Resiliency for Power and Data Connectivity During Outages by Application of Battery Energy Storage Systems, Use of Electric Vehicle Plug-in Points and Broadband Over Powerline

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Abstract: Smart metering infrastructure has a widespread use in modern power systems. The majority of homes in the United States have Advanced Metering Infrastructure (AMI) with capabilities in recording and communicating energy usage information to both users and utility companies. Although power outages are less frequent in the United States, about 25 percent of households see a power outage once in a year. However, in many parts of the world, power outages are a major issue and are more frequent in nature than in the United States. This paper is focused on identifying the technology and concepts known to ensure improved energy resources and data connectivity at users' disposal during either power or data connectivity outages. Innovative concepts in improving the V-2-G concept without integration into the grid were introduced. Additional deployment of mini battery energy storage banks at residential homes was introduced. The cost implications of mini battery energy storage systems for residential use are certainly alarming when challenges with the availability of batteries in the market are concerned. The use of known concepts in broadband over power lines was innovated with an approach of applying fiber optic cables for an internet connection to homeowners along with dedicated fiber optic cables between users and utility companies. The use of EV batteries to discharge into the interconnected homes by renewables and battery energy storage will ensure reliance from power outages and reduce dependence on the grid. Thus, this paper is proposing BPL using a fiber connection to the houses along with EV discharging via plugin points located in close vicinity of battery energy storages to supply power to the power grid to allow V-2-G application.

Keywords: *Battery Energy Storage Systems, Broadband Over Power Line, Electric Vehicle Integration, Smart Grid*.

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I. INTRODUCTION

The smart meters are capable of recording consumption patterns in real-time and enable data reporting [1] [2]. Depleting fossil fuels initiates the need for energy conservation and motivation for a sustainable future, further bolsters the energy conservation initiatives. Some of the known energy conservation initiatives at residential and commercial properties include the utilization of solar photovoltaic systems and energy management systems. Smart grid applications include the deployment of advanced metering infrastructure (AMI) that enables the customers to track their energy consumption and ensures utilities alter generation patterns based on energy usage [3]. Another major use of AMI is to track energy consumption by type of load and prepare a report to notify customers how they can become energy efficient by controlling their lighting or heating & cooling (HVAC) loads. For example, a detailed breakdown of power consumption by the branch circuit breakers from panelboards provides with energy consumption pattern for type of devices connected. In a typical 100A, 120/240V electrical service-rated electrical panelboard, one or more single pole 20A circuit breakers serve lighting and receptacle loads and one or more two pole (30-50)A circuit breakers serve water heater or HVAC systems. Diversegy website shows typical energy consumption pattern with respect to type of load for residential and commercial properties per the Department of Energy.

Power outages are erratic in nature and occur in any part of the grid and power distribution system due to some reasons such as voltage drop, generator loss, loss of lines due to weather conditions, and tampering with the power devices. Table 1. (see Appendix) shows data on the reason for power

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loss with duration and the number of impacted customers. Although a relationship may be established between the weather conditions and the number of outages, there are several other factors, such as the condition and age of electrical lines and support structures, that determine the relationship between the outage and the cause. The issues with power theft may be seen as less prevalent, but it continues to impact the resilience of the power system. Measures to develop tamper resistance electrical junction boxes and equipment enclosures are promising solutions but add to the overall cost of infrastructure. For example, a tamper resistance enclosure cover for underground handhole boxes would be higher than a regular bolted enclosure.

Broad band over power line (BPL) is a proven concept when utilization of the power lines for communication purposes is studied. High speed data transmission from the power lines not only saves the infrastructure required to support the data transmission equipment otherwise but also derives use of Voice over Internet Protocol (VoIP) [4] [5] to provide mobile calling facilities as well. The concept of use of coupler, bridge, and low voltage line with power link is consistent with the researchers in [4] and [6]. This becomes basis of design for the BPL applications in this paper with addition of fiber optic lines which is less known in past literatures. Although BPL has significantly lesser speed than the current provider speeds as shown in Figure 2 and 3 [7], the application for emergency and backup purposes becomes a choice for customer to install BPL at homes.

Electric vehicles (EVs) are at a growing stages both technology innovations [8] and for a large scale adoption [9] [10]. Earth is facing some major challenges with carbon emission hazards and so are the habitants [11] and EVs produce lower carbon emissions. So, EV application for both its regular use and for providing power back to the grid by vehicle-to- grid (V-2-G) [12] becomes at topic of research. In the US the commercial gasoline stations will require major upgrade to EV charging hubs to keep them profitable due to EV transition [13], thereby increasing the burden on power grid. This resultant increase on power grid lets a consideration to ensure uninterrupted power to the customers for their basic needs. Battery energy storage systems for renewable energy integration has promising applications when evaluating some of the pioneer projects in the United States such as 1,00,000kW at Albuquerque, New Mexico; 600,000kW at Morro bay, California; 40,000,000kW at Rosamond, California; 450,000kW at San Bernardino, California; and 409,000kW at Manatee County, Florida [14]. Residential customers are focused mainly on improving their energy consumption [15] mainly to save costs which aligns with utility in devising measures by application of technology in energy management systems that integrates the renewables and battery energy storage systems. Some cities have focused their street lighting to transition to LED, given LED has potential of energy savings when compared to their high pressure sodium counterparts [16].

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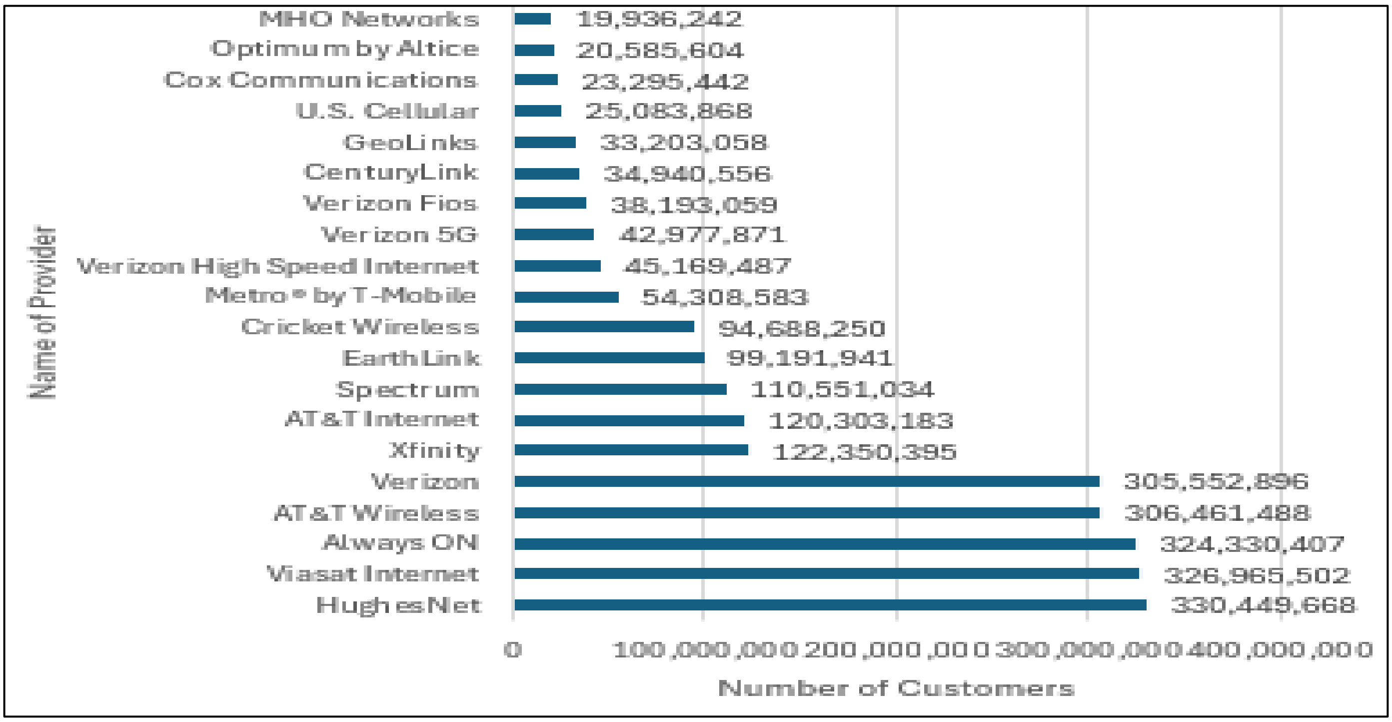

Fig 1: Customers based on Provider [7]

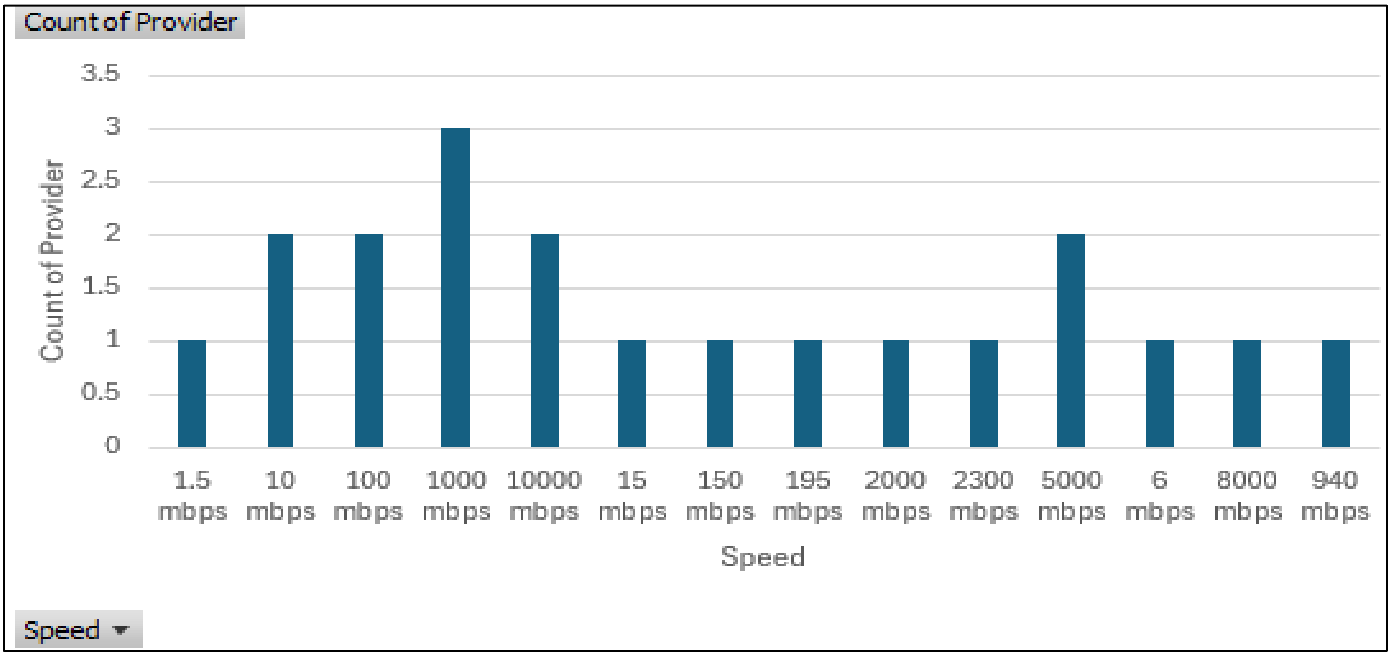

Fig 2: Speed vs Count of Provider

II. METHODOLOGY

Power outages, being erratic in nature, can result in the loss of several key activities and residential properties that otherwise would have been possible with steady power available. The major cause appeared to be the weather conditions and system faults from Table 1. To ensure a resilience the Figure 3 shows a scheme to integrate with mini BESS, renewables, and electric vehicle (EV) plugin points. The inverters for DC to AC power from renewables and battery energy storage were integrated to the respective blocks shown in Figure 2. Mini battery energy storage banks are available at customers' disposal to provide uncompromised solutions to residential customers. Additionally, roof-top solar and electric vehicle batteries may further increase the power generation and storage for use during times when there are erratic outages. Figure 3 solves the problem of the data transmission for power usage via a dedicated fiber optic cable. Additionally, communication over power line acts as an additional resource to report the energy usage back to the utility company. Figure 4 shows broarder picture of the resilience for power and data.

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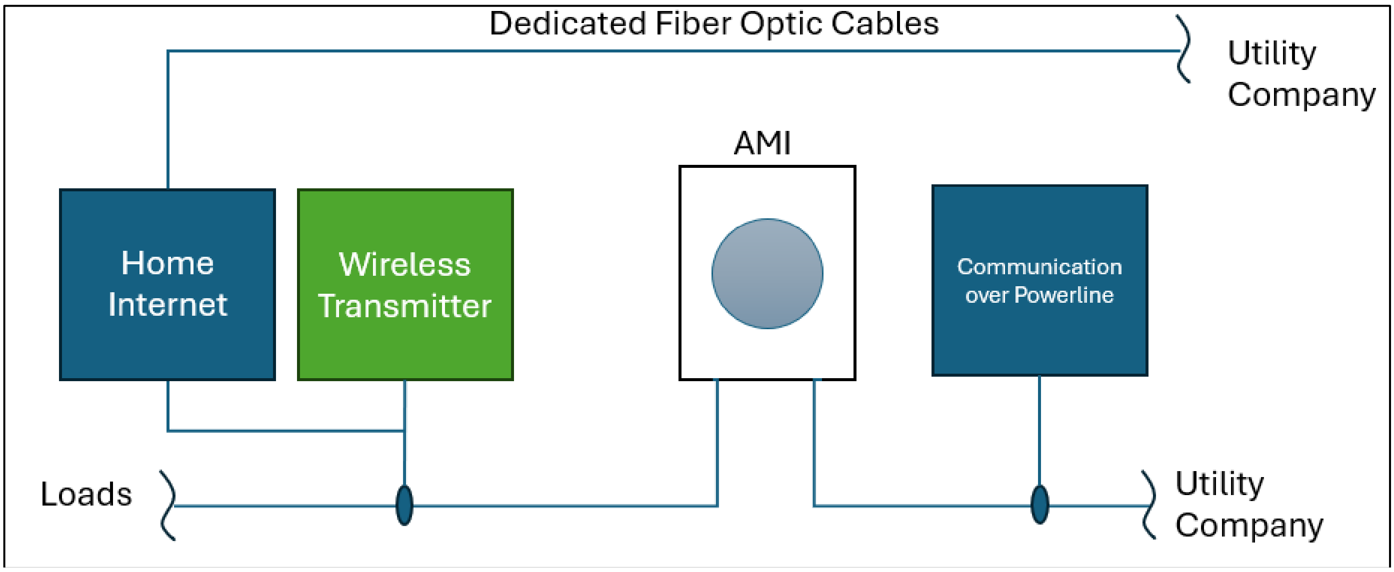

Fig 3: AMI Communication with Utility Company

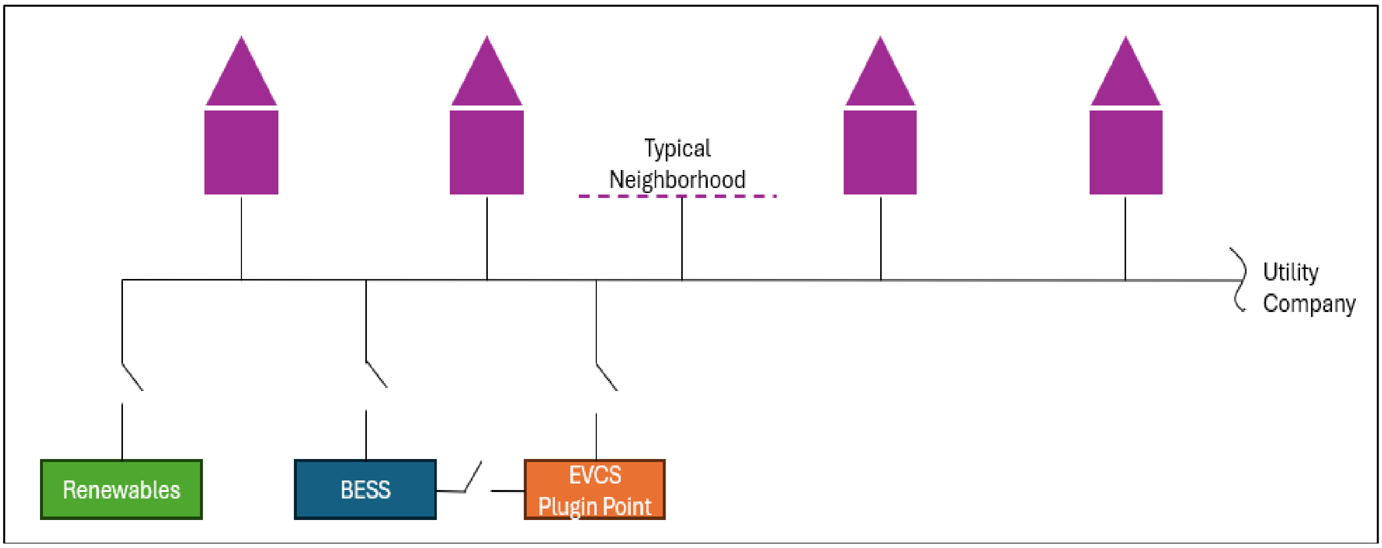

Fig 4: Scheme for Integration of mini BESS, Renewables, and EVCS Plugin Point

A. Use Roof-top Solar

Solar photovoltaic for roof-top applications is a preferred choice for many who are looking to reduce their energy bills and promote sustainable development. However, the impacts of rooftop solar panels on the environment are subject to critique when it comes to the impact on birds and other ecosystems.

B. Use Mini Battery Energy Storage System

Battery energy storage at residential apartments is a feasible solution when the use of UPS units widely been used in the commercial markets. These mini battery energy storage systems may harness the energy generated from solar PV by storing and delivering when required. Additionally, it may also charge from utility power and keep available stored energy for needs during an outage condition.

C. Use Mini Battery Energy Storage System from EV

Since battery electric vehicles have become popular and studies indicate there will be a large-scale shift from internal combustion engines to electric vehicles, EVs come with inherent stored power with the battery that drives the car. This battery becomes a potential candidate for supplying back power to the grid when V-2-G is concerned. However, in this application to solve power outage issues, batteries from EVs may not be directly connected to the grid but to the loads within the residential homes.

D. Outages

Broadband power lines (BPL) are a known method for communicating via power lines. During an outage, this may be utilized to ensure customers' internet connectivity. The speed of connectivity may not be as efficient as regular data connectivity from fiber optic or cellular networks, but a choice is available with customers without the internet. Additionally, many rural areas that have no internet connectivity at all may utilize the BPL as a solution.

E. Reasons for Outages

Power line failures are majorly due to poor weather conditions such as heavy rains, winds, and snow effects. There are many other reasons, such as lightning strikes and

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flooded substations, that cause the loss of power other than some events, such as trees damaging the lines. Many times, trees and vegetation cause conductive paths between the overhead line phase conductors, thereby causing damage. Other major reasons are possible from wildlife interference, aging equipment failure, major natural disasters, exposed to ongoing construction works, increased power demand, and required maintenance outages. Although most power outages are erratic in nature, many related to either planned maintenance or aging equipment failure are predictable ahead of time.

Internet lines are primarily affected by malfunctions to the modem and routers, aging equipment, poor weather conditions, inadequate equipment, congestion, physical damages, cybersecurity breaches, interference from power lines, maintenance and natural disasters. Similar to power lines the outages related to planned maintenance and aging equipment are predictable. Thus, the predicted outages must be conveyed to customers and thus customers may be prepared to utilize the backup options for both internet and power.

III. PRACTICAL APPLICATION AND RESULTS

This part includes the results, tables, figures, formulae with references, data source references, evaluation of validity for calculations, and discussion. This part may be divided into balanced sub-parts.

A. Community Solar

Community Solar installed at common spaces in the residential housing units may either be managed by home owners association or through leasing offices for apartment communities. These community solars will become a shared resource and solve the outage issues.

B. Community Battery Energy Storage System

Community Battery Energy Storage System engages large battery banks installed outdoors to supply power and storage options from community solar or other renewable energy generation resources on site. The battery energy storage becomes a shared resource for all the homeowners and apartment leaseholders.

C. Community Shared Usage of EVs as Energy Storage System

When 100% electrification happens, the household owners become resourceful with energy storage from the EV itself. The communities may engage in programs to charge the battery energy storage system from EV cars to ensure that BESS, in turn, provides power back to the homes. Additionally, there may be plugin points at various locations along the homes or shared spaces that allow power to be fed to them and distributed to the homes directly.

D. Block Diagram

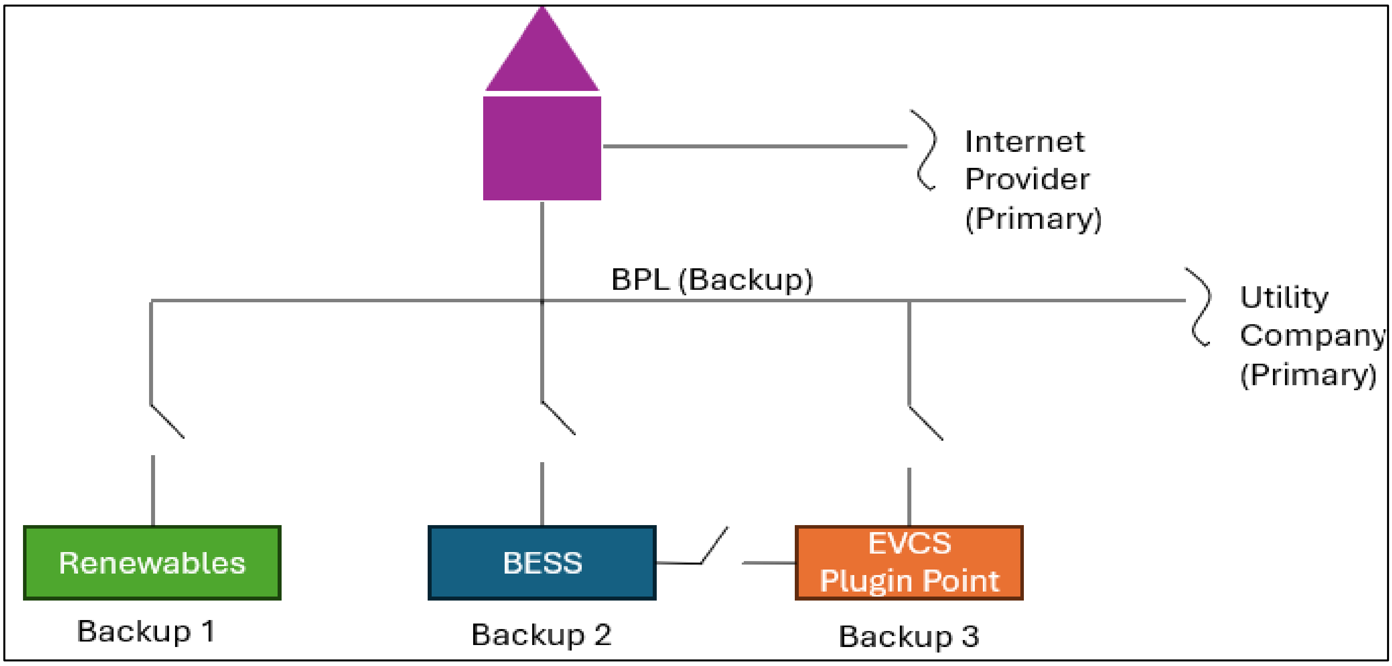

Fig 5: Block Diagram

E. BPL Extractor and Fiber Cable to Homes

The concept for broadband over power line by wireless transmission has been discussed in [17]. However, for the practical application for this study an extractor has been tied to finer optic cables that connect directly to the home modem. Figure 5 gives a diagrammatic overview of layout of the extractor and connections to the power line and homes. Figure 6-7 delves into implementing the scheme presented in Figure 5 to real-world residential homes. The EV plugin point and mini BESS may be located at an optimal location such that the voltage drops from distribution from the same to the homes at a reasonable distance.

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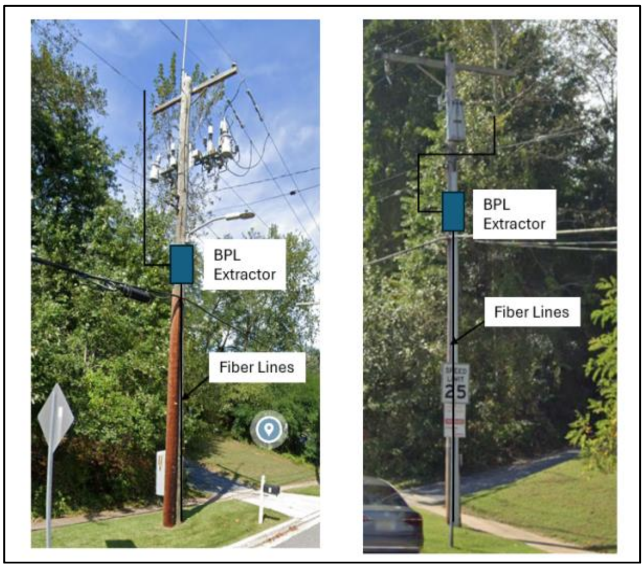

Fig 6: BPL Extractor with Fiber Optic Cables to Homes
(Source for Background Image: Google Maps)

Fig 7: Practical Concept
(Source for Background Image: Google Maps)

The optimal size of the mini power storage system is dependent on the total demand load for the neighborhood. Similarly, the potential of EV plugin points for the distribution of power back to the homes is dependent on the how many cars, the wattage of the battery, availability, and the state of charge at a given point of the day. Some homeowner associations may work directly with a grid to apply V-2-G integration directly from their homes, allowing a bi-directional power flow to the grid. Although the challenges with the integration with the power grid in the V-2-G concept is a topic of further study, a recommendation based on existing literature works well when locating BESS and EV plug-in points for discharging.

IV. CONCLUSION

Outages in the power system are minimal and are caused mainly due to weather conditions, and about one in four homes see an outage at least once a year. The time when the outage hits the customers may be concerning when people may be at work (remotely connected from home internet) and also when there is an elongated period of an outage that limits their capabilities in completing the tasks otherwise. The paper presented schemes that are promising when a power grid faces an outage. Mini BESS and EV Plugin points are assets when a group of homeowners or an entire neighborhood engages together. The issues with home internet outages were resolved by BPL, and the deployment of an extractor with fiber optic cables to homes. Although cost of such infrastructure may have some limitations the resiliency for both power and internet outages is possible with the given scheme. A layout presented for practical application proves to have spaces available for roof-top solar, BPL extractor, EV plugin point, and mini-BESS. Plugin point for EV battery discharging for supplying power to the home is a proposed new concept.

- Ethical Approval: Nil to disclose.
- Data Availability: Nil to disclose.

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APPENDIX

Table 1: Outage Data (Source EIA) [18]

Year	Month	Duration	Utility/Power Pool	Loss (megawatts)	Number of Customers Affected
2024	1	0 Hours, 10 Minutes	LUMA Energy	40	89245
2024	1	0 Hours, 8 Minutes	LUMA Energy	50	64131
2024	1	0 Hours, 14 Minutes	LUMA Energy	0	0
2024	1	0 Hours, 37 Minutes	LUMA Energy	300	161194
2024	1	0 Hours, 11 Minutes	LUMA Energy	130	52423
2024	1	0 Hours, 29 Minutes	LUMA Energy	95	79445
2024	1	0 Hours, 10 Minutes	LUMA Energy	170	89245
2024	1	0 Hours, 1 Minutes	Georgia Transmission Corporation	0	0
2024	1	39 Hours, 56 Minutes	Puget Sound Energy	Unknown	75180
2024	1	33 Hours, 19 Minutes	Southern Company	15	2131
2024	1	. Hours, . Minutes	Duke Energy Carolinas	Unknown	108718
2024	1	7 Hours, 22 Minutes	Duke Energy Carolinas	Unknown	109212
2024	1	1 Hours, 0 Minutes	Exelon Corporation/PECO	Unknown	130000
2024	1	5 Hours, 50 Minutes	Duke Energy Progress	7209	151386
2024	1	112 Hours, 23 Minutes	Detroit Edison Co	Unknown	172481
2024	1	46 Hours, 20 Minutes	National Grid	Unknown	96000
2024	1	24 Hours, 25 Minutes	ISO New England	Unknown	91000
2024	1	0 Hours, 9 Minutes	LUMA Energy	250	142296
2024	1	1 Hours, 44 Minutes	LUMA Energy	0	0
2024	1	. Hours, . Minutes	ComEd	Unknown	186778
2024	1	40 Hours, 23 Minutes	Detroit Edison Co	Unknown	172481
2024	1	. Hours, . Minutes	WEC Energy Group (WEPCO, WPSC, UMERC, WEP-MIUP)	200	250000
2024	1	40 Hours, 17 Minutes	Consumers Energy Co	Unknown	175488
2024	1	55 Hours, 10 Minutes	Portland General Electric Co	4031	165000
2024	1	. Hours, . Minutes	PPL Electric Utilities Corp	Unknown	50000
2024	1	0 Hours, 5 Minutes	American Electric Power (Regulated Generation)	0	0
2024	1	27 Hours, 39 Minutes	Portland General Electric Co	3744	116998
2024	1	0 Hours, 15 Minutes	LUMA Energy	0	0
2024	1	2 Hours, 57 Minutes	LCRA TSC	0	0
2024	1	0 Hours, 53 Minutes	Constellation Energy Generation, LLC	0	0
2024	1	0 Hours, 28 Minutes	LUMA Energy	154	156859
2024	1	0 Hours, 30 Minutes	Apex Generating Station	0	0
2024	1	0 Hours, 10 Minutes	LUMA Energy	20	58680
2024	1	0 Hours, 5 Minutes	LUMA Energy	24	Unknown
2024	2	0 Hours, 21 Minutes	LUMA Energy	0	0
2024	2	0 Hours, 47 Minutes	ISO New England	0	0
2024	2	0 Hours, 1 Minutes	Constellation Energy Generation, LLC	0	0
2024	2	1 Hours, 43 Minutes	LUMA Energy	90	115374
2024	2	1 Hours, 59 Minutes	Sacramento Municipal Utility District	Unknown	167000
2024	2	13 Hours, 0 Minutes	Sacramento Municipal Utility District	1230	200000
2024	2	0 Hours, 1 Minutes	Constellation Energy Generation, LLC	0	0
2024	2	0 Hours, 1 Minutes	Constellation Energy Generation, LLC	0	0

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2024	2	0 Hours, 5 Minutes	LUMA Energy	10	0
2024	2	0 Hours, 24 Minutes	LUMA Energy	Unknown	Unknown
2024	2	1 Hours, 0 Minutes	Lafayette Public Power Auth	200	0
2024	2	. Hours, . Minutes	PPL Electric Utilities Corp	Unknown	100000
2024	2	3 Hours, 44 Minutes	PPL Electric Utilities Corp	Unknown	165000
2024	2	0 Hours, 51 Minutes	CenterPoint Energy Houston Electric, LLC	0	0
2024	2	1 Hours, 0 Minutes	Minnesota Power	0	0
2024	2	0 Hours, 16 Minutes	LUMA Energy	75	66403
2024	2	. Hours, . Minutes	National Grid	Unknown	76076
2024	2	9 Hours, 15 Minutes	ISO New England	Unknown	50000
2024	2	0 Hours, 1 Minutes	Bethlehem Energy Center	Unknown	Unknown
2024	3	0 Hours, 13 Minutes	LUMA Energy	80	90104
2024	3	0 Hours, 1 Minutes	Constellation Energy Generation, LLC	0	0
2024	3	0 Hours, 8 Minutes	LUMA Energy	115	87196
2024	3	0 Hours, 13 Minutes	LUMA Energy	Unknown	Unknown
2024	3	17 Hours, 5 Minutes	ISO New England	Unknown	60755
2024	3	0 Hours, 2 Minutes	Constellation Energy Generation, LLC	0	0
2024	3	0 Hours, 26 Minutes	LUMA Energy	100	90664
2024	3	0 Hours, 25 Minutes	LUMA Energy	Unknown	Unknown
2024	3	0 Hours, 15 Minutes	LUMA Energy	228	Unknown
2024	3	0 Hours, 13 Minutes	LUMA Energy	30	70361
2024	3	15 Hours, 37 Minutes	CenterPoint Energy	Unknown	125077
2024	3	. Hours, . Minutes	National Grid	Unknown	88134
2024	3	54 Hours, 20 Minutes	ISO New England	Unknown	110000
2024	3	7 Hours, 32 Minutes	CenterPoint Energy Houston Electric, LLC	0	0
2024	3	0 Hours, 44 Minutes	Central Maine Power Company	0	0
2024	3	0 Hours, 33 Minutes	LUMA Energy	215	Unknown
2024	3	0 Hours, 13 Minutes	LUMA Energy	Unknown	Unknown
2024	3	0 Hours, 10 Minutes	LUMA Energy	163	Unknown
2024	3	4 Hours, 47 Minutes	LUMA Energy	Unknown	Unknown

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