STORM POWER COMPONENTS

FLEXPOWER

Featured Article from Gregory Smith, CEO, Flex Power

Power Electronics is Coming Home

Decentralization of the Grid has started with the introduction of Distributed Energy Resources (DERs) such as solar, battery energy storage systems (BESS), and the electric vehicle (EV) at the home.

The centralized grid that has served us well is about to go through a transformation that will change how we think about energy and how individual customers relate to it. With those changes, power electronics will become an integral part of the home in the same manner that "Smart Phones" have become an indispensable part of everyone's life today.

With any change, we need to understand the positives and negatives to ensure we can create significant benefit for all stakeholders (i.e. consumer, utilities, vehicle manufacturers). When we talk about modernizing the grid with decentralized resources, we need to have three capabilities for this to be successful:

- Real time awareness;
- Instantaneous communication of information; and
- Controllability

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Let's consider why a centralized grid has prevailed over the years. The cost effectiveness of a centralized grid and its ability to be managed are two main factors. As the push for renewables has grown and their costs have fallen, we are seeing a greater number of these DERs coming online.

What do each of these DERs mean to the grid?

- *Residential Solar* installations in the U.S. hit a record in 2022 of 700,000.[1] The average solar system size in most states in the U.S. is between 6 kW and 12 kW.[2] Of course, the power generation of solar happens during daylight hours, meaning it is typically pushing power back into the grid as household demand is less than what is generated during those hours.
- *BESS* installations took place at over 250,000 households in 2020 and have continued to grow. This represents 540 MWh compared to only 29 MWh being installed in 2017.[3] BESSs range in size from 5kWh to 30 kWh but are typically in the 5 kWh to 15 kWh range. The BESS market in the U.S. is estimated at $3.3 Billion in the year 2022.[4]
- *EVs* on the road in the U.S. number approximately two million today and are expected to hit eight million by 2025.[5] The U.S. Department of Energy says over 80% of all EV charging occurs at the residence.[6]

What is this going to mean for the home? The average U.S. home used 29 kilowatt-hours (kWh) daily in 2021 according to the Energy Information Administration (EIA).[7] The average U.S. daily commute was reported to be 41 miles per day by Zippia in February of 2023.[8] EVs typically get between 2 to 4 miles of range per kWh consumed. This means that for the average U.S. daily commute, we would expect to see a charge requirement of between 10 to 21 kWh per day. What this means is that we are going to see residential power consumption grow by 28% - 58%. Certainly, public charging could potentially help relieve some of this by making it more accessible, but it will never be as convenient as residential charging. This will result in a significant burden on the residential power distribution system.

All of this will cause changes in patterns of energy usage, which will lead to second and third order effects on the grid and why it is so important that we embrace these changes early. For example, when an electric vehicle charges, it could cause issues not only of overloading, but of denying cool-down periods for distribution transformers. These cool-down periods are needed to help maintain the life of the transformer.[9]

Another significant impact of bringing widespread DERs online will be the amount of data that will need to be mined, communicated, processed and acted on to properly manage the grid. How these issues will be addressed will determine the success or failure of a decentralized modern grid.

Today within the grid, each DER is typically an independent, single resource, not coordinated with other DERs. If a location has three DERs (e.g. solar, a BESS and an EV) the grid will have separate interactions with each device at that location. The typical grid controls implemented today are macro-level controls that do not consider what is in the best interest of that location. This creates complexity for the grid because of the number of interactions that must take place and does not allow for the situational awareness that is necessary for ideal operation.

There are new requirements, such as HECO Rule 14H and CA Rule 21 making “Smart Inverters” to help with real-time awareness, communications and controllability, but they still leave the DERs independent of each other, even when they are contained within one household. This needs to be rethought, as ideally, each house could become a wholly self-contained energy operation, or a microgrid within the grid.

Every residence is going to become an interactive part of the power grid. The basic building block of that interactive system will be the power electronics that will be installed in the home. The power electronics will need to be Bi-Directional with the ability to perform under extremely diverse conditions with diverse inputs and be intelligent. This will be a new generation of power electronics beyond what we see in solar inverters, battery converters, and vehicle charging systems. This next generation of power electronics will need to have the following characteristics:

- Grid forming and grid following
- Ability to perform Voltage Source and Current Source control
- Provide a greater level of safety, as these will be in every home
- Affordable
- Have high power density
- Easy to install
- Easy to maintain
- 20-year life to match the life of a solar panel
- Artificial Intelligence, creating situational awareness

Current home power electronics do not typically have the controllability they need for the diverse conditions described above. They are usually grid following, but not grid forming. They don't have the protection and control systems to maintain stable voltage and frequency independent of the grid. They don't have power flow control or perform energy management and load balancing. They do not have islanding (i.e. independent operation from the grid) and grid connection control or fault detection and protection. They do not communicate between DER to DER or perform system monitoring and diagnostics.

Physically they are large, because they are air cooled and they are not integrated systems, leading to multiple boxes. This lack of integration creates challenges because of the complexity of enabling solar, stationary battery, and electric vehicle charging solutions to work together. This complexity extends from installation and setup all the way to implementing the system as a home energy management system (i.e., microgrid). Without proper integration and the necessary intelligence, it will not be able to perform what is necessary to solve the dynamic problems of managing household energy, grid needs, and vehicle charging. Finally, the life of home power electronics tends to be seven to nine years, when it should be 20 years to align with the life of solar panels.

The role that power electronics is going to play in this new interactive grid, is to enable controllability down to the building level, which we have never seen before. The ability to control and balance power at the lowest level will establish capabilities that will allow us to control the grid more effectively. This will enable power to be dispensed or absorbed at the nano level, making the end points of the grid active participants in its management (See Figure 1). Additionally, this will enable each household to create its own backup power and to reduce their cost of energy. Effectively, this next generation of household power electronics is democratizing energy. This will allow consumers to become *prosumers*, who are not only purchasing power, but are selling the power they generate as a grid service.

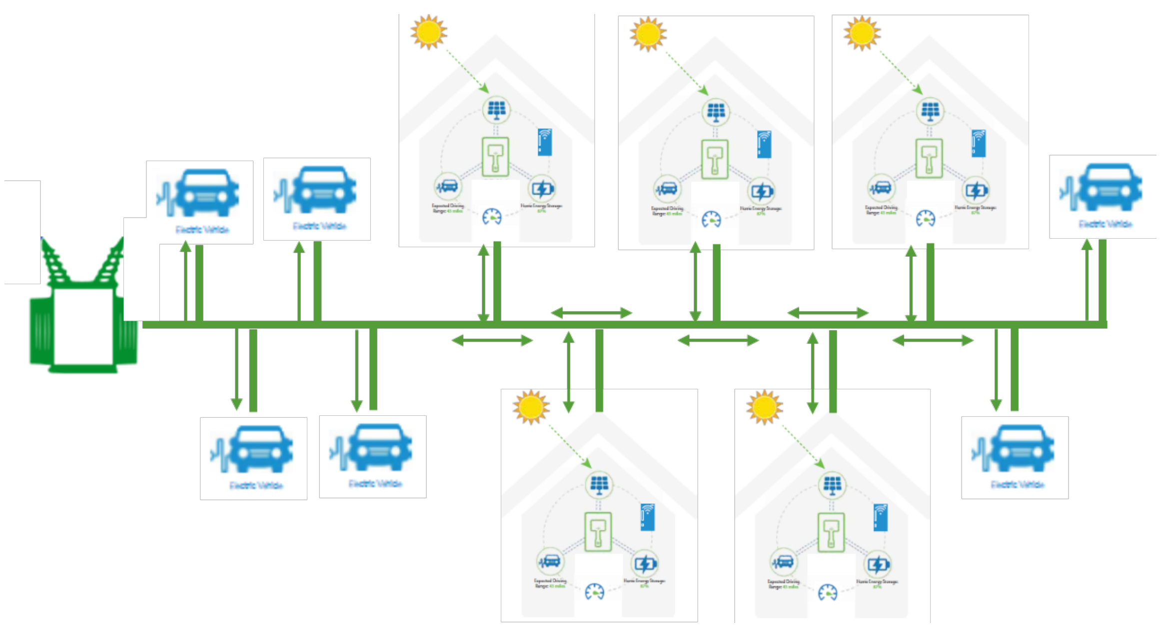

Figure 1 – Modernized Grid

What are the Benefits and Costs of an Integrated Power Electronics System for the Home/Grid?

BENEFITS: The three areas that will realize benefits are Grid Services, Resiliency, and Energy Cost savings:

Grid Services

- Distribution Peak Savings of $1,100 per year. Grid services, also known as ancillary services, are a set of essential functions and capabilities provided by electricity grids to ensure the reliable and efficient operation of the power system. [10]
- Resource Adequacy of $1,200 per year. Resource adequacy refers to the ability of an electricity system to reliably meet the expected demand for electricity at all times, while maintaining an acceptable level of reliability. [10]
- Renewable Curtailment of $454 per year. Renewable curtailment mitigation refers to the strategies and measures implemented to minimize or eliminate the curtailment of renewable energy generation. [10]

Home Resiliency

- According to Energysage, power outages cost homeowners between $25 to $25,000 per event.[11] These costs are made up of replacing spoiled food, emergency supplies, lost productivity, property damage, and alternative housing. Briggs & Stratton has calculated the average cost of power outage-related property damage to be $1,916.[12]

Home Energy Cost

Lowering a home's energy cost can be done by taking advantage of the ability to avoid buying power from the grid during high peak demands by consuming energy from DERs at the home. A University of Kentucky report calculated a yearly savings of $2,477.[13] This was for a 2,500 square foot house in Southern California. DERs included solar, stationary energy storage, and an EV.

Above we have laid out the savings from creating a home energy management system utilizing the BESS, vehicle energy storage, and solar for purposes beyond what is done today.

Let's also not forget the efficiency of integrating these DERs into the home and grid can make power distribution more efficient. For example, homes can use solar panels to generate electricity for charging EVs, which can be more cost-effective and environmentally friendly than using grid electricity.

All of these benefits are not cumulative, but some can be. The potential of substantial benefits exists and is worthy of consideration by homeowners.

COSTS: Attempts to create the home energy management systems that have this type of functionality today, could range from $20,000 to $30,000.

However, by looking at the problem and designing an appropriate system to address the issues of multiple DC sources and loads, it is also possible today to provide an integrated system solution with all the functionality for less than $10,000.

What does this mean to the power electronics industry?

As mentioned earlier, power electronics will need to be Bi-Directional and be able to work under a set of wide operating conditions to enable it to work with the grid, solar, BESS, and EV. This will be a 4-quadrant inverter circuit giving it a grid connection point, to enable power injection into the grid or absorption of power from the grid. This Bi-Directional building block will become the heart of the integrated system solution. The system will need to be an Energy Management System that monitors the grid conditions, household power demands, BESS and EV state-of-charge. Taking user preferences, it will coordinate the power flow between all the connected DERs at the home and the grid. This integrated system will become an indispensable part of life going forward. This new application will require new materials and components to provide the value proposition to the consumer. The areas of work needed are as follows:

- Lower cost
- Improved thermal
- Improved isolation
- Reduced mass
- Higher efficiency to reduce losses (e.g., heat)
- Improved switches and packaging
- Life of greater than 20 years
- Greater integration and redundant safety

Developing these components and the know how to apply them will become critical to the future of power electronics. This will make power electronics an indispensable part of the home, creating an advanced grid and new type of relationship between power and consumers. That will allow the grid to be improved faster without the delays from complex approvals associated with large scale projects, lower the cost of energy for all, and provide continuous power for households.

What will this mean:

1. People will have continuous power.
2. The grid will be modernized at a much faster pace.
3. Energy costs will be lower.
4. The grid will be more energy efficient.

Life going forward will change for the better, and it will be because of power electronics.

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