INTELLIGENT ENERGY:

Operating System for the Solar Homes and Microgrids of the Future

By Timothy Schoechle, PhD

This article features the Energy Management and Metering Architecture (EMMA) technical international standardization initiative of the International Electrotechnical Commission (IEC) as a key to the transition to a sustainable and resilient utility of the future. These standards are under continuing development in ISO/IEC Subcommittee 25 (Interconnection of IT equipment) under the IEC in collaboration with its international sister committees and outside liaison groups including the Smart Electric Power Alliance (SEPA), the GridWise Architecture Council (GWAC), and others. The IEC was established in 1907, with the introduction of electricity, for worldwide standardization of wires, plugs, transformers, the electric grid, and electrical products.

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A consequence of the looming climate crisis has been the failure of electric power grids in many parts of the country due to devastating wildfires and other severe weather events. For example, recently towns in parts of California have been burned, left without power, or entirely destroyed. This was attributable in part to vulnerable transmission lines together with high winds and extreme drought conditions. Severe windstorms have recently flattened parts of Iowa, also leaving whole communities without electricity.

Many cities and communities have adopted goals to achieve a 100% renewable electric supply within the next decade. Achieving a renewable, sustainable, and resilient electricity system has become of primary importance and has introduced a new way of looking at how to structure an electric grid, as damaged communities are being rebuilt or existing systems are being improved. One way to move toward 100% is to replace carbon with renewable generation, but centralized grid structures and variability of wind and solar make the last 10-20% hard to achieve. An alternative approach is decentralization and "microgrids".

Enter: Microgrids

An important key to the 100% goal will be the ability to implement solar and storage technologies at the distribution level, generating local power on or near the premises where it is used. Such systems can facilitate sharing of electricity in coordination with other homes and buildings within the local

Above: Transitional hybrid grid: combined centralized and solar microgrid.

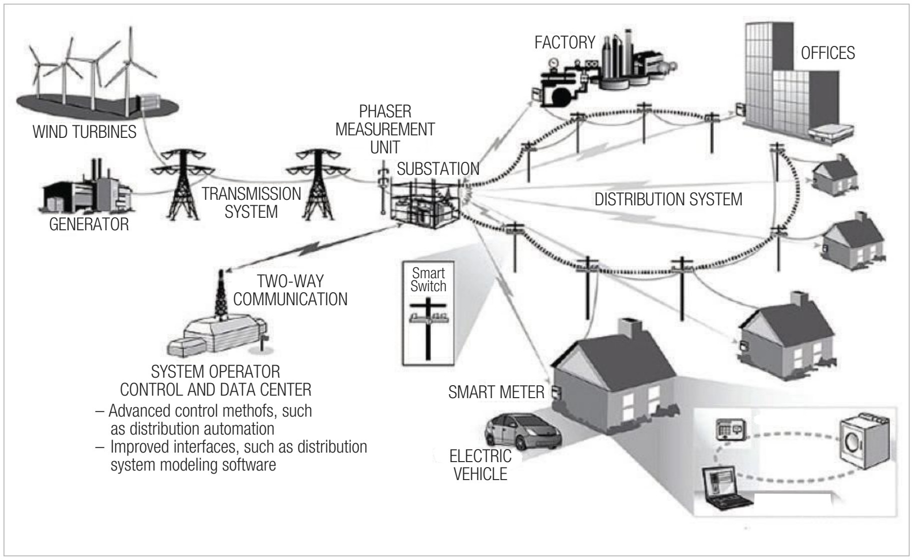

Figure 1: Conventional centralized electricity grid.

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community as a semi-independent, detachable district or neighborhood—known as a *microgrid*. This approach is made feasible by the dramatic reduction in the cost of solar photovoltaic (PV) panels, batteries, and power electronics.

Such a distributed energy system depends on automated control of premises-based generation, use, and storage of electricity, and on coordination with the other nearby premises as a microgrid. To achieve such control involves carefully managing certain essential on-premises equipment including solar inverters, batteries, and appliances (e.g., electric vehicle chargers, heating and cooling equipment, water heaters, refrigeration, and other "smart" devices). Suchmanagement is the goal of a newly emerging standardized premises gateway and a platform for Energy Management and Metering Architecture, EMMA—the ingredient that makes these elements work together to balance and optimize local energy.

The recent availability of new economical consumer-scale electricity technologies for generation, use, and storage (e.g., solar PV, batteries, power electronics, appliances, controls, and communications protocols) offer a powerful way to answer the question of how to eliminate carbon and get to 100% clean renewable energy. This path supplements the historical producer-oriented view that built our electric system with a local consumer-oriented view.

Figure 1 shows a model of the present electricity grid where electricity flows from utility scale generators on the left, through transmission lines, to distribution facilities, and ultimately to the customers on the right. Although some buildings or substations may acquire solar and/or storage (commonly called "distributed energy resources" or DER), it is not depicted in diagrams such as this because, until recently, such resources have been seen as adjunct or ancillary—the primary generation and control model remaining centralized and consistent with the historical industry grid paradigm.

However, it is becoming clear that in order to achieve the climate change goals and to increase the resiliency of the electric system which will be required to handle the disruptive weather events brought on by climate change, this historical model needs to be extended to incorporate the emerging vision described here—introducing a new alternative, yet complementary, grid paradigm. The distributed consumer-oriented (and consumer-scale) technologies bring new localized[1] options (e.g., customer premises-based solar PV, storage, and microgrids, etc.) which can deliver levels of renewable energy, reliability, and resilience not previously possible. Local clean energy also delivers reductions in generating and transmission costs—and pollution.

These localized options are based on a grid network incorporating distributed quasi-independent community microgrids composed of individual prosumers, where every consumer is also a potential producer. These microgrids offer a new level of resiliency as well as efficiency, reliability, and decentralized autonomy by allowing microgrids to continue to function when the larger grid fails. Each microgrid is based on resources situated on-premises or within the distribution grid, including solar PV, batteries, "smart" inverters, premises control systems, and high-speed communications networking.

Some may have concerns that the new distributed paradigm may be incompatible with the existing system, may disrupt a century or more of established institutional structures, or may strand, or make obsolete, massive investments in older generation and transmission facilities. Certainly, business and technical adaptations will be necessary, however, experience has shown that the two paradigms can be mixed well, and that the newer facilities can actually improve overall grid capacity, stability, and resilience. They can also give utilities more options as they shift to the more climate-friendly model that the public is increasingly demanding.

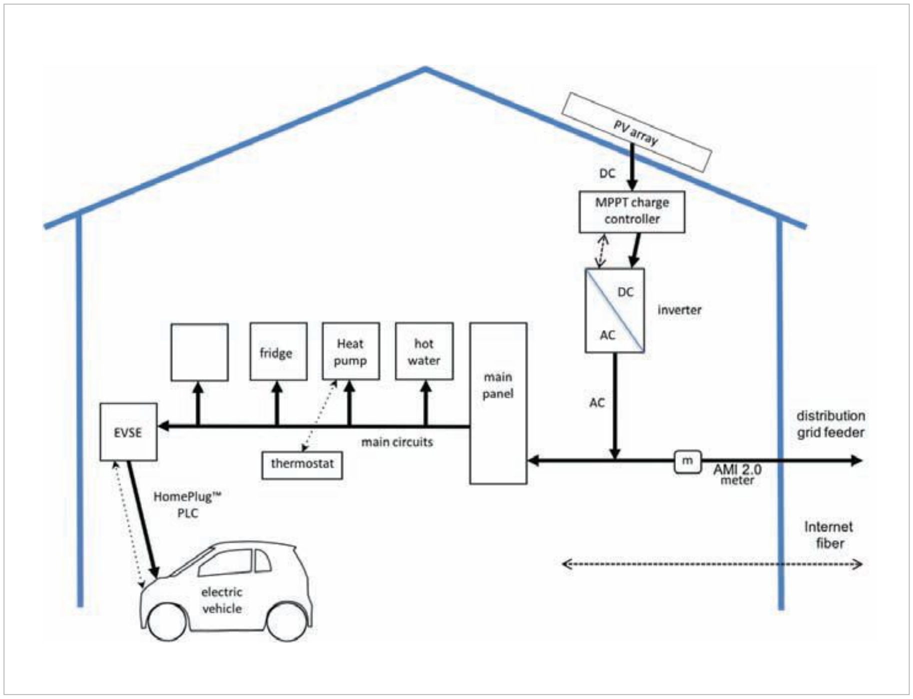

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Figure 2: Conventional premises general architecture, with solar PV (no storage)

The Localized View

The localized view is a "bottom-up" perspective that sees the home or building as an "island" that generates, uses, and stores power—like a boat or RV.[2] From this perspective, the power management problem becomes one of primarily managing the local premises resources, and it considers the electricity grid as a massive energy source—a big battery to be charged and discharged. With the widespread installation of solar-plus-storage, every home and building can utilize rooftop or adjacent space and become a potential contributor, as a generator, user, and store of energy.

This locally-sourced energy can be first managed on-premises, then within the community, and finally within the local distribution feeder or grid. Such a perspective offers to greatly reduce the demands on the grid and to vastly simplify the overall control problem by letting each premises manage its own energy. When combined with advanced methods for sharing of energy among premises (e.g., using dynamic pricing mechanisms, "transactive" control tariffs, etc.), the local utility grid management/control problem can be further simplified[3]

EMMA Manages Premises and Local Energy

This local approach requires a technology which enables the required component interconnection and management. This brings us back to what Energy Management and Metering Architecture (EMMA) provides. EMMA is part of a premises control system known as the ISO/IEC HES gateway platform, or HomeGate™, developed by a set of international standards committees, that provides an array of communication and control functions for the home or building.[4] EMMA is intended as also part of a local electricity distribution microgrid for enabling coordination of electricity flows—sharing power between neighboring premises by utilizing advanced demand response protocols, dynamic pricing tariffs (or similar means), and a reliable local high speed fiber optic network connection.

Premises Energy System Architecture

Presently, a local rooftop solar PV system without storage sells all its excess solar energy directly to the grid. Unfortunately, the solar may not be producing at the optimal time of day and may overload the grid. The solar-plus-storage model, enabled by EMMA, shown in *Figure 3*, adds storage to correct this condition. This model entails four important key concepts that define the EMMA premises environment.

The first key concept in the new solar-plus-storage model is that premises load circuits are divided between two circuit breaker panels, a main panel and a priority load panel. The priority load panel controls circuits that will continue to be powered by the battery/inverter system in the event of grid power interruption. The main panel controls the other load circuits in the building, and these will lose power whenever the grid loses power.

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A second key concept in the EMMA model is the expanded solar-plus-storage element shown in *Figure 3*. This element consists of a "smart" DC-coupled inverter that has two bi-directional AC output/input ports to serve the two circuit panels. The grid is connected to the house via the main panel, as usual. The inverter draws DC power from a 48 Volt DC bus (connection) to generate AC for the house. The battery is connected to the 48 Volt DC bus and can be charged from the grid by the inverter, if needed. The 48 Volt DC bus is charged by the solar array and charge controller, also charging the battery. In the future, household devices (many of which already operate internally on DC) could be powered directly by the DC bus, saving the energy that is currently lost by converting DC to AC and then back to DC.

A third key concept is the EMMA control system that measures and manages electricity within the residence, communicating directly with all major premises devices, including "smart" appliances and metering sensors. The EMMA standardized software resides in a "gateway" or "platform" that also hosts other application services ("apps"), and communication interfaces for home devices and external networks. The EMMA software functionality[5] provides the conventional utility metering functions consistent with the Advanced Metering Infrastructure (AMI) standards. The *HomeGate* standards also include provisions for consumer privacy, cyber-security, and safety services for protecting the premises, its occupants, and devices.

A fourth key concept is the ability of EMMA to communicate with the grid and with other premises (using a local public optical fiber network) to negotiate the sharing of energy with neighbors, depending on its own conditions and on external supply/demand conditions, essentially in real-time. One class of protocols and tariffs for this purpose is known as *transactive energy (TE), currently under development*.[6]

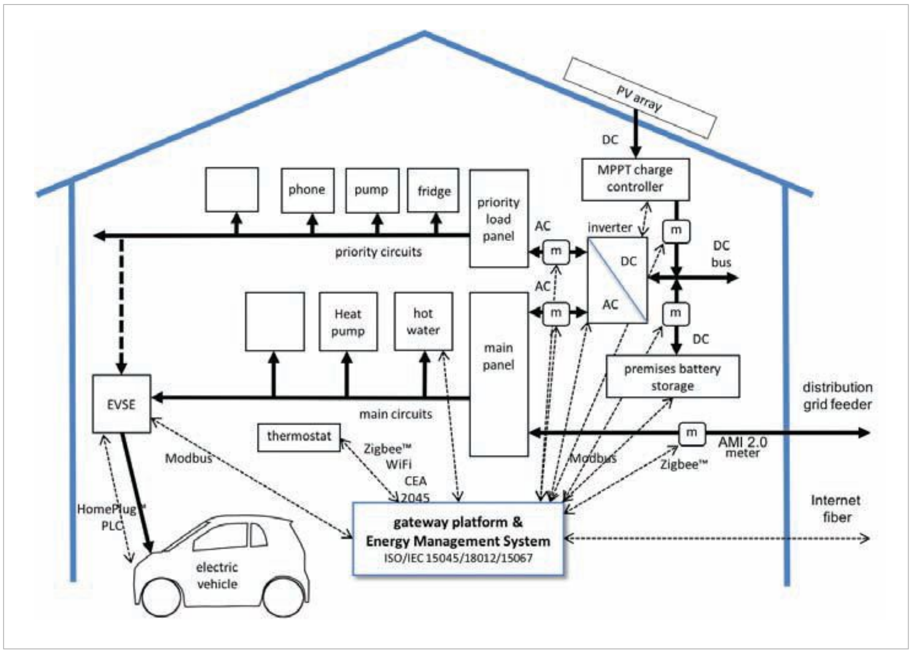
Transition to the Utility of the Future

With this approach, the home or premises will be a new parallel building block of the "utility of the future". Individual premises will be able to use their solar PV generation and battery storage to operate in a semi-autonomous manner in case of failure of the local grid. Distribution feeders that connect buildings to a substation will be arranged in microgrids that can allow clusters of buildings, campuses, or communities to operate in a semi-autonomous manner sharing and optimizing their energy—contributing resilience and efficiency to the overall grid.

The utility will continue as a large scale energy provider, while also maintaining its substations and distribution grid (i.e., poles, wires, and transformers) and will also continue to buy or generate electricity, selling it to consumers wherever necessary, but will move in parallel toward enabling its prosumers to generate and store much of their own energy. Because all homes and buildings may not be suitable for solar PV, utilities will also build or enable community-based (distribution level) solar gardens and storage facilities, where appropriate.

Strategies for this transition will vary depending on the local situation. One strategy will be to phase in premises solar-plus-storage and local solar gardens. The utility would also implement energy sharing methods such as transactive energy and work toward reducing external energy purchases and transmission where possible. *The utility might also develop incentives to install solar-plus-storage and fiber networks from the cost savings on avoided power purchases.* The fiber broadband service would also be a recurring revenue source, incurred from providing internet access to

Figure 3: HES/EMMA premises architecture, with solar-plus-storage.



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customers, as an added benefit. Rooftop-scale solar and storage could be installed much more rapidly than large generation and transmission projects that must meet more extensive environmental impact, financial, public review, and other permitting requirements (i.e., weeks vs. years). In any case, the power grid will likely be a hybrid of the conventional centralized grid and the new distributed energy grid for a long time, as depicted on page 16-17.

Conclusion

By building distributed microgrids with *Energy Management and Metering Architecture (EMMA)* as a foundational building block, utilities can gain a key advantage in meeting their 100% renewable, and sustainable energy goals. They may be able to get there more quickly than by relying entirely on centralized wind and solar farms or other large renewable facilities. Local permitting and approval requirements can be managed under local governance. Utilities can also structure attractive subsidy, financing, or incentive programs to encourage their customers to undertake much of the capital expense of installing the systems. EMMA can help utilities can gain a key advantage in achieving their 100% renewable, sustainable, and resilient energy goals on the aggressive schedule which the public is increasingly demanding. ■

Resources

1. In this context, "localized" means located within the local distribution grid on lower voltage substations or feeders.
2. bit.ly/2YyuRc6
3. bit.ly/3lgTnbq
4. ISO/IEC 15045 HES gateway series and ISO/IEC 18012 Product Interoperability series
5. ISO/IEC 15067-3 Energy management model
6. bit.ly/3lgTnbq