Extreme Weather Event Electrical Power Risk Mitigation for Homeowners

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Introduction

Every year in Canada extreme weather inflicts tremendous suffering and loss on homeowners: summer temperature extremes that become unsurvivable without air conditioning and overtax the grid leading to outages, forest fires that destroy the power distribution lines feeding a community, and extreme wind, rain, or snow events that result in days-long loss of grid power.

This paper presents the lessons learned as the author progressed through the journey from curiosity to discovery, commitment, and implementation of a resilient off-grid-capable micro power plant:

Step 1: Installing solar panels for a grid-tie system to reduce monthly cost.

Step 2: Upgrading a grid-tie system to facilitate using, in real time, the power generated by the solar panels in order to operate central air conditioning during a grid failure.

Step 3: Upgrading the off-grid system to add storage to facilitate operating the house's critical loads during an extended grid failure.

Step 4: Considerations for the possible future evolution of the micro power plant.

The system described is specifically optimized for British Columbia, Canada. Each of the three steps described include the system design, representative costs, and relevant issues in sufficient detail to replicate for a typical British Columbia home, or to inform the criteria for adapting to different scale implementation or different latitude or climate deployments.

Extreme Weather is Upon Us

May 22, 2022: *"A major cleanup effort is underway following Saturday's fierce storm that left at least eight people dead and hundreds of thousands without power after it swept across southern Ontario and Quebec. While it's not unusual to have such high numbers of customers temporarily without power — which for Hydro One stood at about 226,000 early Monday — the extent of the damage, including the toppling of metal transmission towers in the Ottawa area, is notable. Hydro-Québec said that at the peak, the storm cut power to 550,000 customers from Gatineau to Quebec City, while as of about noon Sunday, there were some 370,000 customers still in the dark."*[1]

November 9, 2021: *"Not only has B.C.'s coast been hit with outages induced by high wind, but as of Tuesday morning, more than 2,000 customers from Quesnel to Williams Lake were without power as gusts of up to 70 kilometres per hour swept through the area. Handfuls of homes in Prince George and*

[1] CTV News

Mackenzie were also affected. High wind and trees falling on power lines are the two leading causes of power outages and Gammer noted that B.C. is home to three times more trees than any other jurisdiction on the continent."[2]

July, 2021: *"An investigation into hundreds of deaths in British Columbia during a weather phenomenon known as a "heat dome" showed that nearly all the deaths occurred indoors.*

Chief Coroner Lisa Lapointe and a death-review panel released a report Tuesday, saying 98 per cent of the deaths happened inside. The report also revealed that 67 per cent of those who died were aged 70 or older and 56 per cent lived alone.

Extreme heat in 2021 claimed 619 lives across the province as temperatures broke records and surpassed 40 C for several days in a row in late June and early July. B.C. saw quadruple the number of deaths the region typically sees during that time."[3]

Step 1: Residential Solar Grid-Tie System

The designs contemplated below are a representative baseline for a typical solar-candidate BC home. The typical entry point for a residential solar installation is a grid-tie system sized to annual generating capacity roughly matching your annual consumption. Therefore, a typical 32-panel grid-tie "Net Metering" installation will reduce your annual power bill to zero with a small amount of excess power to sell back to BC Hydro or Fortis at $0.0999 per kWh.[4]

Assumptions:

- The baseline (typical) home has a 200 amp or higher service panel. Canadian Electrical Code permits connecting solar panel capacity capable of supplying up to net 20% of the panel rating. This means that for a typical home with 200 amp service, you are permitted 40 amps (9600 AC watts) of solar capacity, equating to roughly thirty two 355-watt panels. The reason for the 20% limit? If the property draws the maximum possible current from the grid without tripping the 200 amp breaker plus the solar array is producing another 40 amps, the bus bars inside your panel will be carrying 240 amps. The 40 amp solar limit is to mitigate the risk of overloading and overheating the bus bars in the panel.[5]
- Each solar panel will supply about 1.8 kWh per typical sunny day in July and 0.1 kWh per typical overcast day in December, or total daily system energy (32 panels) of 57.6 kWh in July and 3.2 kWh in December. Annual average expected output of a 32 panel system in British Columbia is 36 MWh per year.

[2] Global News

[3] CTV News Vancouver, June 7, 2022: "Coroners' review reveals true death toll of B.C.'s 2021 heat dome"

[4] BC Hydro Net Metering program details: https://app.bchydro.com/accounts-billing/electrical-connections/net-metering.html

[5] Canadian Electrical Code para. 64-112: http://neighbourpower.com/blog/ce-code-64-112-120-125-percent-rules/

Table 1 presents the bill of materials and approximate cost to install and commission a 32 panel roof-top solar system in British Columbia. Figure 1 shows an actual 28-panel deployment using the bill of materials in Table 1 (28 panels having consumed all usable roof space).

Table 1: Example Baseline British Columbia Grid-Tie Solar Array, 32 panels, 9600 Watts AC

Quantity	Description	Supplier	Price Ea	Price Extended
32	Solar panels, 355 watt DC	Longi 355	$280	$8960
8	Micro Inverter, 1200 watt AC	Hoymiles HM-1200NT	$475	$3800
1	Racking, electrical items, and hardware		$3500	$3500
1	Electrical Permit		$200	$200
1	Installation / Commissioning[6]	IPS, West Kelowna	$4400	$4400
			Total	**$20,860**



Figure 1: 26 panel, 8.5 kW Solar Array

[6] System design, installation, and commissioning provided by Integrated Power Systems (IPS), #101-2387 Dominion Road, West Kelowna, BC 250-769-2843, http://ipwr.net/

Step #2: Upgrade the System to Operate Air Conditioning During a Grid Failure

45 degrees C is not survivable in BC without air conditioning[7]. Should the power grid fail during a heat dome event similar to the one that occurred in June 2021 that resulted in 595 deaths in BC[8], a homeowner will have no choice but to abandon their property and seek out a safe haven with cooling and safer temperatures.

If you have a grid-tie solar system installed on your house, you probably have the ability to generate enough power to run your central air conditioner. However, for the safety of Hydro workers responsible for repairing the grid, the Canadian Electrical Code requires that a grid-tie solar system be automatically de-energized when the grid fails, therefore you cannot use your solar array unless you install a system upgrade to take your array off-grid when the grid fails. The critical design requirement in Step 2, to risk mitigate a heat dome, is to harvest power from the solar array in real time, when the sun is shining, to operate a central air conditioner.

Central air conditioning draws a lot of power, typically over 4000 watts. Our baseline solar array produces 9600 watts at peak output therefore there is an area of intersection that will facilitate operating the air conditioner during the hottest part of the day during the summer. Tapping that potential requires 3 upgrades to the baseline grid-tie system:

1. a power transfer switch that will automatically disconnect your property, and therefore the solar array, from the grid when the grid goes down,
2. a power management system that manages the microinverter frequency and phase, or, if your system uses a single inverter instead of microinverters, an inverter with sufficient capacity, and
3. a soft start unit for the air conditioner compressor. This is required because an air conditioning compressor that draws 16 amps (4000 watts) steady state will draw up to 80 amps “locked rotor” startup current which is no challenge when you are connected to the grid with access to effectively unlimited surge capacity but will almost certainly exceed the current rating on most candidate off-grid inverters.

The system design in Table 2 uses a Sol-Ark Hybrid Inverter to perform the power transfer and to manage the microinverters. The selected Sol-Ark is rated at 9 kW continuous AC output, therefore capable of operating not only the central air conditioner, but also up to an additional 5 kW (40 amps at 120 VAC) of load the solar array will be producing at peak. The Micro-Air soft start installed on the air conditioner compressor will reduce the air conditioner startup current spike to a value the Sol-Ark is capable of sourcing.

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[7] https://climate.nasa.gov/ask-nasa-climate/3151/too-hot-to-handle-how-climate-change-may-make-some-places-too-hot-to-live/

[8] Government of BC Emergency Management: https://www2.gov.bc.ca/gov/content/safety/emergency-management/preparedbc/know-your-hazards/severe-weather/extreme-heat

Referring back to the requirement, to cool the house when the grid fails during a heat dome, a 32 panel array will generate 4000 watts or more from approximately 8:00 AM through 4:00 PM Mid-May through Mid-August.

Table 2: Bill of materials for an "off-grid central air conditioning" upgrade

Quantity	Description	Supplier	Price Ea	Price Extended
1	Inverter / Power Transfer Switch	Sol-Ark-12k-P	$11,500	$11,500
1	Compressor Soft Start	Micro-Air Easy Start 368	$500	$500
1	Incremental Installation Cost	IPS, West Kelowna	$1000	$1000
			Total	**$13,000**

Step #3: Upgrade to Add Storage to Facilitate Operating the House's Critical Electrical Loads During an Extended Grid Failure

November 2021 delivered the most devastating natural disaster ever to strike BC in recorded history: an "atmospheric river" that washed out every major highway in the province and caused widespread flooding and power outages followed immediately by freezing temperatures. While extended power outages have been rare in the past, the consequences of an extended outage in the winter can be significant and these events are predicted to present a much higher risk in the future.[9] A winter outage lasting even a relatively brief 24 hours can result in frozen water pipes[10] and force a homeowner to abandon the property.

An extended grid failure during winter is a different class of problem than a heat dome during summer. A system design to mitigate this risk must provide for a low power draw, at a minimum enough to operate a furnace, over an extended period when there is likely to be heavy overcast, snow, and little sunlight from which to harvest solar energy. This requires off-grid capability – solar panels and an inverter -- plus energy storage.

The solution is to install another upgrade: a critical load system with battery backup. This requires:

1. a second electrical panel housing only the critical load items that will be energized by the inverter and will stay energized when the transfer switch disconnects the system from the grid, and
2. battery storage.

Table 3 list the critical loads used for a system design. Power consumption is actual measured value for this particular home.

[9] https://climate.nasa.gov/news/2740/climate-change-may-lead-to-bigger-atmospheric-rivers/

[10] https://www.wbdg.org/guides-specifications/mechanical-insulation-design-guide/design-objectives/time-freezing-fluid-insulated-pipe-calculator

Table 3: Critical Load List Used for System Design

Description	Peak Load (W)	Daily Energy (kWh)
Furnace	600	1.2
Refrigerator	140	2.4
Freezer	150	1.0
Internet modem, switches, etc.	70	2.0
Television with sound bar	150	0.6
Garage door opener	150	0.2
Doorbell	nil	nil
Selected lights and plugs	varies	nil
Total		**7.4**

We specified two 100 Ah 48 V lithium cells for battery storage, providing 9.6 kWh of capacity. Under worst-case conditions, wherein heavy snow load on the panels reduces solar panel output to near zero, this is sufficient capacity to operate all 7.4 kWh of critical loads for about 30 hours, or just the furnace 1.2 kWh load for 8 days.

A 32-panel solar array in December, with snow-free panels, will produce about 8 kWh per day if it is sunny or 2 kWh per day in heavy overcast. Therefore, if the sun is shining, the batteries will reach 100% charge during the day, so the system will be self-sustaining. In heavy overcast, the batteries will gain 6 hours of run time for the complete critical load list, or will be self-sustaining to run only the furnace.

Table 4 lists the additional equipment needed to add critical load storage to the system. Note that the Sol-Ark inverter selected in Step 2 above includes lithium battery management, therefore this design does not require an additional battery management hardware module.

Table 4: Bill of materials for a "critical loads" upgrade

Quantity	Description	Supplier	Price Ea	Price Extended
1	Battery cabinet	Rack Basics 8U	$600	$600
2	48 V 100 Ah LiFePO3 3U Battery	Sacred Sun FCIFP48100A	$3700	$7400
1	100 Amp Panel & Breakers		$1000	$1000
1	Incremental Installation Cost	IPS, West Kelowna	$500	$500
			Total	**$9,500**

Complete System Overview

Figure 3 shows the as-installed equipment in the utility room. Figure 4 is the schematic for the entire system. Table 5 presents the total installed system cost.

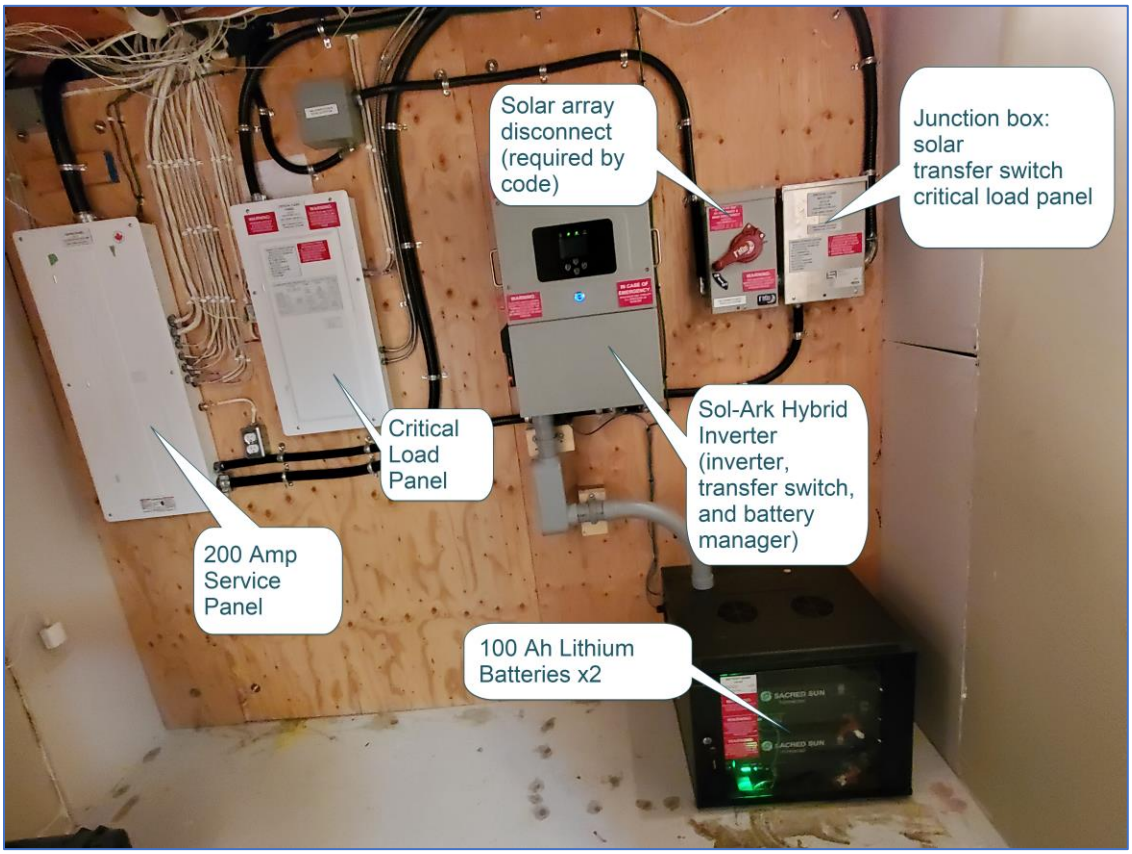


Figure 2: Electrical Room Equipment

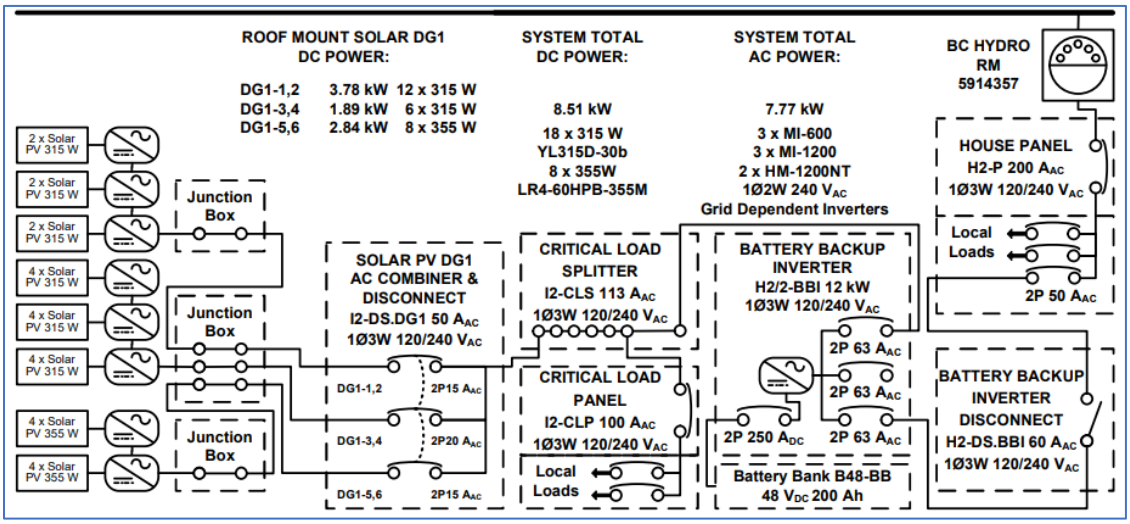


Figure 3: System Schematic, As Installed

Table 5: Total System Cost, Installed and Commissioned

Description	Cost
Step 1: Grid-Tie Solar, 9600 watt	$20,860
Step 2: Add: Off-Grid for central air conditioning	$13,000
Step 3: Add: Battery storage for critical loads	$9,500
Total	**$43,360**

Step 4: What the Future Holds

The system described in this paper keeps the home livable and damage-free indefinitely if the grid fails, but this system also has future potential, to become part of a distributed energy resource (DER)[11] for the province. The missed opportunity with this design is that there is an expensive energy storage system that resides on the property completely unutilized until a grid failure brings it into play. The "right way" to do this would be to make the energy storage available to the grid for peak shaving, load management, line loading, and power factor correction. This on-premises energy storage could supply the grid mid-day when power is expensive ($0.09 per kWh) and load levels are high and the grid could re-charge the batteries overnight when power is cheap ($0.05 per kWh) and load levels are low. The utility company benefits because it does not have to invest in expensive capacity simply to serve peak loads. The homeowner benefits because they will be paid for the energy they provide to the grid.

Electricity demand in Canada is forecast to increase by 50% in the next 30 years[12]. Power transmission and distribution grids are designed to serve peak demand, therefore the average load on the grid is only about 50% of capacity. DER has the potential to unlock tremendous grid capacity without utility company investment in any new generating facilities. A nice win-win – passive income for the homeowner and cost avoidance for the utility.

The path to DER in BC will require a significant system-wide re-engineering effort. BC power utilities transmission / distribution systems have good protection for their 500+ kV transmission system but virtually no protection for the low-voltage distribution lines that carry power to the point of consumption. Current grid monitoring will detect and protect against overcurrent at a substation. The challenge as more DERs are added to the distribution lines is the DERs will provide fault current so that local failures are masked from the existing grid fault detection system. This is where emerging Internet of Things (IoT) and artificial intelligence (AI) technologies can be leveraged. Low cost highly redundant IoT-enabled remote sensors detecting faults and fault precursors combined with the power of a predictive maintenance AI engine will enable a highly reliable and safe distributed grid and facilitate a world where the majority of power for residential use is economically generated right at the point of consumption.

[11] Distributed energy resources (DER) refers to often smaller generation units that are located on the consumer's side of the meter. Examples of distributed energy resources that can be installed include: roof top solar photovoltaic units, wind generating units, battery storage, EVs, water heaters. An important distinction of a DER is that the energy it produces is often consumed close to the source.

[12] https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021/key-findings.html

Conclusion

The system presented in this paper completely delivers the design specifications for a grid-tie solar array that can be installed in a home that, in the event of a grid failure, will facilitate using solar power to operate a central air conditioner in the summer and operate a furnace plus other critical loads in the winter. If you are installing a grid-tie solar array, the incremental cost of adding heat dome and atmospheric river risk mitigation is relatively low for peace-of-mind and preventing extended stays in hotels and extensive damage from frozen pipes.

There are many "soft" future potential benefits that are difficult to quantify:

- The efficiency gains by producing power at the source of consumption, eliminating line losses and facilitating grid "peak shaving" reducing the need for expensive grid infrastructure.
- The increase resilience of the grid resulting as more homeowners install local micro-capacity
- Distributed storage for renewable energy generation, which in the end can smooth local demand peaks and help offload the demand from EVs and electric heat pumps.

Homeowners investing in grid-tie solar infrastructure with off-grid and energy storage capability will not only benefit directly from reduced power bills and extreme weather risk mitigation but are positioned to be part of the mix in a solution to the expected future increase in electricity demand.

About the Author



Barry Allen, M.B.A., P. Eng. is a high-tech executive who has worked globally in aerospace, satellite communications, Internet-of-Things, and worker safety technology. He has recently been involved in the solar power sector and is an advisor to the Kelowna-based high-tech startup Crwn.ai with innovative technology applying artificial intelligence and remote sensing to real-time monitor transmission and distribution networks for fault detection and predictive maintenance. He serves on the board of the Energy Efficiency and Renewable Energy Division of Engineers & Geoscientist British Columbia.