Integrated Implementation of Virtual Power Plants (VPP) & AI & IoT Enabled Concepts to System LOAD

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Outline

- Definitions
- Challenges in System Expansion
- Daily Load Analysis
- Integrated Concept Application
- Conclusions and Recommendations
Summary

● To reduce CO2 emissions, there is a need to accelerate transition from fossil fuels to renewable energy generation.
● Considering intermittency of wind and solar resources, a number of energy storage technologies are being developed to help increase the penetration of renewables.
● With current developments in Internet of Things (IoT), Blockchain and Artificial Intelligence (AI) technologies and Smart Appliances, power system load can be controlled more efficiently by integrated application of VPP and VPL concepts.
Virtual Power Plants (VPP) (Reference US DOE)

VPPs are aggregations of distributed energy resources (DERs) such as rooftop solar with behind-the-meter (BTM) batteries, electric vehicles (EVs) and chargers, electric water heaters, smart buildings and their controls, and flexible commercial and industrial (C&I) loads that can balance electricity demand and supply and provide utility-scale and utility-grade grid services like a traditional power plant. VPPs enroll DER owners – including residential, commercial, and industrial electricity consumers – in a variety of participation models that offer rewards for contributing to efficient grid operations.

Virtual Power Plants (VPP): Pathways to Commercial Liftoff (energy.gov)
Virtual Power Lines (VPL): Innovation Landscape Brief (irena.org)

Virtual power lines (VPLs) allow for large-scale integration of solar and wind power without grid congestion or redispach, avoiding any immediate need for large grid infrastructure investments.

1. Charges based on previous renewable generation to avoid congestion and curtailment
2. Discharges to demand-side storage whenever grid capacity is available

Supply-side-storage

3. Charges when renewable-based generation and network capacity allow
4. Discharges to address peak demand

Demand-side-storage
Potential Challenges for Renewables Expansion

- Renewables is an **Intermittent** power supply
- **Transmission Line** need major upgrade to support renewable integration targets
- Push towards **all electric loads**
- **Upgrade** of power **distribution** system
Potential Challenges – Residential Sector

- **All Electric Loads**
- **Improper sizing** solar and battery system due to lack of load understanding
- High cost for residential solar installation
- High cost of **energy storage** (batteries)
- Solar only available during daytime (**Duck Curve**)
Historically – Load Flow

Generation → Transmission/Distribution → Load

Focus - Load as it dictates power to flow and through path of least resistance.
Present – Load Flow to Power Flow

Focus – moved to Generation
- System Reliability criteria
- Market Structure Introduction
To meet the goal of **All Electric Load** we need to:

- **Integrate residential** energy systems in system planning
- Understand the **LOAD, as it dictates flow of power**
- **Peak, Minimum** and **Average** load, as it affects system capacity, reliability and stability
- **Peak Shaving** involves shifting energy consumption from peak to off-peak hours to maintain average load
- **Load Shedding** involves temporarily reducing non-essential loads during periods of high demand scenarios (VPP)
Average American home uses an average of **10,632 kilowatt-hours (kWh)** of electricity per year.

**Implementing All Electric appliances/load** - key items that consume 1 kW or more electricity.

- **Oven/stove**: 2,000 to 5,000 watts (US$ 2,000)
- **Heat pump**: 545 to 7,500 watts (weather dependent) (US$ 15,000)
- **Space heater**: 1,500 watts (US$ 100)
- **Central air conditioning**: 3,000 to 4,000 watts (US$ 10,000)
- **Water Boiler**: 5,000 watts (US$ 8,000)
- **Window AC unit**: 500 to 1,400 watts (US$ 500)
- **Washing machine**: 400 to 1,400 watts (US$ 1,300)
- **Dryer**: 1,500 to 5,000 watts (US$ 1,200)
- **EV**: 19,000 watts (EV price - US$ 20,000 - 100,000-250,000)

**All Electric Load**, depending on configuration, will significantly increase residential load, and may need major distribution system upgrades in some areas

*How much electricity does an American home use? U.S. Energy Information Administration (EIA)*
*How Many Watts Does it Take to Run a House? | EnergySage*
*How Much Do Home Appliances Cost? (2023 Prices) - HomeGuide*
Understanding Load – Energy Consumption – Continued

Reason for peak load. Compared with days temperature.
- Well insulated house (analyzed by utility)
- Major Electrical Appliances (Loads)
  - Air Conditioning
  - Water Boiler
Load Breakdown Analysis

- Peak Load = 12.1 kW
- Water Heater = 4.3 kW
- Air Conditioning 1 = 1.92 kW
- Air Conditioning 2 = 1.47 kW
Daily Load Curve (Residential Load Sample)
Daily Load Curve (Sample Residential Load) - Continued

- Analyzing Summer, Winter and Moderate weather loads
- Peak load = 5.5 kW
- Average Load = 3 kW (Summer)
- Average Load = 2 kW others
- Minimum Load = 0.66 kW (Moderate)
- Goal to reduce peak to average Load (3 kW)
- Major loads are air-conditioning and water heater
- Shift load from peak to fill valleys
Future - Power Flow

Generation

Renewable energy resources

Transmission

Energy storage - Utility scale

Load DER

DER / Micro / Mini / Community Grid

Smart Controller
Energy Storage Control system
Vision – VPP+VPL Application to Load - DER

Transmission

Substation

Distribution Feeder
Residential/Commercial

Distribution Feeder
(Industrial)

Potential Power exchange

Load
DER - Micro/Mini Grid
Behind the Meter (BTM)

Micro / Mini / Community Grid

Smart Controller
Energy Storage
Control system
AI & Open architecture
Blockchain
Communication Connectivity

Utility – Split into smaller batteries (BTM)

Apartment Load

Business Load

Community Energy Storage

Industrial Load

Apartments

Residential/Commercial

Generation

Transmission
AI – Artificial Intelligence

Example: Open AI’s NEW Text-To-Video AI Model
https://youtu.be/nEuEMwU45Hs?si=du0q4PYupp3785A
Community Blockchain platforms empower local energy communities to securely trade renewable energy credits and optimize energy consumption. By enabling transparent and decentralized transactions, they promote sustainability and community engagement in energy management.

*Blockchain in Energy & Utilities — Indigo Advisory Group*
Smart Equipment
Vision – VPP+VPL Application to Load - DER

- **AI and Data Analytics** for load analysis and self learning and updating based on actual usage pattern
- **Residential Solar System** (BTM – Behind the Meter battery)
- Transformation to **DER - IoT**
- **Smart Controller** (Control demand to meet preset criteria) – VPP integration
- **Smart Communication**
- **Smart Appliances**
- **Connectivity** within micro grid and bulk system
- **Blockchain** – within community and energy spot market.
- **Plug and Play – Open Architecture**
Proposed Strategy - Residential Load

- Considering All Electric Loads, **Understand the load**
- Electrical characteristics of individual loads
- **Goal:** Predetermined, Constant, Stable and Predictable Load
- **Charge batteries** during day using renewables. **Use batteries** during peak conditions. **Charge batteries** partially or/and EV at night using utility power
- **Utility Target** area / goal (e.g.) **30% reduction** in distribution feeder load on average. Combined affect as seen at substation, including residential, commercial and industrial loads
- Utility supported detailed load analysis, as utility controls system wide the data
- Utility funded/subsidized modular **Generation Kits** for residential customers. Market off the shelf products consist of standard sizes, potentially increasing system cost.
- **Smart Control** system – Support VPP
- **Residential** customer with option to **Sell power** back to Utility or **Blockchain** application within community or neighborhood
Benefits

- **Optimized size** for battery and solar/renewable generation
- Increased renewable installations – increased renewables penetration
- Reduction in carbon footprint
- Increased transmission capacity to add more renewables generation
- Improved **distribution system stability**
- **Capital cost reduction** to maintain distribution system stability
- **O&M cost reduction**
- Increased EV penetration
Conclusion - Recommendations

1. **Integrated Implementation** of VPP+VPL system to Load.
2. Define **System Design Criteria**
3. **Pilot Projects** - lessons learned
4. **Best Practices** supported by local utilities
5. Time of day tariffs
6. **Utility system cost sharing** criteria to encourage Behind the Meter Renewables
7. Apply to Commercial and Industrial loads as next phases (II and III).
Thank You
General Discussion
Pilot Projects

VPP
- Texas: Tesla Electric Virtual Power Plant Beta with ERCOT
- VPP4ALL - Electric Power Research Institute (EPRI)

VPL
- Vermont: Tesla's Virtual Power Plant (Green Mountain Power)
- Florida FPL | Energy My Way | Battery Storage
*Tons of clean energy stuck waiting in line (cnbc.com)
*Queued Up… But in Need of Transmission | DOE
*California rooftop solar installations drop 80% following Net Energy Metering (NEM 3.0) – (PV-magazine) – Dec 01, 2023

*Confronting the Duck Curve: How to Address Over-Generation of Solar Energy | Department of Energy