DLT and IoT as Plasticity and Flexibility Means for the Smart Electrical Grid

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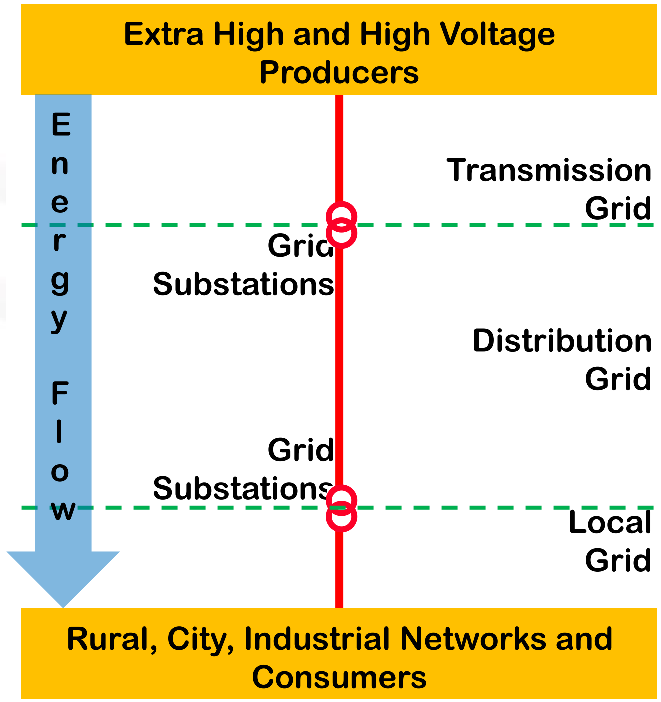
Introduction

- Long-standing indicators that the traditional electricity infrastructure needs to be re-engineered and its management system rethought
  - Long transmission lines, lossful, susceptible to faults, prone to cyber-physical attacks
  - Carbon footprint, environmental impact, nuclear residues (coal, oil and gas, hydro, and nuclear power plants)
  - Impact on indigenous and forest people, and landscape
  - Damage to archaeological estates
  - Climate change pressure
  - Distributed energy resources (DERs):
    - Distributed generators: renewable solar/wind power generation, electric vehicles, datacenters and HVAC (Heating, ventilation, and air conditioning) devices
    - Energy storage devices/systems

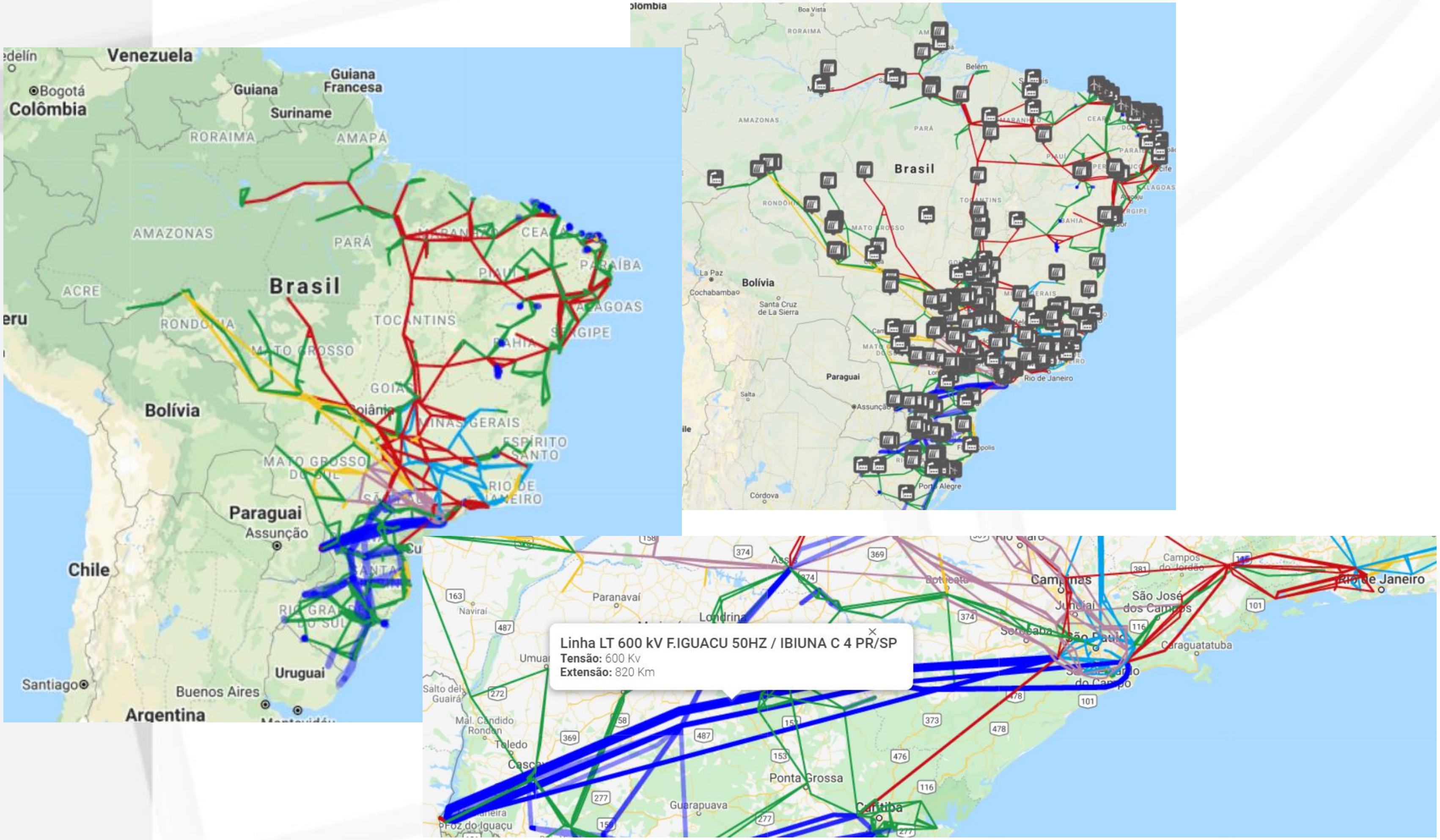
Introduction

- Towards a sustainable electrical system yielding availability with controlled costs
  - Distributed energy resources (DERs): distributed generators (DGs) and storage devices/systems (ESs)
  - Prosumers: energy producers that can easily become consumers and conversely
  - New operation dynamics
    - Reconfigurable energy transmission
    - Automated DER command/response
    - Active electricity management
    - Balance of fluctuating power generation
  - Possible direct energy commercialization among prosumers
  - Smart grid, integrated and intelligent energy system, energy internet, decentralized/transactive energy marketplace

Traditional Energy Grid (Very Simplified)



Traditional Energy Grid (Not So Simple)



http://www.ons.org.br/paginas/sobre-o-sin/mapas (Brazilian National Energy System Operator – ONS)

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Itaipu Hydro-Electric Power Plant

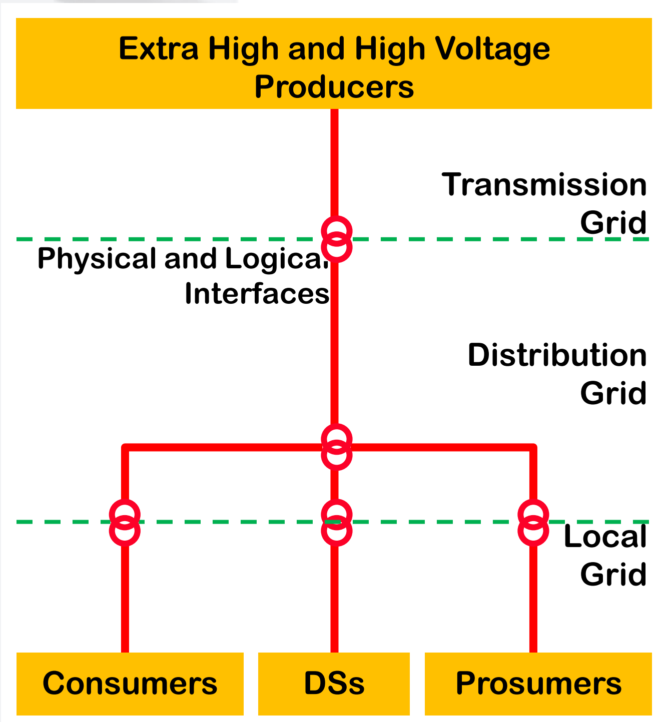
Paraná River

Iguassu Falls

Brazilian National Electric System Operator (ONS):
Possibility of a power deficit at the end of the year 2021, which would force the country to import 2,000 MW of power per day, equivalent to the daily production of two nuclear plants (Angra 1 and 2).

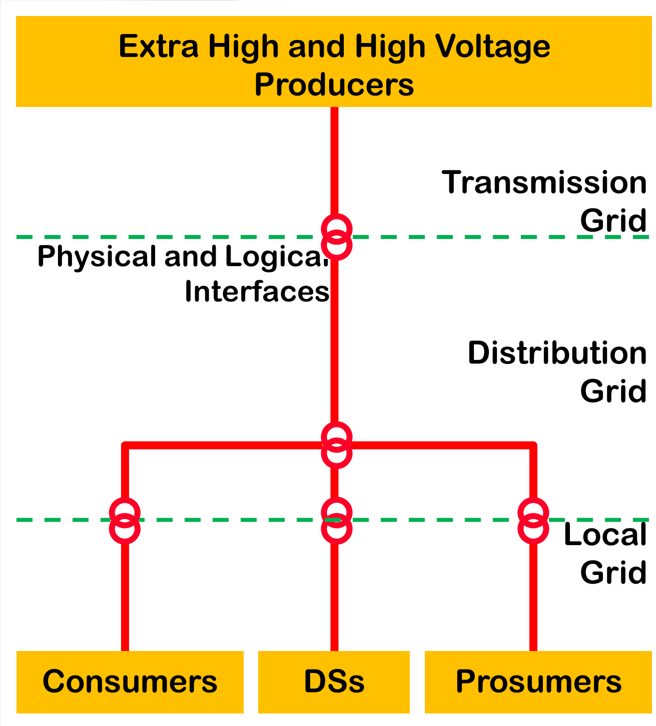
https://g1.globo.com/pr/oeste-sudoeste/noticia/2020/04/08/estiagem-transforma-paisagem-do-rio-parana-responsavel-pela-energia-gerada-em-itaipu-veja-fotos.ghtml
https://g1.globo.com/pr/oeste-sudoeste/noticia/2021/05/15/baixa-vazao-do-rio-iguacu-impacta-paisagem-das-cataratas-fotos.ghtml
https://g1.globo.com/economia/noticia/2021/07/23/ons-preve-dificuldade-de-atender-demanda-de-energia-em-novembro-e-pais-pode-ter-que-aumentar-importacao.ghtml

Smart Energy Grid (Very Simplified)



- Prosumers: renewable solar/wind power generation and energy storage devices
- Peer-to-peer interactions/relationships
- Simultaneous and parallel energy and information flows
  - metering, (self-)configuration, commercialization, security, billing, auditing
- Relevant motivations to associate DLT, for data and transaction preservation

Smart Energy Grid (Very Simplified)



- M2M, IoT operations command and control for responding to configuration plasticity and operational flexibility
- The IoT as backbone for fully distributed cybersecurity measures*: fault management, intrusion/tampering detection, recovery to safe states, self-healing
- Metering data mining** and ML-based demand forecast, contract negotiations, operational decisions and scheduling
- Relevant motivations to associate (possibly multiple) DLTs, for data and transaction preservation*** and support to other cybersecurity measures

* D. A. da Silva, R. T. de Sousa, R. O. Albuquerque, A. L. S. Orozco, L. J. G. Villalba. IoT-based security service for the documentary chain of custody. Sustainable Cities and Society, Volume 71, 2021, 102940,ISSN 2210-6707,https://doi.org/10.1016/j.scs.2021.102940.
** L. C. de Almeida, R. T. de Sousa, A. S. Nery, D. A. da Silva Filho, E. D. Canedo and R. R. Nunes, "Design and Evaluation of an SNMP-based Energy Consumption Monitoring System for Electrical Grids," 2019 Workshop on Communication Networks and Power Systems (WCNPS), 2019, pp. 1-6, doi: 10.1109/WCNPS.2019.8896232.
*** Pinheiro, A.; Canedo, E.D.; Albuquerque, R.d.O.; de Sousa Júnior, R.T. Validation of Architecture Effectiveness for the Continuous Monitoring of File Integrity Stored in the Cloud Using Blockchain and Smart Contracts. Sensors 2021, 21, 4440. https://doi.org/10.3390/s21134440

Actors in a Smart Grid and Transactive Marketplace

- Grid-Centric Actors
  - Power Generators (as specialized large central power generation)
  - Transmission Systems Operators (as specialized long haul power transfer)
  - Distribution Network Operators / Distribution System Operators
  - Load Serving Entities/Utilities (as governing entities and primary energy generators and/or distributors)
- Grid-Edge Actors
  - Consumers (residential and industrial end-users/loads)
  - Prosumers (consumers with the partial or full ability to self-power)
  - Aggregators (of grid-edge participant assets)
- Market Participants and Monitors
  - Bi-lateral traders
  - Governing bodies
  - Auditors
  - Market forecasters

IEEE Blockchain Transactive Energy (BCTE) - A Bridge to a Democratized Energy Marketplace. IEEE Position & Vision Statement Paper v.3.0 Release Date – 25 May 2021. https://blockchain.ieee.org/verticals/transactive-energy.

Perspectives

- Towards a “software defined” smart electrical grid
- Data ownership/sovereignty as key factors
- Machine Learning in network control and operation, and energy trading*, require reliable mechanisms to secure different players assets (data, ML models) and protect utilization/compensation
    - Orchestrated control and coordination mechanisms using advanced monitoring, control and automation schemes
    - DERs as active peers in system-wide and local coordination tasks
    - Operational decisions based on data captured in transactions between participants
- Interoperability issues in IoT, DLTs/Blockchain
- Still emerging topics needing scientific advancement, prototyping, test cases, standards, best practices, governance

* Junior, J.M.; da Costa, J.P.C.L.; Garcez, C.C.R.; de Oliveira Albuquerque, R.; Arancibia, A.; Weichenberger, L.; de Mendonça, F.L.L.; Galdo, G.d.; de Sousa Jr., R.T. Data Security and Trading Framework for Smart Grids in Neighborhood Area Networks. Sensors 2020, 20, 1337. https://doi.org/10.3390/s20051337

IEEE Blockchain Initiative (BLK)

- BLK Effective January 1, 2018, as the hub for all IEEE Blockchain projects and activities
- Blockchain Local Groups
  - Formed worldwide to bring together experts and provide networking opportunities for attendees working on blockchain projects
  - Example: IEEE North-Central Brazil Blockchain Group

https://blockchain.ieee.org/about.

IEEE Blockchain Initiative (BLK)

- Published Standards
  - 2140.1-2020 - IEEE Standard for General Requirements for Cryptocurrency Exchanges
  - 2140.5-2020 - IEEE Standard for a Custodian Framework of Cryptocurrency
  - 2142.1-2021 - IEEE Approved Draft Recommended Practice for E-Invoice Business Using Blockchain Technology
  - 2143.1-2020 - IEEE Standard for General Process of Cryptocurrency Payment
  - 2144.1-2020 - IEEE Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management
  - 2418.2-2020 - IEEE Approved Draft Standard Data Format for Blockchain Systems
- Standards Under Development
  - P2418.1 - Standard for the Framework of Blockchain Use in Internet of Things (IoT)
  - P2418.5 - Standard for Blockchain in Energy

https://blockchain.ieee.org/standards.

Blockchain-enabled transacted energy (BCTE)

- Technology that has the potential to create an open, trusted, and transparent energy marketplace
- Important to society
  - Has the potential to lower the cost of renewable energy investments
  - improve our ability to combat climate change
  - Encourage more participants into the renewables market
  - Increase the amount of innovation through transparent standards and access to the grid

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Conclusion (Aligned to BCTE)

- To fulfil the potential of Blockchain, IoT, AI/ML, Cybersec to create a smart energy grid
  - Architecture Plan and Blockchain-based platforms design
  - Standards coordination and certification services
  - Solutions and Applications: Use Case development and Demonstration
  - Research, Education, Outreach

IEEE Blockchain Transactive Energy (BCTE) - A Bridge to a Democratized Energy Marketplace. IEEE Position & Vision Statement Paper v.3.0 Release Date – 25 May 2021. https://blockchain.ieee.org/verticals/transactive-energy.

Iguassu Falls (2007)

https://commons.wikimedia.org/wiki/File:Iguazu_D%C3%A9cembre_2007_-_Panorama_7.jpg (Creative Commons CC0 License)