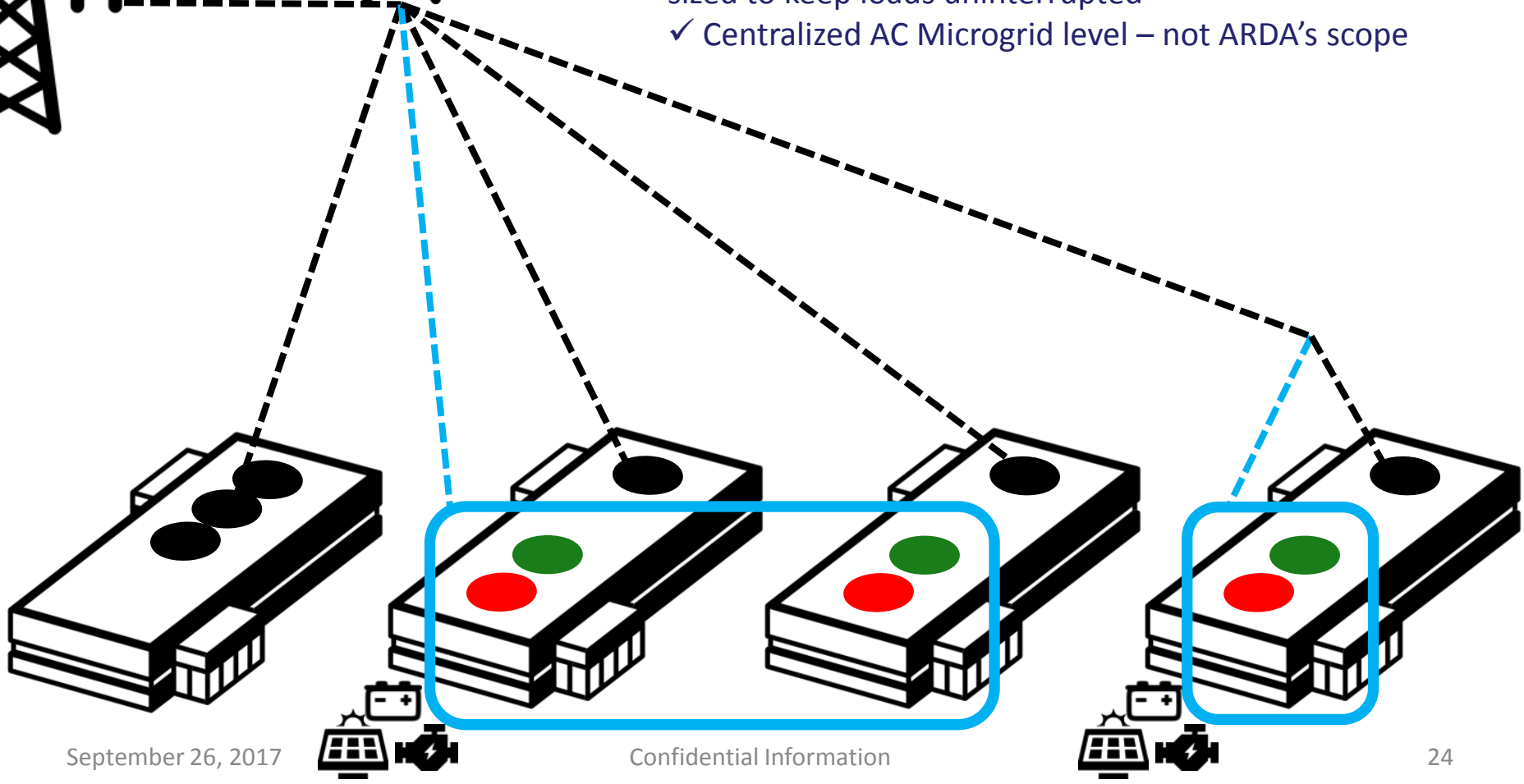
Microgrid of Microgrids

ARDA power DC-connected energy



Better, Simpler, Less Expensive AC Microgrid

- ✓ Fast AC islanding not needed, Less non-linear loads
- ✓ "Microgrid of Microgrids" DERs (centralized + local) are smaller than centralized only DERs, as only local DERs are sized to keep loads uninterrupted
- ✓ Centralized AC Microgrid level – not ARDA's scope



ARDA™ power

DC-connected energy

Generic Back-up Slides

Pioneers of DC Microgrid Technology

Luis Zubieta

Peter Lehn

Aleksey Toporkov

Kostya Strilets

Peter Lewis

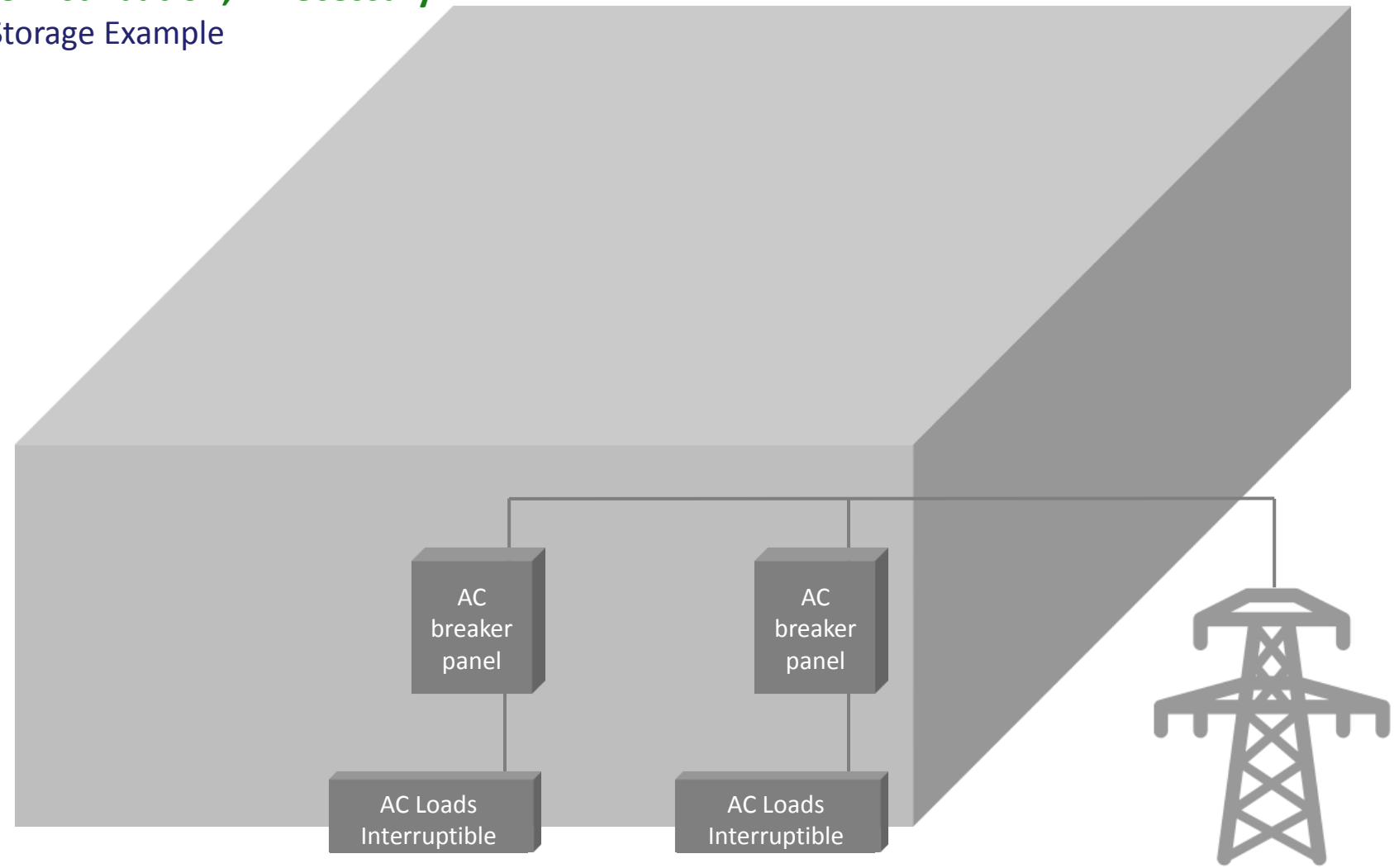
The Team that has made a Miracle

- ✓ Power Electronics
- ✓ Entrepreneurship
- ✓Cleantech Project Development
- ✓ Academic Research
- ✓ Executive Management
- ✓ Fast Growth

DC Microgrid for AC Distribution

Keep AC Distribution, if necessary

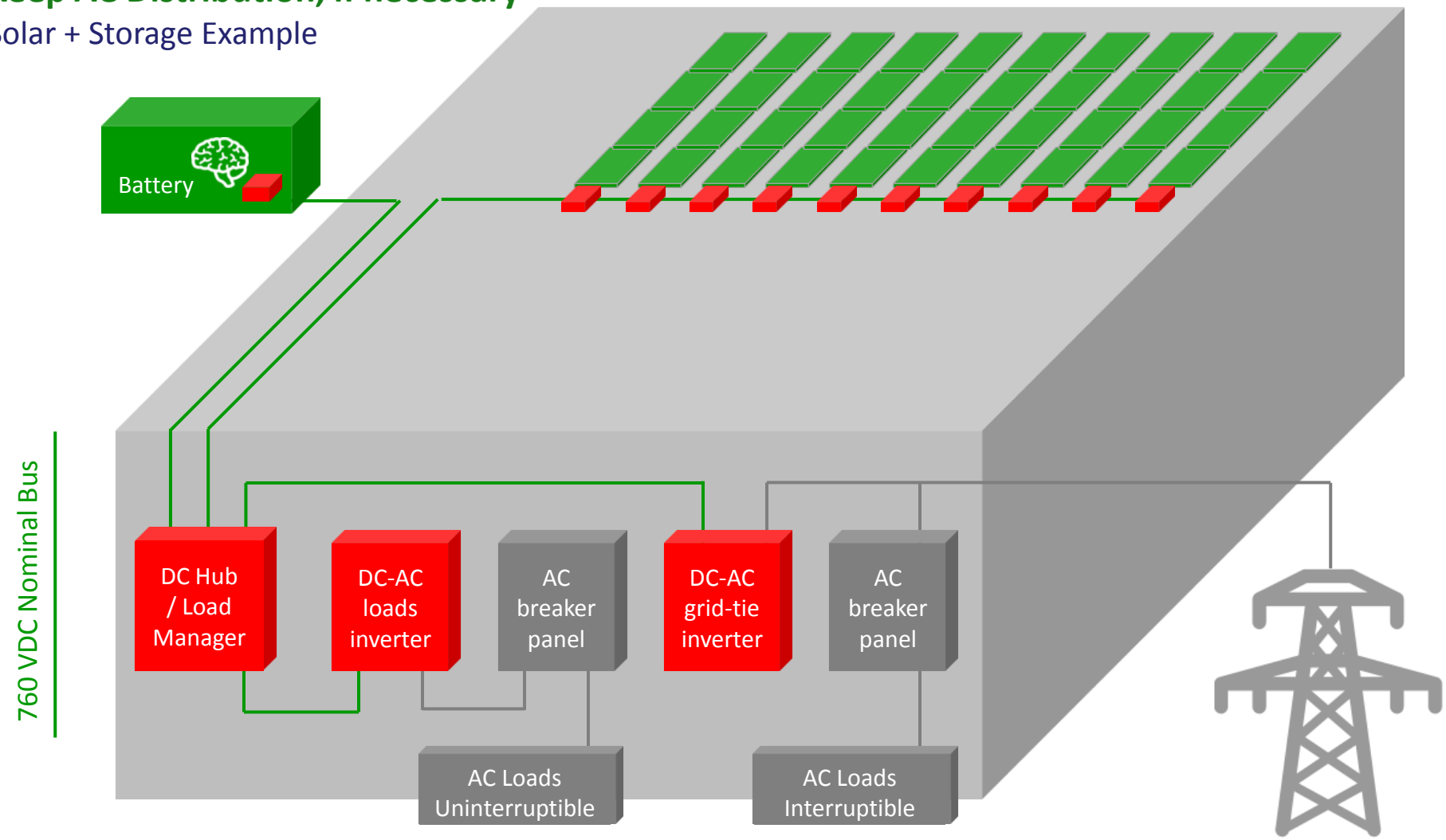
Solar + Storage Example



DC Microgrid for AC Distribution

Keep AC Distribution, if necessary

Solar + Storage Example



Partner Friendly Microgrid Controls

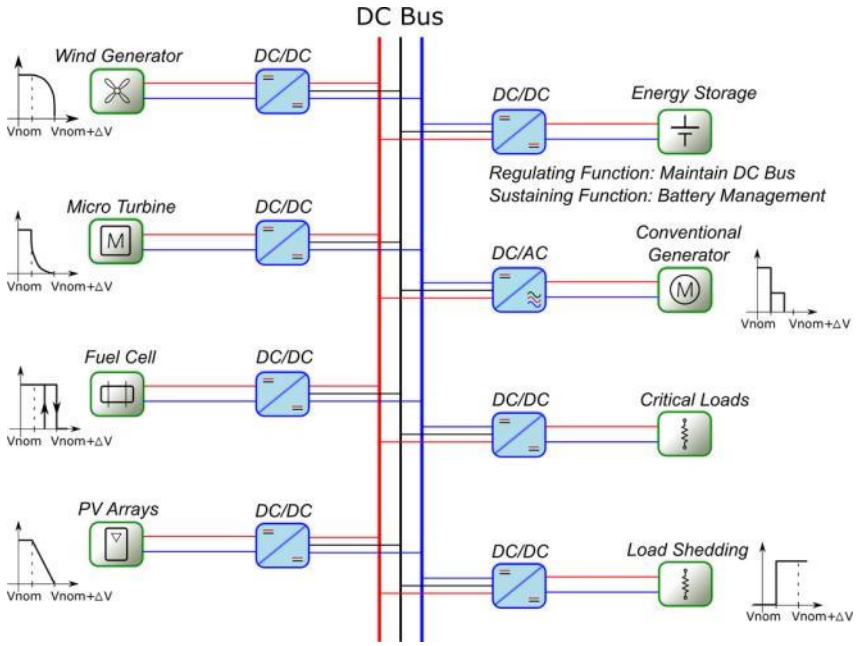
ARDA Power's partners can now focus on economics and performance objectives while not having to worry about the Microgrid Control's complexity.

✓ The Microgrid Control's 1st Layer (Regulating Function – Maintain DC Bus Voltage) and 2nd Layer (Sustaining Function – Energy Balance through Battery Management) are not affected by setting and changing the response algorithms/functions of the 3rd Layer of the Microgrid Control (Optimizing Function – Optimize Operating Cost and Performance).

Flexibility at no Cost to Plug-and-Play nature

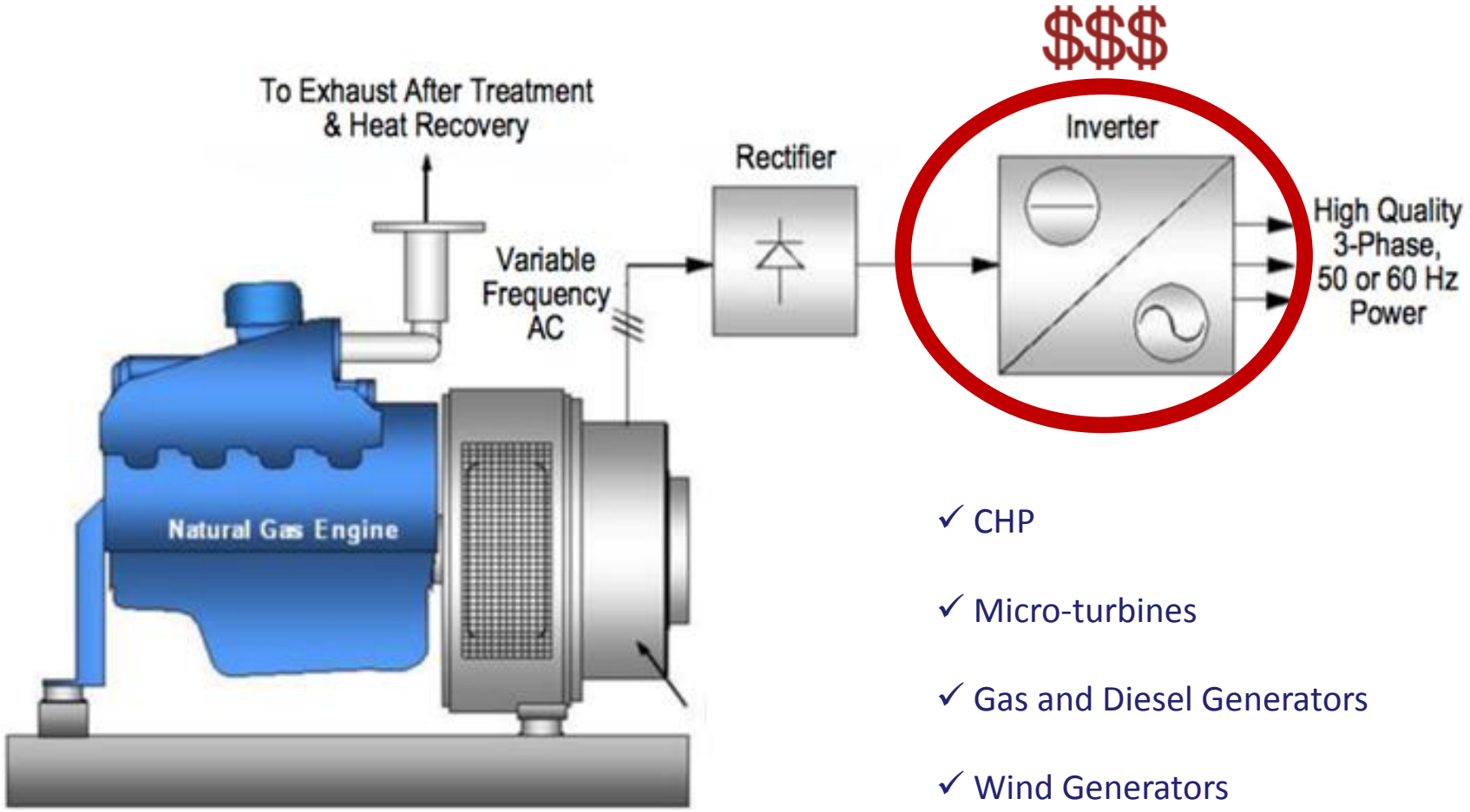
✓ The 2nd Layer's Sustaining function is separate from the battery supplier's BMS function.

✓ Third party Energy Management Systems can be used to optimize the overall Microgrid's and an individual element's performance based on electricity and fuel pricing, weather and other external data. This includes real time decisions on the import and export of energy/services to and from the Utility Grid.



Variable RPM AC Sources: Better via DC

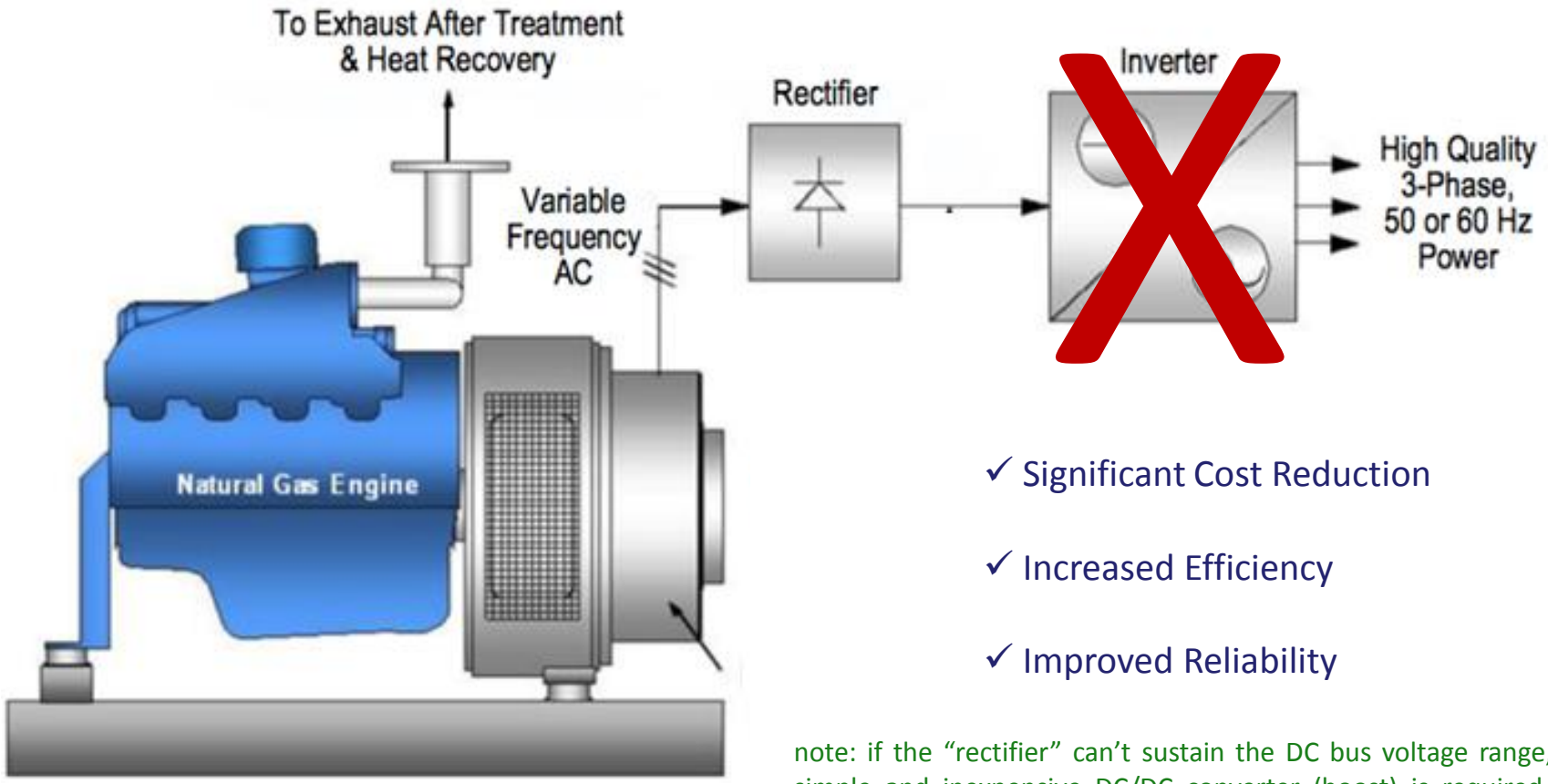
Modern AC Sources operate at variable AC Frequency/Voltage enabling variable RPM



- ✓ CHP
- ✓ Micro-turbines
- ✓ Gas and Diesel Generators
- ✓ Wind Generators

Variable RPM AC Sources: Better via DC

When part of ARDA DC Microgrid Platform, costly DC-AC Inverter component is eliminated



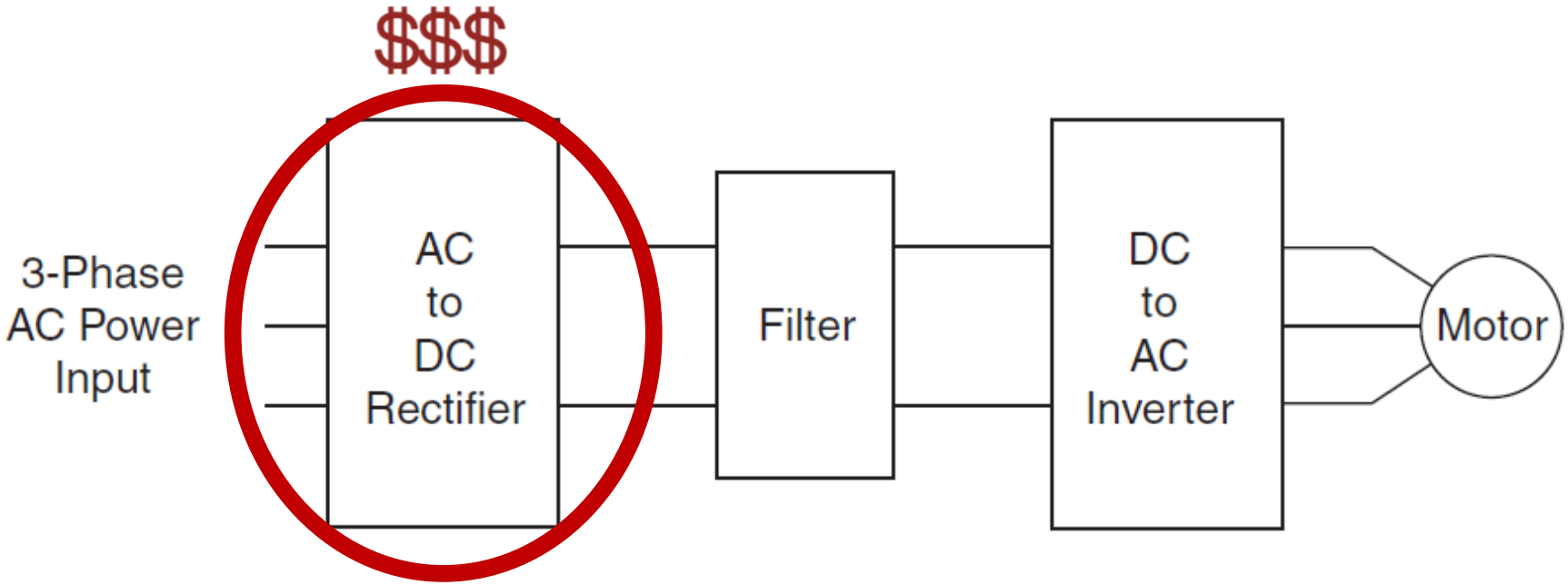
- ✓ Significant Cost Reduction
- ✓ Increased Efficiency
- ✓ Improved Reliability

note: if the "rectifier" can't sustain the DC bus voltage range, a simple and inexpensive DC/DC converter (boost) is required in place of the more expensive and less efficient inverter.

VFD equipped AC Loads: Better via DC

Modern AC Loads employ VFD (variable frequency drives) enabling higher efficiency

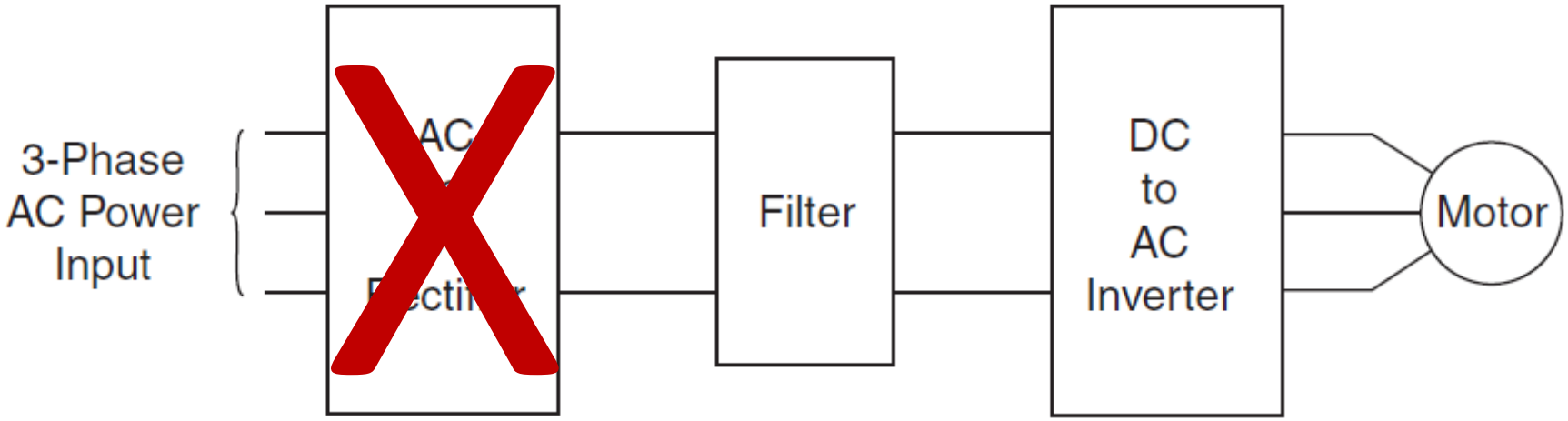
- ✓ HVAC (blower fan, pump, compressor)
- ✓ Refrigeration
- ✓ Elevators
- ✓ Ceiling fans
- ✓ Industrial Air Compressors
- ✓ etc.



VFD equipped AC Loads: Better via DC

When part of ARDA DC Microgrid Platform, AC-DC Rectifier is eliminated

- ✓ Cost Reduction
- ✓ Significantly Increased Efficiency
- ✓ Improved Reliability



note: if the DC voltage of the inverter is < 700VDC, a simple and inexpensive DC/DC converter (step down) is required in place of the more expensive and less efficient rectifier.

ARDA's "LEGO" Building Blocks approach

Requirement	Description	Building Blocks excl. off-the-shelf
Manage Microgrid	Power Management, Energy Management including Load Management sub-level	SW: Microgrid Controls
Interconnect Grid	interfaces Microgrid (DC) from Utility Grid (AC)	HW: DC/AC Inverter
Connect AC Loads	existing/new AC Loads or transformer	HW: DC/AC Inverter
Connect AC Sources 1	with fixed RPM	HW: DC/AC Inverter
Connect AC Sources 2	with variable RPM via AC/DC rectifier	HW: DC/DC Converter
Connect AC Sources 3	with variable RPM via AC/DC inverter	directly on the Microgrid's DC bus
Connect Solar	isolate solar arrays	HW: Solar DC/DC Converter
Connect DC Loads 1*	with lower Voltage as the DC bus Voltage	HW: DC/DC Converter
Connect DC Loads 2*	with same Voltage as the DC bus Voltage	directly on the Microgrid's DC bus
Connect Battery	house Microgrid Controls	HW: DC/DC Converter

** Including AC loads with internal DC link (VFD driven) with eliminated unnecessary DCAC converter component*

ARDA's approach:

3 x HW Components + 1 x SW element = satisfy all applications, mixes and sizes