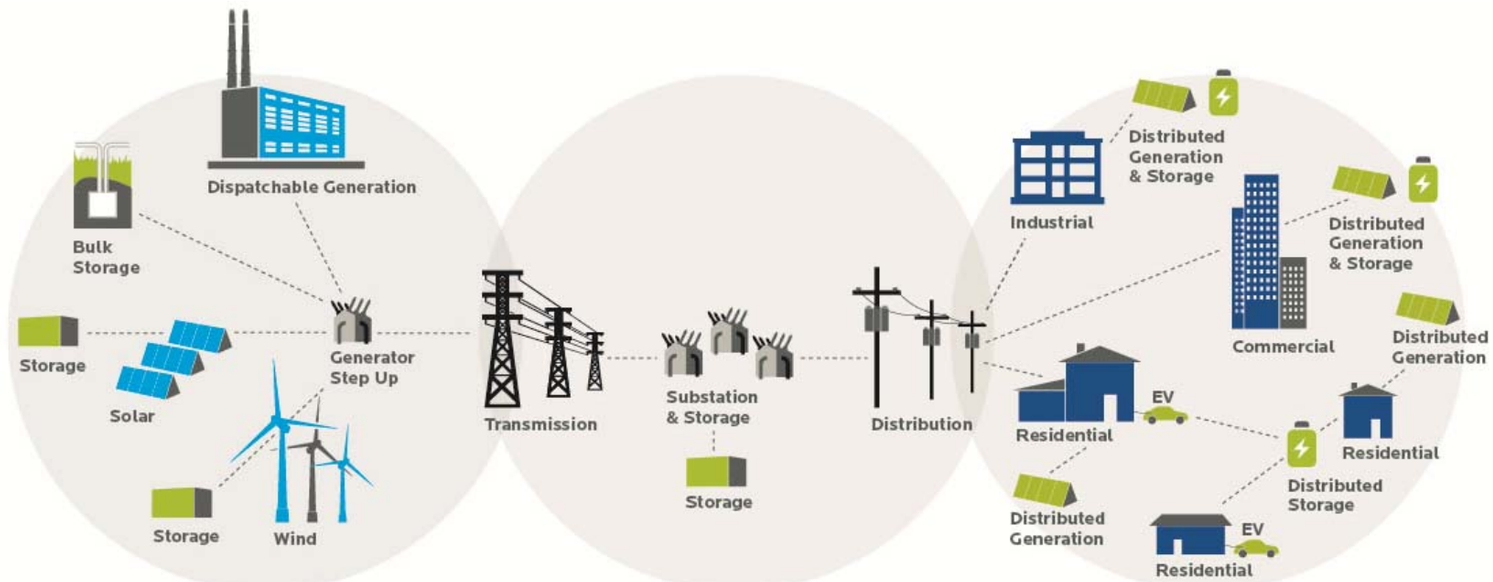
MICROGRIDS 101
CIBO TECHNICAL COMMITTEE MEETING - MARCH 2017

BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH

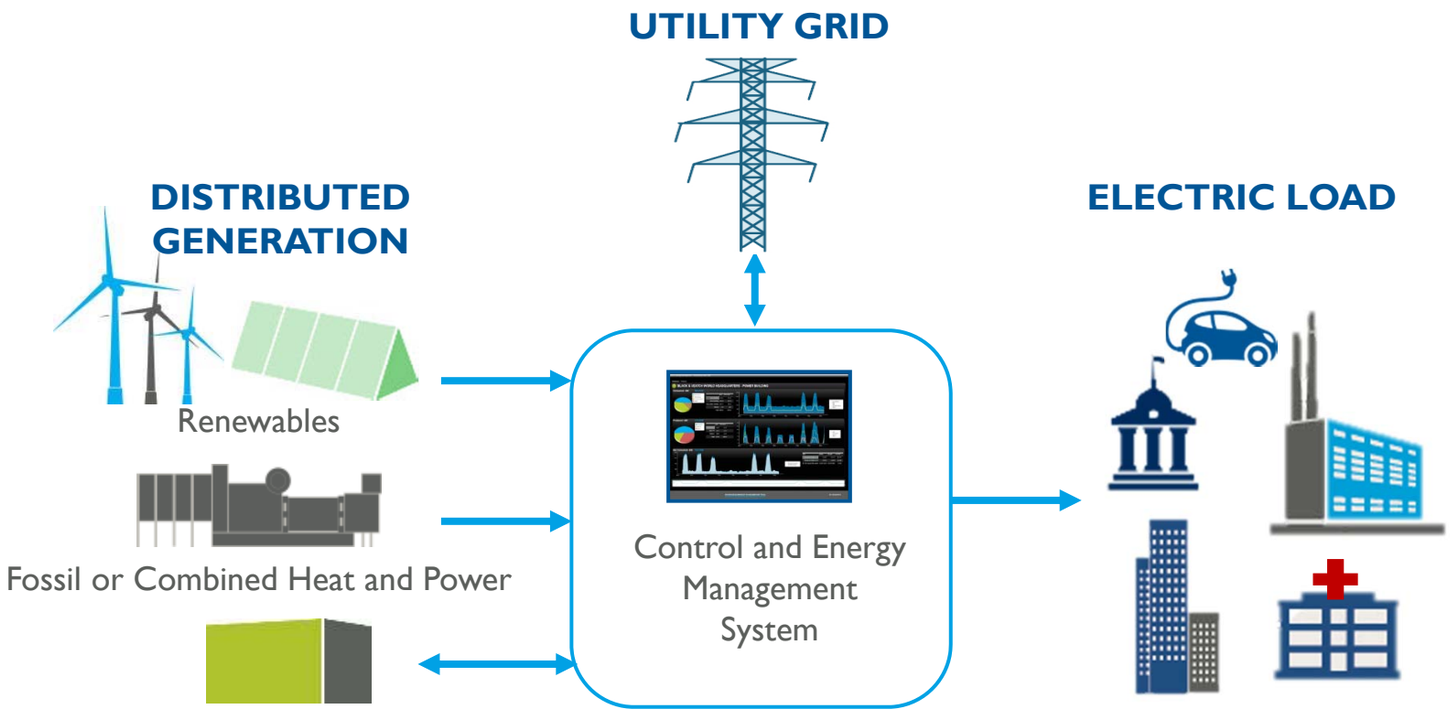
Distributed Energy Resources

The grid is becoming more distributed, driven by improvements in technology, declines in cost, advanced analytics, and a focus on sustainability and resiliency



Microgrid

Integrated system of multiple generations and load, operated as a system, with the ability operate as an island from the power grid



Functional Definition of a Microgrid

A group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid connected or island mode."

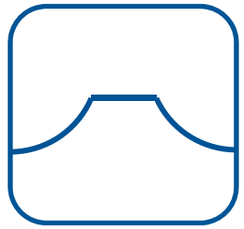
Localized generation and load

Island or grid-connect mode

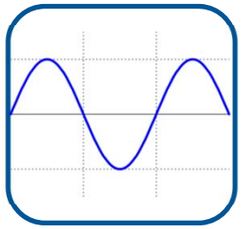
Smart controls

Advanced Functionality

Enables advanced site energy management and potential for services to the utility



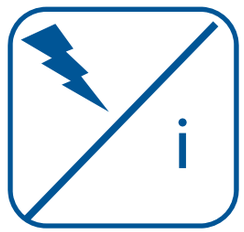
Peak shaving



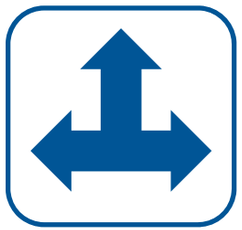
Power quality

Grid services

Energy management



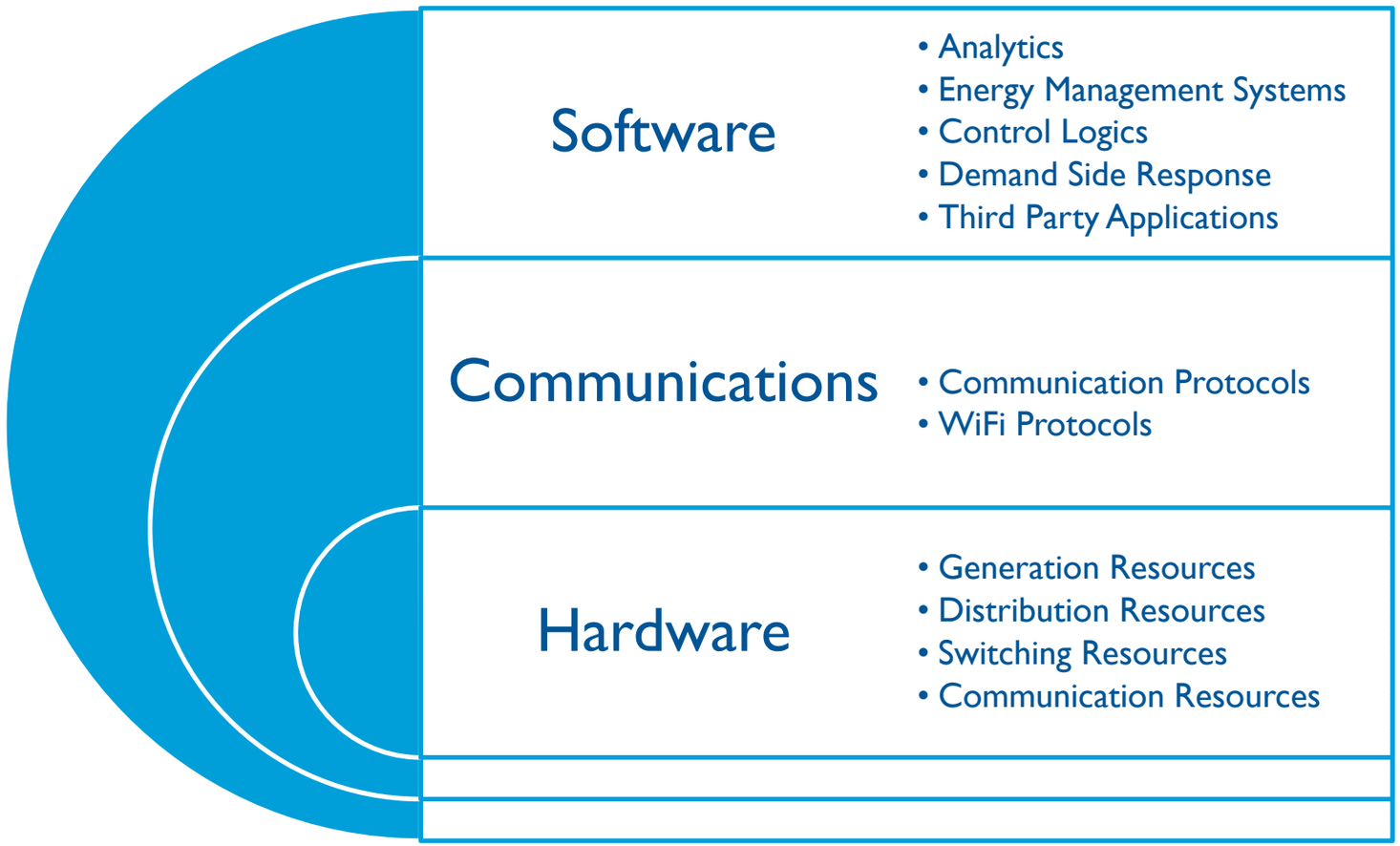
Island operation



CHP or tri-generation

Microgrid by Layers

The core of the microgrid is the hardware layer. The communications layer sits on top of the hardware layer. The software layer sits on top of the communications and hardware layers, and all layers combined form the microgrid.



Generation Resources for Microgrids

Microgrid is an integrated systems that could include fossil, renewable, and storage assets

Fossil / Biogas

- Reciprocating engines
- Gas turbines
- Combined heat and power
- Fossil fueled boilers

Renewable

- Solar PV
- Wind
- Biomass/Biogas (digesters)
- Waste to energy

Storage

- Batteries
- Compressed air energy storage
- Storage electronics (fly wheels, capacitors, etc.)

Distribution and Switching Resources

The distribution and switching resources form the major component of the electrical infrastructure. The electrical infrastructure forms the backbone of the microgrid.

- Cables (distribution ring bus)
- Low voltage transmission
- Electric vehicle (EV) charging stations
- DC to AC converters
- Electrical interconnection and feeders switch gear
- Islanding and anti-islanding protective systems
- SCADA systems
- Master energy controller
- Microcontrollers
- Other power quality and reliability controllers

Communication and Data Resources

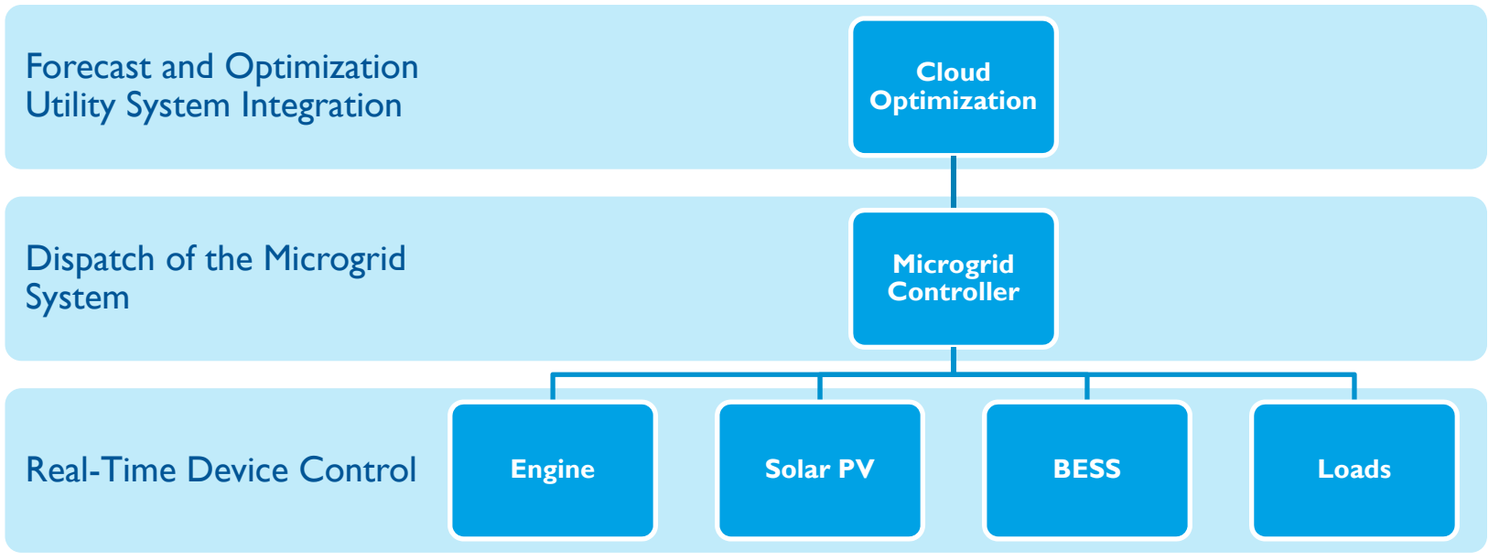
- Sensors
- Monitors
- Wired and wireless routers
- Ethernet cables
- Data storage
- Metering

Communications and Software Layers

- The communications layer of the microgrid consists of wired and wireless protocols and other communication protocols that enable individual pieces of equipment to communicate with each other
- The software layer of the microgrid typically consists of control logics and demand side response for operation, detailed analytical tools for the evaluation of performance and reliability, and high-level summaries for company and community engagement.

Typical Microgrid Controls Architecture

Smarter controls enabled by computing power and communications to gain more value from microgrids and distributed resources



Black & Veatch World Headquarters Microgrid

Demonstration, test-bed, and innovation center for microgrid technology

- Design-build of a microgrid demonstration project at Black & Veatch's World Headquarters
- Scope includes:
  - 50 kW Solar Photovoltaics
  - 150 kWh Li Ion Battery Energy Storage System
  - 2x65 kW CHP microturbines
  - Custom design control system
  - Integration with Asset360 remote monitoring and diagnostics platform
  - Public kiosk display

[Virtual Tour of BV Microgrid]

Microgrid Applications

The best applications achieve multiple objectives around resiliency, sustainability, and economics

- **Remote Power**
- **Facility / Campus**
- **Community**
- **Utility**
- **Government / Military**

Mobile Remote and Fixed Power Plant Project
Indonesia
Worked with PLN to define a strategy for development of reliable power supply for remote communities across Indonesia

Utility Non-Transmission Alternatives
United States
Developed solutions of multiple microgrids to address transmission system issues and high load pockets in the US Northeast

Miramar Military Microgrid
United States
Black & Veatch and Schneider Electric are executing an EPC Contract for an advanced microgrid at the Miramar facility in California. Multiple technologies and advanced controls.

Key Drivers for Microgrids

Microgrid can be designed to address multiple goals. Microgrids can save you money and can also generate a revenue stream.

- Resiliency
- Enhanced Reliability
- Utility Cost Savings
- Sustainability goals
- Rate Stability

Resiliency

- Resilient to catastrophic events that can lead to extended loss of grid power
- Extended operation beyond what could be served by local fuel after loss of grid.
  - Fuel deliveries may be impacted by event due to road conditions and high demand. On-site loads can be prioritized to conserve fuel.
- Load supplemented with solar and other resources to further extend fuel supply.

Enhanced Reliability

- Enhanced reliability of supply for the consumer
  - Power quality and loss of power
- Enhanced reliability of the local utility distribution system
  - Microgrid can respond to local power quality issues

Utility Cost Savings

- Energy Cost Savings
  - On site generation such as solar PV and biogas reduces energy purchased from the utility, automatic load shifting of flexible load to high generation periods
- Demand Charge Savings
  - Onsite generation can provide “peak shaving” to off-set demand seen by the utility.
  - Automatic load shifting of flexible loads to off-peak periods, and energy storage to load shift non-flexible loads.

Sustainability Goals – Reduce Carbon Footprint

The majority of grid power generation comes from fossil fuels plus transmission line losses thus integrating renewable generation with conventional generation can reduce carbon footprint

Rate Stability

Utility energy and demand charges are likely to increase over time

- Microgrids with integrated renewable energy can reduce uncertainty for future energy cost
- Increased value of load flexibility to respond to changes in utility rates by using automation that provides flexibility to respond to new “on-peaks” and “off-peaks”.
- Changes in energy market may allow for monetization of services microgrid can provide for the grid (voltage and frequency response)

Candidate Sites for Microgrids

- Facilities with greater than 9 cents/kw-hr industrial electric rate
- Facilities located in states with incentives and grant money for microgrids, efficiency and resiliency – especially areas in the Northeast and Southwest
- Facilities with onsite renewable energy onsite or contemplating these in the near future
- Facilities contemplating demand response with the local electric utility to generate revenue and investigating both utility grid-connected and islanding operations
- Facilities located along the Northeast and South/Southeastern seaboard – prioritizing storm resiliency
- Facilities with cohesive relationship with local electric utility provider – Favorable utility interconnection agreements.
- Facilities with existing power quality and availability issues

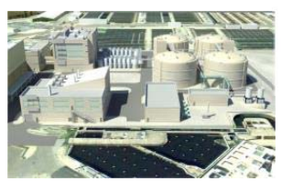
Experience

Deep experience with the full spectrum of distributed energy technologies

300+ Tesla Supercharging Stations in North America

40MWh + Behind-the-Meter Battery Installations

50+ Rooftop Installations 19,000MW of Solar PV experience



8,000MW+ of CHP Experience

Microgrids from 200kW to >25MW

Learn more at bv.com.