Electric Vehicle Charging Infrastructure – Challenges & Opportunities

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GT Center for Distributed Energy

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Creating holistic solutions in electrical energy that can be rapidly adopted and scaled

WORLD ECONOMIC FORUM

TOP 3 TRANSMISSION GRID INNOVATIONS 2010-2020

"Accelerating the Energy Transition"

Platform Initiatives

Grid Asset Augmentation


7.2 kV 50 kVA Hybrid Transformer


13 kV 1 MVA Modular Transformer

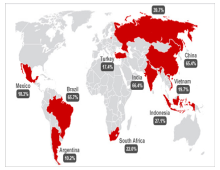

Smart Wires

- 13 kV/50 kVA FUT
- 13 kV 1 MW Power Router
- 67 MVA Modular LPT
- Improving Grid Resiliency
- Smart Wires
- Meshed Grid VVC

Energy Access in Emerging Markets

- 'Exponential' Tech
- Self Organizing Nano Grid
- Pay-Go Smart Meter
- Low Cost DA for Grids
- Ad-Hoc Bottom-Up Grids
- Empower a Billion Lives


Emerging Technology: D-Light


Top 10 Emerging Markets
Source: Global Intelligence Alliance

Next Generation Grid Power Electronics

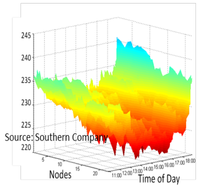

4 kV MVSI for Large PV Farms


7.2 kV 50 kVA SST

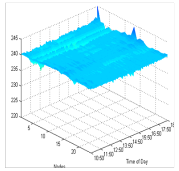
- 5 kV DC Grid Building Block
- 7.2 kV 50 kVA Grid Connected SST
- 4 kV MVSI for Large PV Farms
- Triports for PV/Storage/Grid
- MVSI with Integrated Storage
- Microgrid-Grid Interface Device

Decentralized Grid Control Techniques & Markets

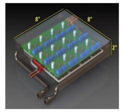
- Grid Edge Volt VAR Control
- Collaborative Control
- High PV Integration
- DER Micro grid Impact
- Self-Pricing Island Grids
- Virtual Power Plants

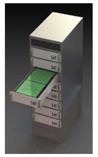


Feeder Voltage w/o and with GE Control


Feeder Voltage w/ Grid Edge Control

Next Generation Industrial Power Electronics


100 kVA EV Drive System


200 kVA Isolated Drives


2 MVA Industrial SIVOM

- Industrial CVR Energy Efficiency
- 100 kVA EV Drive System
- 25-500 kVA Isolated Drives
- Energy Hub – DC Fast Charging
- Programmable Load/Source
- Data Center Power Sources

Global Asset Monitoring Management & Analytics (GAMMA)

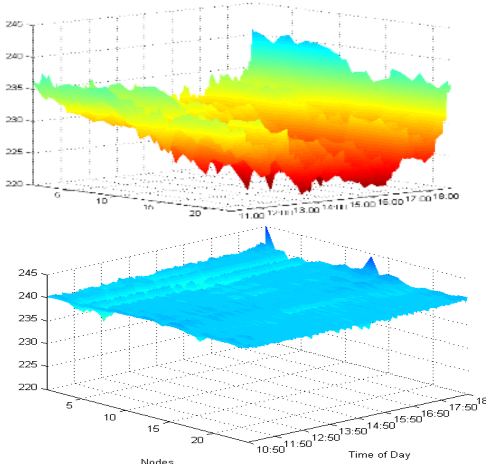
- Low-Cost Communications
- Cyber-Security
- Data Management
- AMI Data Analytics
- Global Sensor Networks
- Cloud Based GAMMA System


GAMMA Platform


Gamma kernel

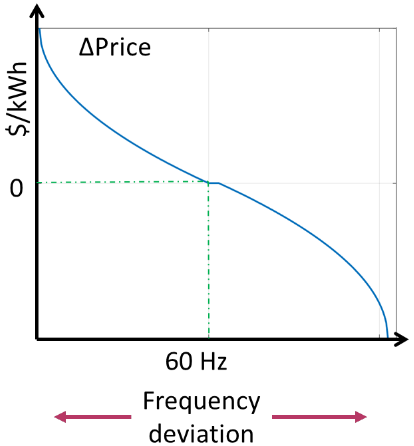
Primary Drivers

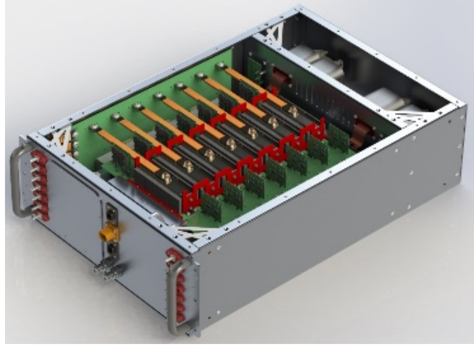
Digitalization Decentralization Decarbonization



COLLABORATIVE CONTROL
Varentec

TRANSMISSION POWER FLOW CONTROL
Smart Wires





SELF-PRICING MICROGRIDS
Transactive/Physical Grid

ENERGY ROUTER
Grid Block

Energy and Climate – Overarching Goals

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Faustian Bargain: Climate OR Growth
(especially for emerging economies)

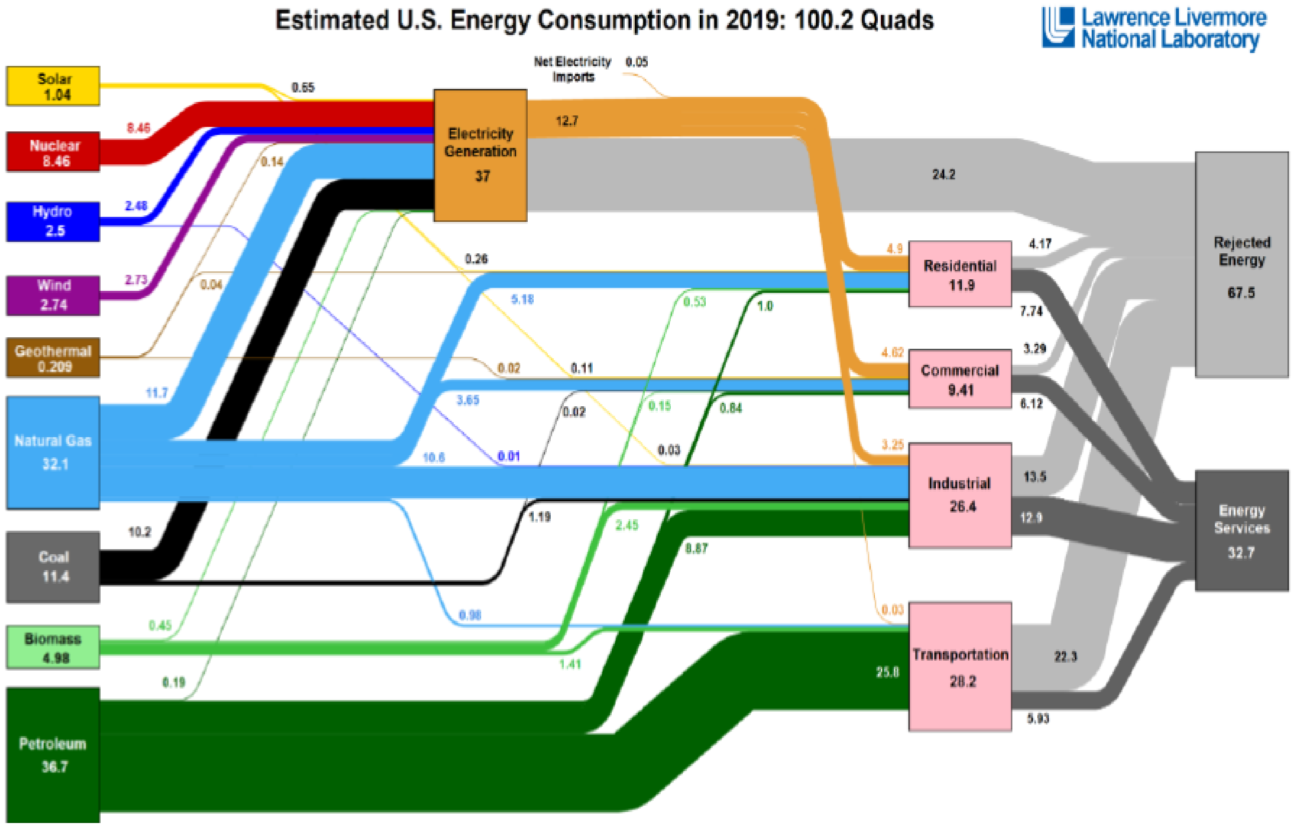
NEED:

- Address climate change – eliminate carbon emissions in 30 years, electrification is a key element
- Maintain economic growth – abundant, reliable and low-cost energy (whenever/wherever it is needed)

The transformation to a low-carbon economy is not possible with 20th century technologies!

OPPORTUNITY:

- Rapidly develop & deploy higher-performance lower-cost 21st century technologies that are also sustainable
- Sustainability transformation should be equitable and reduce gap between haves and have-nots



- 100 Quads → 85 Q Fossil → 67 Q Rejected (waste heat)
- **Transportation represents 5.9 Q used from 28.2 Q (21%)**

Rapid Growth of Transportation Electrification

Electrification → Hi-Performance Low-Cost

Electrification of transportation proceeding at rapid pace – 60% YoY growth – BNEF mid-estimate ~ 125M EVs by 2040

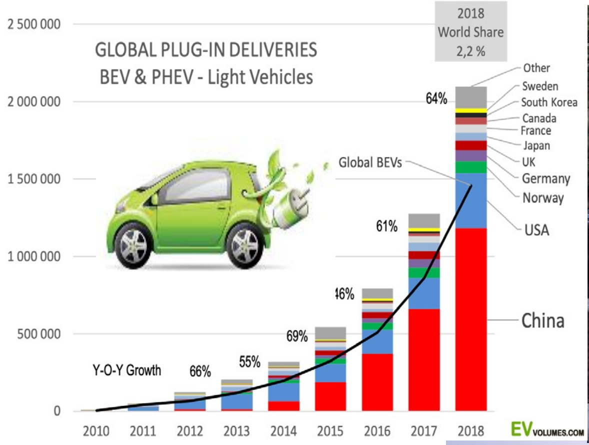
Low cost of manufacturing/ownership for EVs, buses, trucks and semis – suggest that this will be difficult to stop

Issue of equitable access to EVs & charging infrastructure also needs to be addressed for broad deployment to occur

Rapid growth of electrified transportation will stress a grid already under transformation – integrated approach is critical

- Without adequate cost-effective charging infrastructure, broad EV adoption will fail - economics, not range anxiety is key issue

- Related Issue: What happens if we build charging infrastructure for 125M EVs, and they don't come for many years?



Finding 5.8*: …. <u>peak load for large numbers of EVs with fast charging could be a very large fraction of peak U.S. generation.</u>

Scaling EVs and Impact

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Charging Requirements and Issues

Type	Requirement	Charging Issues
Level 1	120 volt AC 1.5 kW 4-6 mi/hour	Only opportunity or emergency charging
Level 2	240 volt AC 6-10 kW 25 – 40 mi/hour 6-10 hrs full charge	Require home/office garage 240 volt 30-50A service $1.5K-6K first cost
Level 3	DC Fast Charging 50-250 kW 150-1000 mi/hour 10-20 min charge time	Charging station needed Visibility to availability Critical to ensure scaling $100-200K per port
Fleet	DC Fast Charging 50-250 kW	Depot charging for Van/Bus Overhead access for buses
eSemis	DC Fast Charging 250 kW - 1.5 MW 100-750 mi/hour	Truck stops or service areas Complex electrical systems Challenging business model

Cost-effectively powering fast-charging infrastructure is critical for success of transportation electrification

Automotive companies are familiar with issues of design, supply chain and manufacturing – ensuring ubiquitous equitable charging infrastructure poses a new challenge that can derail progress

- By 2040, 125M EVs will consume ~125 TWHrs/yr, or 3% of US electricity generation – no issue over 20 years

- 125M EVs with Level 2 charging at 6 kW is 750GW peak load – coordinated charging will reduce this peak

- 10M EVs (8% of 2040 estimate) charging at 100 kW = 1000 GW, equals current US generation, worse with fast growth in e-semis

- 10 port DCFC station - 2.5 MW, low duty cycle, high demand charge

- 50 trucks need 50-75 MW, 6000 truck stops = 300 GW of new load

Over the next 10 years, most fast charging stations will be poorly utilized and will be challenged by grid access & business model

Bloomberg: Pure play DCFC operators cannot be commercially sustainable..

Intersection of Transportation & the Grid

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- EPRI Summer Meeting set a target of 50% carbon emissions by 2030 and 0% by 2050 – highly disruptive
- Utility sector is regulated and risk-averse with long planning cycles, change happening outside their control
- Centralized control of bulk system → decentralized IBR dominant system – how this will be controlled?
- Everyone is thinking in their own silos and moving fast, while assuming everyone else is standing still!!
- Complex system with strong interdependencies with adjacent areas – need flexible adaptive solutions
- Need to holistically address problems of sustainability, reliability, resiliency, affordability and life cycle cost

Distribution System Issues - Examples

- Multiple L2 chargers on one xfmr can reduce life from 30+ years to 3 years – no visibility to stressed devices
- Cannot coordinate with distributed DERs in real-time, capacity at desired locations may not be there

Bulk System Issues - Examples

- 50-75 MW truck stop or loading center will need new substation and sub-transmission – 10+ year cycle
- Peak/average demand for DCFC results in stress on grid, challenging with high DER, significant asset overbuild

Requires Holistic System Level Thinking

Viable business models for ubiquitous charging are a big issue – overbuild grid-edge generation and DERs for resiliency and grid services offer unique opportunity to serve transportation needs

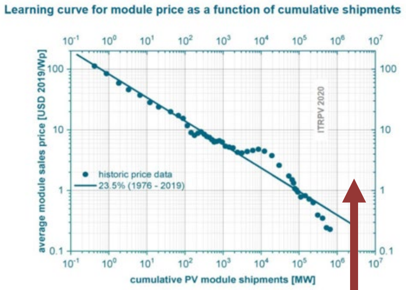
"Mitigating distribution transformer lifetime degradation caused by grid-enabled vehicle (GEV) charging", ECCE, IEEE, 2011

Rapid Uncontrolled Changes in Adjacent Areas

Increased DER Penetration at Grid Edge

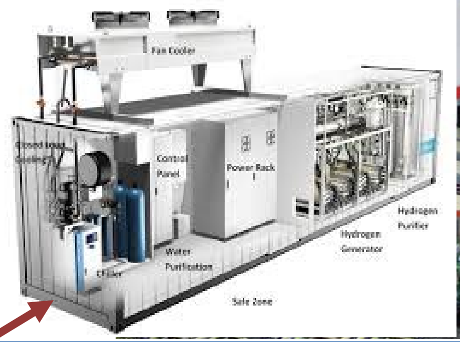
- PV/wind/storage dropping continuously, $10-20/MWHr in 2 years
- Energy storage projected to <$100/kWHr, makes RE dispatchable
- **Not under utility control**





Electrification of Everything

- EVs and e-trucks accelerating at 60% YoY growth – ~125M by 2040
- Hydrogen, e-fuels and Direct Air Capture will be fast growing sectors
- Potential to electrify major industry sectors
- **Not under utility control**




Grid Under Stress

- Centralized control challenged by rapid DER growth
- Grid processes move slowly (10-20 years), do not respond rapidly
- Load growth estimates drive investments in grid infrastructure

Most change is outside utility control

Grid needs to be flexible and adaptive to respond to new realities and rapid changes – today it is NOT!

Increased Resiliency at Grid Edge

- Hurricanes, fires and cold-snaps can lead to long outages at grid edge
- Cyber-physical attacks & bulk system failures can impact large service areas
- Low-cost DG serves local loads and provides grid services – grid defection?
- **Not fully under utility control**


[1] "Experts assess damage after first cyberattack on U.S. grid", E&E NEWS, available at: https://www.eenews.net/stories/1060281821

Flexible Grid Resources – Multiple Value Streams

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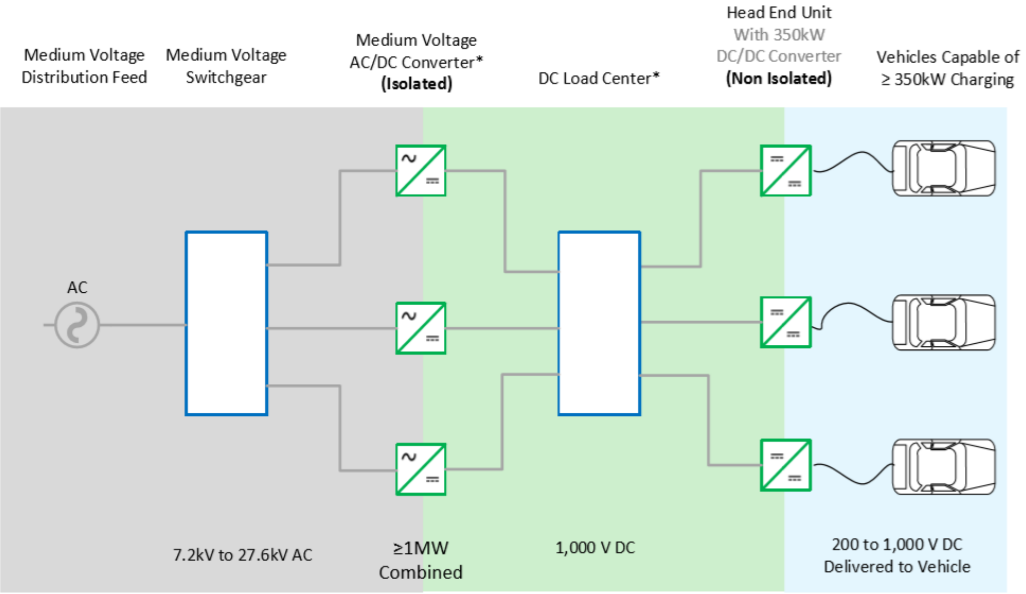
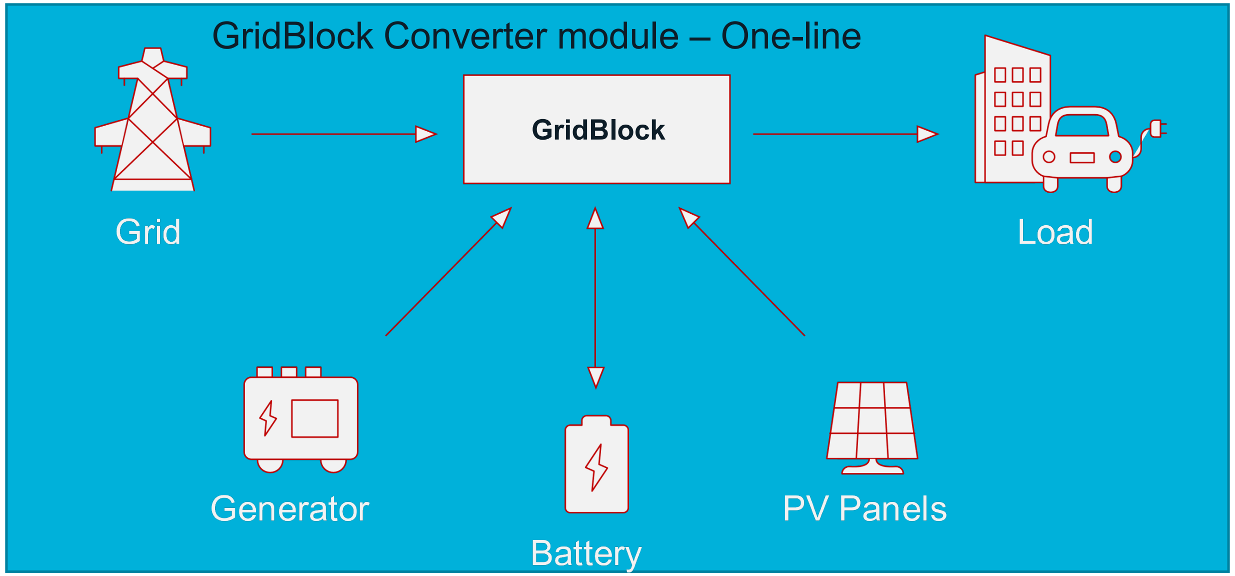
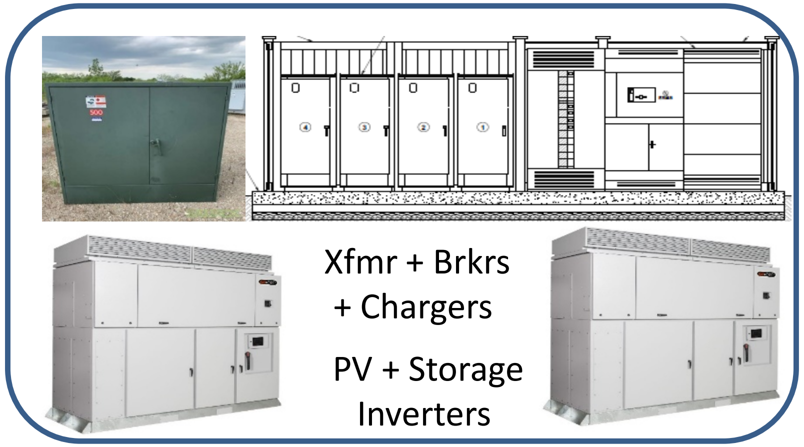
- Future grid needs tremendous new capability at the grid edge, including microgrids and DERs for resiliency, energy storage for reducing grid stress & to serve data centers, transportation & new industry loads
- This new infrastructure is being built in isolation of other needs (e.g. EVs) – integration of this functionality is key
- Use of grid-connected EVs for resiliency (V2G and V2H) and grid support could pay for charging infrastructure
- DC as a Service has been proposed by the utilities, but has not been technically or economically viable
- Flexible Energy Router by Grid Block allows integration of PV, storage, load regulation and multiple EV charging in one integrated device – enhances value and functionality



DCasaS architecture for DCFC (EPRI)

Flexible Energy Router – www.gridblock.com





500 kVA GB 13/20 kV AC

Licensed from GT-CDE to GridBlock

Conclusions

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- There is rapid global growth in electrification of transportation – driven by lower cost to build and operate vehicles, and by higher performance
- Availability of ubiquitous fast-charging infrastructure is a critical enabler for wide scale deployment – but cost may not be recoverable, especially in the early years
- Rapid disruptive change in the highly regulated utility sector will compound the difficulty of ensuring that charging is available where and when it is needed
- Holistically solving sustainability, reliability & resiliency issues at the grid edge provides a unique opportunity to create a new flexible electricity infrastructure

It is difficult to make forecasts, especially about the future – *Danish Proverb*

The system is on the cusp of fundamental transformation, **many elements of which are not under industry control**.

EV manufacturer representative's comment to: **What happens when an irresistible force** (e.g., EV mfr) **meets an immovable object** (e.g., utility) – **We Go Around It!! We Don't Want to Run EVs with Coal!!**

IEEE Empower a Billion Lives - II

Energy Access needs new fresh thinking – holistic solutions, high-impact, scalable and lower cost

Key Challenge:

- 3 billion live in extreme energy poverty, ~1 billion live off-grid (only 15 million have Tier 2 (>200Wh/day)
- Solving energy access with today's solutions will result in 3.7 Gtons of CO_2 emission – not OK
- Existing assumptions relying on grid extension, SHS & microgrids are not working out as expected

Challenges:

- **Don't need energy – need livelihood and services**
- Factors - low purchasing power, aspirations, neighbors
- Low-tech users, interoperability, tech-obsolescence
- Last-mile sale, commission and maintain challenges
- Scalable - start small & grow as needed
- Need flexible and sustainable business models.

IEEE Empower a Billion Lives (EBL) is an interdisciplinary global competition to develop/demonstrate innovative solutions to energy poverty & resiliency.

Teams are invited from across the globe and from all walks of life, including companies, research organizations, entrepreneurial startups, as well as student teams from colleges and universities.

Participating in EBL-II is easy. Log on to www.empowerabillionlives.org to register your team. Review the requirements and submit a brief 3-page Concept Paper in the required format by **Nov 30, 2021.**

Building on the success of Empower a Billion Lives – I (EBL-I), IEEE PELS has launched EBL-II. EBL-I was held in 2019 and attracted over 450 teams from 70 countries. Over $500,000 was awarded to teams in prizes and support. Grand prize of $100,000 was won by Team SoULS from IIT Bombay, India