**Introduction**

What can be done to ensure grid security against attack threats? What could happen, how could it happen, what do we do to avoid or stop it if it does happen? We use less electricity by using efficient devices like LED lighting. How much market penetration has something that groundbreaking made so far? What about electric vehicles (EV)? When will EV penetrate 10% market share and will all those charging EV batteries help the grid by storing as well as charging? What are some of the most promising grid storage batteries? Will nuclear power expand as the major generator of base load? These are the areas this essay will study with a focus on grid resiliency and security.

The most important component of our nation’s economic security comes from the stability of our electric grid. Imagine the economic and life quality we would experience if our power supply became intermittent or fails completely. Grid security involves threat assessment. These threats can come from cyber-attacks, instability of electric supply, and even mother nature. Resiliency of our power grid is essential to every part of our economy and daily lives. Electric demand is undergoing tremendous transition which requires us to focus on the security of our power grid.

Power generation is transcending from large, centralized fossil fuel and nuclear generation to smaller diverse power suppliers through use of microgrids for local supply and excess capacity grid contribution. Renewable energy sources are increasing and have become the best cost-effective power sources available. Renewables largest contributors are solar and wind power. The sun does not shine, nor the wind blow according to our power demand needs. Therefore, the need for battery storage is becoming evident. Rapid change and new wide power source diversity is requiring a re-think of exactly what grid security entails.

Grid security involves so much more than protection from sabotage. Diversity of generation and the rise of micro grids are essential keys to grid security / reliability. Recent events in California and Texas are examples of power grid faults. (Bhambhani )Widespread blackouts left millions of customers without power. We can study these disastrous events and learn how to avoid future mishaps which cause supply interruptions.

System vulnerability verses flexibility, interconnectivity, transmission, generation diversity, decentralization, and SCADA are some of the areas that will lead development of future grid architecture. These oncoming transitional grid changes focus on efficiency through demand load shaping.

**Threats**

Storms pose threats be prepared, blind (Accessible)

More storms now than historic (Buteau)

Eyewitness news captures the reality of power failure blackout . The combination of moving traffic and inoperable traffic lights is a dangerous example **(**Eyewitness News)

Threats to our power grid can be classified as known or unknown and natural or intended sabotage.

Cyber threats are frequent and dangerous. As outlined in a recent N Y Times article, a recent threat from Russia concerned a multiple system wide nationwide hacking of corporations and control systems. All of the U S based systems were compromised, and this went undetected for years. (Sanger,2020) These cyber attacks are attempted daily by foreign government sponsored terrorists and others. There are a long list of successful attempts to hack U S control and data systems.

Recent events between China and India give us an insight to how cyber warfare is used today. China is responsible for collapsing the Mumbai, India power grid as a warning according to an article from India’s English News. (W)

In todays changing world we face multiple sabotage threats to our electricity supply. The wide diversity of power generation sources has created more invader entry points to the grid control system.

Resiliency is yet to be defined by regulatory entities mainly because stakeholder profiteers enjoy using this word as reason to push revenue in their direction.

I propose one portion of the solution can involve utilizing genuine closed networks with proprietary operation software for power grid control. Currently engineers access control for troubleshooting with “secure” wireless phones to operate switching control systems. With a closed network, nothing can enter the control software and operating system (o s) without a physical hardwire attachment of the device. In conjunction with a closed network, the networks used can have a unique proprietary o s, software, and hardware. which makes the entire control system incompatible without available known industrial system components. This would place the hacker is a similar position to the German attack force attempting to enter Russia by rail and finding the railroad tracks in Russia were several feet wider than the German supply trains wheel trucks. In this case, there is no easy way to enter and easily navigate about within the control system for the hacker.

Reliability is resiliency. Resiliency is threatened simply by fast moving need for architectural grid system change. Renewables emerging as new forms of cost effective power supply threaten the cyclical resiliency of our grid. We are playing a game of catch-up because of oversupply from cheap renewables which lacks storage capacity. A lack of storage causes solar power generation to be ineffective. Solar power generation is out of sync with the power demand cycle. We don’t need the power at the time of day solar generation is at it’s peak but we need peak power when solar is unavailable.

We hear much about “Greening the grid” and looking both forward and back we see consistent controversy about renewable energy sources. In fact, the rise of renewables is presenting tremendous challenges for grid security and control. Frankly, the growth of renewables as a source of power generation is driving the need for energy storage because when solar power is producing at highest levels for the day, electricity demand is low. The short term key to this storage dilemma is to study and understand exactly how many hours of short term energy storage is needed to balance supply with demand. Long term, seasonal storage solutions come into play.

In 1980 wind and solar were far too expensive. Even just 5 years ago, Government representatives scoffed at the possibility of today’s reality. Renewable energy is cheaper than ever. In fact, wind energy is the cheapest form of electrical production with a ( ) cost per kW according to( ) . There is one huge caveat to this explosive growth of renewables. We have to store the electricity renewables produce because demand spikes when the sun is down and demand drops when the sun is shining bright. Meeting electric demand is all about an ability to meet peak demand. (Operators) work tirelessly project usage needs and to stay ahead of minute to minute demand. We do this by continuously covering a baseload and turning on more generation during demand spikes. We must focus on electricity storage devices. This is where the race to develop grid battery efficient technology explodes. Can we become cost efficient with battery storage technology soon enough?

TrendMicro security flaws in scada control (One)

**SCADA**

Supervisory Control and Data Acquisition (SCADA) is the interactive control at the heart of the smart grid. Is there too much demand during a 15-minute period near noon on a sunny day? SCADA can leave thousands of air conditioners off and turn them on as demand subsides or more peak power generation comes gently online. This is accomplished by sacrificing individual unit control to a region wide control system. What could possibly go wrong?

“All SCADA systems collect real-time and historical information and then provide operational personnel with a wide range of modes in which this information can be displayed and accessed.”

“SCADA systems generally cover large geographic areas with the controller application housed in the appropriate terminal that is controlled by an operator working centrally.” (Mehta, 2021)

TrendMicro security flaws in scada control (One)

This article from Science Direct gives an overview of SCADA control systems hardware and how it is used to monitor and control the smart grid system. The information is taken directly from the Pipeline Planning and Construction Field Manual. The Manual is available by link at the Science Direct website. There are several other SCADA related articles available at this website. (Pipeline)

**TEXAS**

Practical Engineering gives an in-depth explanation of the Texas Power Grid structure and unstable frequency shifts which cause blackouts in this YouTube video.( Gradyhillhouse)

**EPRI President and CEO, Dr. Arshad Mansoor expects changes**

**Houston police chief deems Texas power outages to be an epic failure (**TODAYNBC)

Who is responsible for the Texas blackouts? Why are entrenched stakeholders and profiteers blaming renewables? (ABC)

Texas unprecedented snow storms (CNBC)

Texas troubles far from over(Nova)

**SMART GRID**

to reference a great “how it works manual” for understanding the smart grid. (EPRI)

Lessons Learned

California government dreaming of ending nuclear power generation recently decided to order nuclear plants shut down. The infrastructure for replacing nuclear generation is not in place. This bold move is spurring California to lead the way in developing energy storage technology but the move also caused unnecessary brown outs to multiply.

**SOLUTIONS**

Proactive/ reactive

resiliency = Diversity

Demand side management (EIA)

Rose advocates new legislation for energy renewables. Author Julietta Rose wrote The PURPA Haze: Clearing the Way for PURPA Implementation in a Changed Energy SystemThe article focuses on the effects of climate change and renewables with grid energy distribution concerns. “The Public Utility Regulatory Policy Act has been only moderately successful in supporting the development of small renewable generators: however, a different implementation framework could make the Act strong. effective tool for supporting the transition to the renewable and resilient electricity we need.” (Rose)

Author Stefanie Phillips makes a case for proactive threat readiness as she identifies the current reactive response structure and why it is in place today (Phillips)

There is still a widespread assumption that secure perimeter and air gapped networks are enough to protect critical systems.

The invisible hand and freedom of capitalism in the economic power generation marketplace can be a large portion of the answer. Power generation diversity in itself can be grid security.

As the age old saying goes: The more the merrier. We have moved from a power generation system owned and controlled by (28 entities) in (1940) to (millions) of independent sources for power generation. These sources can be as small and simple as a homeowner’s rooftop mini microgrid to a large baseline power geothermal generation project. This isn’t your father’s power grid generation system anymore. The wide diversity in itself offers resiliency from natural threats while simultaneously providing more open doors for cyber sabotage entry points. Profiteers and politicians no longer retain complete control over who can enter the market to generate and sell electricity. The main ticket to entry today is to meet the specifications an d standards necessary for quality. Security known as grid resilience is becoming centered in development of microgrids.

When will the EV penetrate 10% market share? Will that cause grid disruption through massive demand? Maybe yes if we don’t prepare. However, think about all those batteries and their potential to both create demand and be small widely distributed storage devices. These millions of EV batteries can also be used to balance the grid and add to grid diversity

Author Lei Wu and his associates outlines the design for reconfigurable controls involved with microgrids in this Science Direct article An integrated reconfigurable control and self-organizing communication framework for community resilience microgrids. (Wu)

Blockchain software may play a role in grid security(Kim)

Manual and info (ELECTRIC POWER EPRI)

Burgeoning renewables (Electric)

**Cyber Threat Solutions**

”According to TrendMicro, Here are some steps organizations can follow, some of which are based on National Institute of Standards and Technology’s [NIST’s guide to ICS security](https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-82r2.pdf):

* **Use virtual patching to help manage updates and patches**. Patching for vulnerabilities though critical for SCADA systems means heavy planning and scheduling to prepare for possible downtime these patches may require. Virtual patching can help manage vulnerabilities and prevent exploits when patches cannot be immediately deployed or at all implemented.
* **Apply network segmentation**. Partitioning networks can prevent the spread of malware and efficiently contain attacks. Network segmentation also minimizes the chances of exposure of sensitive information.
* **Use adequate security measures between the ICS network and corporate network**. Although safety in both networks is important, using adequate security measures like firewalls between such networks can prevent the lateral movement of attacks from one to another.
* **Properly manage authorization and user accounts**. Regularly monitoring and assessing who has authorization and access to certain facets of SCADA systems can help reduce unexpected openings for both cyber and physical threats.
* **Use endpoint protection on engineering workstations connected to SCADA for device programming and control adjustments**. Adequate endpoint protection creates a stronger defense against perimeter threats.
* **Maintain strict policies for devices that are allowed to connect to SCADA networks**. Implementing strict policies for connecting devices to SCADA networks reduces unforeseen entry points for potential attacks.
* **Restrict the roles of transitory SCADA nodes to a single purpose**. Having a single purpose for transitory nodes lowers the chances of unknowingly exposing these nodes or having them accessed by unauthorized users.
* **Prevent the use of unknown and untrusted USB devices**. Removable devices are potential attack vectors that can be overlooked by users. Using only trusted USB devices can minimize the chances of malware infection.” (TrendMicro, 2021)

Challenges in upgrading our grid architecture…. Aguero, 2017)

Agent-based computing and multi-agent systems( (Akram)

NREL is a great resource for understanding grid threat mitigation (Energy)

NIST cyber security framework (SHACKELFORD)

believe their study will demonstrate superior performance for grid control security and help to avoid potential large economic losses from potential cyber-attacks. (Kim)

Energy security and resilience (Energy)

**Efficiency**

The lucrative bang for the buck higher grid efficiencycan come from lessening the cost and ease of transition from baseload demand to peak demand.

Power generation efficiency starts by pairing electricity supply accurately with demand. The complexity level of accomplishing this balance effects the cost effectiveness of power supply sources. The less large peaker generation plants needed to satisfy demand cycle peaks the easier satisfying demand surges becomes. Pump- Hydro is a widely used quick start efficient battery which helps meet peek demand. Pump Hydro is efficient because it can be quickly started. It is not efficient concerning location and size logistics. New battery technology will allow exponential efficiency in meeting peak demand cycles and surges. Batteries will become more effective as battery capacity increases and scalability allows more able to store energy for longer times. We have a just in time supply/demand system. Early on batteries will allow minutes of excess power generation storage. As the storage program advances there will be a clear goal to have **HOURS** storage capacity. According to standford achieving the goal of **HOURS** brings enough efficiency to make renewables the efficient generation source for peak demand **show chart data**(Standford)

**LED**

We use less electricity by using efficient devices like LED lighting. How much market penetration has something that groundbreaking made so far?

“The U.S. Energy Information Administration (EIA) estimates in the Annual Energy Outlook 2021 that in 2020, the U.S. residential and commercial sectors combined used about 219 billion kilowatthours (kWh) of electricity for lighting. This was about 8% of total electricity consumption by both of these sectors and about 6% of total U.S. electricity consumption.” (EIA, 2021)

“Light-emitting diodes (LEDs) are gradually taking over the global lighting market. While in 2019, [almost half of all light sources in the world were LEDs](https://www.statista.com/statistics/246030/estimated-led-penetration-of-the-global-lighting-market/), it is projected that by 2030, some 87 percent of all light sources will be LEDs.” (Statista, 2021)

**Energy Storage**

NREL article “Declining Renewable Costs Drive Focus on Energy Storage” is a discussion of the potential for the power grid incorporating new technologies in energy storage. The article gives us insight on why renewables are driving the race for research and development in storage technology(NREL)

the handbook, *Modern devices thermodynamics: Batteries, fuel cells and supercapacitors* to help give us a basic understanding of the composition, mechanics and uses of technology such as air batteries, super capacitors, and much more. This is a great reference to understand relatively new electronic technologies (Hoxha)

Currently the predominate use of energy storage comes from pump-hydro.

What about electric vehicles (EV)? When will EV penetrate 10% market share and will all those charging EV batteries help the grid by being used for temporary storiage?

Aluminum Air battery (Pino)

Liquid metal batteries (Kim)

Liquid air batteriy (Mtf169) This simple process rivals gravity batteries by using air to store energy by compressing it down and when energy is needed the process is reversed to allow the air to turn a turbine. Pumped Hydro (Gravity) is currently the overwhelming choice for grid energy storage (see attached illustration) because they have multiple gigawatt hours of storage capacity. Liquid Air can be a viable high energy density cost efficient alternative which overcomes height and area size limitations of pumped hydro. (Mtf169)

MIT’s lithium-metal battery(Atwell) **This liquid metal battery could replace lithium-ion batteries to provide power to hospitals, manufacturing facilities or a subdivision of several hundred homes.**

Taking the expanding need for EV charging stations and numerous design issues into consideration, expansion must be a focus on intuitive proactive considerations for building a better smart grid. (Vidangos)

Polarium is retailing energy storage batteries today(Energy storage)

Next big opportunities storage: **this article offers great stats charts and hypothesis** (standford online)

**Future Power Generation**

**Nuclear**

Nuclear power is a must for future power generation. (Bragg-Sitton)

SMR’s face challenges (Cooper)

“Advanced Small Modular Reactors (SMRs) are a key part of the Department’s goal to develop safe, clean, and affordable nuclear power options. The advanced SMRs currently under development in the United States represent a variety of sizes, technology options, capabilities, and deployment scenarios. These advanced reactors, envisioned to vary in size from tens of megawatts up to hundreds of megawatts” (Office 2021)

How small can nuclear reactors be(DNewsChannel.)

This article, Advanced Small Modular Reactors (SMR) and others from the Office of Nuclear Energy give us a a realistic insight of the future for Nuclear Energy involved in grid energy generation. The size and application versatility of new reactor designs has given power generation new hope for the best economical efficient power generation without all the dangers and shortcomings of past reactors. These articles discuss an ability to produce reactors on a commercial assembly line, store and use radioactive fuel safely, and enjoy a long product life with cost efficient power generation. All of the safety and high -cost worries are overcome. Even the radioactive fuel containment and disposal dynamics are changed to a no hassle level. (Office)

**Hydrogen**

The future of home hydrogen generation is now (Lavo)