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There's Energy Resilience in the Garage!

An Essay on Electric Vehicles and Emergency Back-Up Power

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Energy Resilience

We've all gotten used to the concept of electric vehicles. Simple. Like an appliance, they draw power from your home and provide exceptional mobility. So far, EVs have been about drawing power away from buildings. What about the other way around?

How about powering buildings with cars? What about using electric cars, trucks, and buses to plug in and charge? This is the vehicle to grid movement (V2G) – linking our mobility with our homes and businesses, finding synergies.

A subset of this is powering our homes during power outages. This short article focuses on how our cars can someday serve as emergency power sources! Cars to buildings... more accurately car batteries to buildings. Let's dig into the nuts and bolts of this simple concept. As more and more of us drive EVs, their use for emergency back-up will be common in the future.

But what about today? What would it take to bring a mobile battery – such as a car or generator - to a facility that has lost power? It could be a mobile battery (such as MobiGen), an EV car, a Ford F-150, or even an Ebus! My Chevy Bolt has 60 kWh on board. How can I route this energy to my house when the grid goes down?

In the future, we'll likely all have bi-directional EV chargers that allow for easy connection between our cars and our homes. Every home, every building, perhaps every parking spot... will be connected. But for now, let's dig into the nuts and bolts of connecting a battery to a building.

Hooking Up Emergency Back-up Systems

Traditionally, remote power, and back-up power has been provided by generators. Our society has considerable experience with generators for household and business use. Now, more than ever, generators are being installed at a record clip given the increased frequency of power outages due to climate change. The horrific western fires and the recent German floods, all point towards a new and devastating climate reality in which power grids are threatened.

1. The Most Basic Resilience

Let's think about energy resilience at a small scale, a home for example. You want back-up so you're off to Home Depot to buy a household generator. Depending on its wattage, a small generator costs around $600. It can run on gasoline or propane. It must be located outdoors since it gives off fumes, notably carbon monoxide. You can plug extension cords into it and run them through an open door or window into your home to power your fridge and television. The fuel cost is on the order of $1 per hour. That's the cheap solution.

2. The Plug and Play Solution

The next step up from mobile generators and extension cords is creating a plug-in system for a generator that is located outside. Instead of a few power cords, now the generator – whether it is mobile or stationary - powers the building by tapping into its main electric panel. A permanent Power Inlet Box is mounted outside. Also known as Generator Tap Boxes – these

Power Inlet Boxes allow for simplicity in hooking up a generator with a single plug or multiple plugs for three-phase electrical systems.

For a traditional, single-phase household electrical system, the receptacle looks much like a plug behind your clothes dryer, a 240-volt plug, NEMA-1430. They cost about $50 to buy. Then there's the installation cost. A power cord runs from the generator to the Power Inlet Box on the exterior wall of your house. From there, an electrical wire runs into the home. Once inside, there are two basic options:

1. Interlock Kits

The most basic option is to run a wire from the Power Inlet Box to the Main Electrical Panel. In this configuration, all circuits are eligible to be powered by the generator. They can be pre-labeled and marked to make clear which circuits are planned for emergency operations. All other circuits must be manually turned off.

The key to this interconnection is something called the Interlock Switch. It's an inexpensive part, a piece of metal fixed onto the panel. It's a mechanical device that shifts up and down and assures that you are either drawing power from the grid or from the generator... but not both. This is the manual way to island your household resilient system.

Note that to use the Interlock Switch, the line from the Power Inlet Box must go into the top right breaker location. If there is a breaker, or two breakers there, in the #2 and #4 positions, it/they will need to be moved so that the Interlock Switch can perform its function and turn off the main breaker when the generator is in use.

Transfer Switches

The second option is to run the wire from the Power Inlet Box (that has come from the generator) through the home through a transfer switch to a subpanel. The subpanel is wired with circuits deemed critical in the event of an outage. During normal operations, the subpanel is powered through a breaker on the main panel. During outages, the transfer switch is manually or automatically activated, protecting the grid and its line men from back-feeding. Only the circuits on the subpanel are energized.

3. Stationary and Hardwired

Stationary generators that run on natural gas, propane, and/or diesel, are inexpensive to buy. They are, however, at odds with environmental goals regarding climate protection and stemming the use of fossil fuels. Stationary generators are presented only to frame the market. They are usually wired with Automatic Transfer Switches that automatically isolate from the grid, start the generators, and then shut them down when normal utility power is restored. In the future, it may be possible for generators to run on renewable diesel fuel or renewable natural gas.

Automatic Transfer Switches

In the generator world, perhaps the ultimate form of preparedness are generators that are placed on cement pads, with diesel tanks full of fuel or systems permanently hooked up to natural gas lines, sometimes even backed up with propane tanks. They continuously monitor grid power and come on automatically in the event of an outage... within seconds. They can control main panels or subpanels.

Automatic Transfer Switches (ATS) toggle from grid power to emergency back-up power automatically. They only allow one source of power at a time. When the utility power is restored, the generator shuts down automatically. The ATS units are self-acting and intelligent. They are governed by dedicated control logic, enabling continuous delivery of power, but from only one of two sources at a time. Some of these generators test themselves once a month.

While certainly more high-tech than the manual interlock switch, and potentially automated, there are some drawbacks to the transfer switch/subpanel approach. It might limit power use on site. Imagine a generator coupled with solar on a sunny day. There's no reason to limit emergency operations during the day to a subset of onsite loads. More sophisticated building controls allow for energy management, such that the loads can follow the available capacity. Some call this "more granular control" of the circuits. The new Span smart electrical panels, that monitor and control each circuit, may be ideal for household applications. Currently, Span only makes a 200-amp version.

Vehicle to Grid - V2G

Let's dig into V2G, the vehicle-to-grid future. Think of electric cars, trucks, and buses as mobile sources of battery power. They provide tremendous flexibility, and they are inherently mobile. They can be deployed when and where power is required. They may already be in your garage!

EVs have lots of battery storage and discharge capacity. A typical EV has 60 – 80 kWh on board (compared to a 13.5 kWh Tesla Power Wall), and most drivers only use a fraction of that daily, leaving the majority of capacity for grid use and, in this case, for emergency power backup. A school bus holds 150 kWh; a city bus ~300 kWh. These are large battery banks!

So how can you take power from an electric vehicle and supply it to a building? The direct current battery power in the vehicle needs to be converted to alternating current using an inverter. All EV charging stations are "inverters on legs." They take alternating current grid power and convert it to DC for the batteries. To take the power the other direction, from vehicle to grid, or from vehicle to building, the inverter needs to be a bidirectional inverter. These are available.

For some time, Elon Musk reportedly shunned the idea of V2G. Now Tesla has changed its tune, and soon Model 3 Teslas will be fitted with bidirectional onboard inverters. They will be V2G ready. By bringing the inverter on board, the car can take AC power, and give it back, largely eliminating the need for EV chargers as we know them. Much of the allure of V2G is for vehicles to support grid operations on a daily basis. We salute that. This paper focuses on emergency operations. How can we take power from our EVs during emergencies to power our refrigerators, or charge our phones?

Ford's Breakthrough F-150 – The Lightning

Ford's F-150 pick-up truck is not only the best-selling truck in the United States for 44 years, in recent years it has been the best-selling vehicle of any type in the world. Last year Ford sold 790,000 F-150 units. Soon enough, this truck may be revolutionizing electric mobility. The all-electric, brand-new F-150 is called the Lightning. It has many features; one that is relevant is that it provides back-up power... up to 9.6 kW of power. It is the first EV designed to be a back-up, mobile power source.

Ford earned some notoriety during and after the Great Texas Black-Out. Some of its 2021 F-150 hybrid models featured back-up power. They were perfect for job site power, tailgaters grilling burgers, keeping beer cold before ball games, and camping. Yes, you can plug your fridge, phones, and other electronic gear into the high output 120 and 240 volt plugs in the beds of these trucks. Pretty cool, and in some cases, life-saving.

How does it do this? The trucks come equipped with bidirectional inverters. They can take household power and turn it into DC power to store in their batteries. Inversely, they can release DC power from their battery banks and convert it to AC power for use. The trucks have

AC outlets that you can plug into.

Fast forward... the new, all-electric Lightning trucks can provide for household energy resilience... without extension cords. With the 240-volt, 80-amp Ford Charge Station Pro, plus home management system, if the F-150 is plugged into its charger, it will automatically kick in to power your house during a power outage. With Ford's Intelligent Power Backup there are no extension cords required!

How is this accomplished? Ford notes that homes will need to be properly equipped and have transfer switches to disconnect the home from the grid. Home bases for the Lightnings will need bidirectional chargers; in other instances they can be used to power up facilities with no chargers... thus entering the electrical system through a Power Inlet Box.

In terms of duration, Ford estimates that the trucks can power typical homes for up to three days... or up to 10 days "if properly rationed." The integration of this charging station into the homes electrical system permits the charge to automatically redirect the power flow into or out of the battery when the power blinks off or back on, while safely isolating the house from the powerlines to protect line workers trying to fix the grid.

The cost of the F-150 Lightning is ~$50,000 for the extended range version that offers the B2B capability, with a range of up to 300 miles. Ford estimates 40% savings on maintenance as well. This is the working man's truck, an EV solution will appeal to a different demographic than those who buy Priuses and Teslas. The F-150's body looks standard, but its 563-horsepower engine can go from 0 – 60 in five seconds, making it the fastest pickup.

In the future, Ford reports that the F-150 Lightning will be even more functional. Like stationary batteries, they will not only be available for power outages, but they will support the grid when it is fully functional. The batteries may well be cycling daily to optimize on energy arbitrage and peak demand limiting. They will buy and store inexpensive power, and then discharge when electricity rates are higher, cutting power costs. They may be used for power company's ancillary services.

Ford is planning to promote a home energy management system to make the back-up power last by rationing the power for longer duration. Ford is also working with SunRun – its preferred EV charger installer – on installations that include solar systems to back-up the back-up in the event of a long-term outage.

The Future is Now... or Soon!

This space is moving quickly. Soon, our homes and businesses may well be ready to receive power from sources other than the local utility. Many will have their own back-up systems, some based on solar + storage. In some ways, the days of electric utility monopolies are over. Consumers now have options. For emergencies, you may well be able to power your home with your car, or your school with your school bus! Furthermore, emergency back-up power systems can be configured for emergency operations only, or to provide workhorse services, generating savings on a daily basis. Imagine your car earning income as you are off on vacation!

There are lots of exciting V2G demonstrations. And we're not talking about V2G for homes anymore. How about a football stadium? The Johan Cruuff Arena in Amsterdam is the home of the Dutch football club, Ajax. The stadium features 1 MW of solar as well as 3 MW of storage capacity in repurposed EV batteries. In addition, the stadium will allow visitors to both charge their cars, and to put power back into the stadium!

Ultimately all 2,000 parking spots will have V2G capability; each spot will be successively equipped with intelligent charging infrastructure. "Consenting drivers" can allow a percentage of their onboard power to power the stadium. If 100% of the 2,000 cars parked for the game allowed for 3 hours of discharge at 6 kW, that would be 12 MW of capacity! A typical football stadium draws 10 MW during its night games.

The future is now... or soon. Soon we will be able to hookup our cars to our homes. Soon we will be able to hook up our school buses to their schools, while charging with solar all day long. Soon all homes will be wired for resilience, either with generators and power inlet boxes, or solar and storage systems. We'll know what to do in emergencies. We'll have redundant systems.

While we focus in this paper on emergency backup, in the future the technology that provides emergency backup power will also have a day job. A great benefit of a V2G future is the ability to balance the grid by using fleets of electric cars to absorb excess electricity during periods. EVs thus have value beyond transport. And in terms of energy resilience, now you will soon have 2 -3 days of usable electricity parked in your garage.