Architectural and Systems Approach Imperatives for Digital Transformation

Unified Digital Infrastructure Reference Architecture

for

Electricity Utilities

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The World We Live In

The EVOLUTION we NEVER EXPECTED

It's a small world. It's also an increasingly hot, crowded, and contentious one.

The combined effect of climate change and society's impact on the earth is intensifying struggles over natural resources while also threatening our infrastructure, food systems and quality of life.

"Nature no longer runs the Earth, we do"

Climate is not politically strong enough to fight Carbon by itself.

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Where are we (globally)?...Struggling to do enough

"Someone's gotta do something!" (someone else, ideally!)

Analogy: I want to lose weight... But don't want to exercise or change my diet**

(** there's no Ozempic or magic pill for climate change)

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Myth: We're all in this together

Climate Change Misconception:

"We're all facing the same storm"

Climate Change Reality:

Same storm, but different boats

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The fundamental problem:

We are trying to fix a stock problem (accumulation of carbon) with *future* flow instruments

Think of a bathtub about to overflow…the last cup may tip it over, but the problem wasn't that cup

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Learn from our past mistakes – History always repeats itself…

Past failures to consider environmental consequences early have been costly:

- Semiconductor Industry (Metals, Solvents)
- Synthetic Chemicals (PCB, DDT, Freon)
- Applications of Natural Compounds (Chlorine, Asbestos)
- Transportation, Energy (Air Pollution, Global Warming, Nuclear Wastes)

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Future of Life… on EARTH…

It has been observed that the technologies developed by human beings in the last 2-3 centuries have had a major impact on the earth's climate and our nature's equilibrium

Some believe that we have reached a point of no return. This can have a huge impact on *life on earth*, especially on the *human species*.

However, while technology has been responsible for most of it, technology also seems to have a solution for it.

It's increasingly clear that today's environmental conditions are not sustainable. Over the past few decades, we have made huge progress fighting disease, poverty, and illiteracy.

Now we must apply that same ingenuity to the problem of global warming and other consequences of human activity.

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CONTEXT…

Disruption is everywhere and the future is uncertain — no one knows what the world will look like even a decade from now. As we head into future, we are surrounded by disruptive innovation

As we look to the years & decades ahead, tech-disruption will be driven as much by the methods and systems as it is by the devices, we associate with tech disruption.

The pace of innovation is incredibly fast, with new things getting discovered daily. The future trends in technology are very diverse, very intertwined, and very promising…

There are several developments that have and will continue to shape business strategies. From **Automation** to **Sustainability**, organizations are adapting to a whole new wave of consumer preferences.

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Electricity – The Golden Thread…

- Electricity is the cornerstone for economic development and social wellbeing, serving as the golden thread across all SDGs.
- The Electricity Infrastructure is undergoing a paradigm shift in wake of changing societal imperatives and onslaught of disruptive digital technologies.
- The Electricity Utilities are also undergoing a technological metamorphosis to cope up with global imperatives like Climate Crisis, Net Zero, Decarbonization, Energy Security, Renewable Energies, Smart Grids, Energy Efficiency, Electric Mobility etc. demanding a fresh thinking and approach to transform the electricity infrastructure across the globe into a sustainable and resilient lifeline of the society.

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Shifting paradigms…

From a Centralized, One-Way, Passive Energy System,

to a Distributed, Multi-Way, Active, and Predictive, Energy System

Today

Emerging

At stake: *Build a cross-sector "System of systems" value for future energy systems, based on a harmonized data landscape*

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The Imperative…

- The complexity of Distribution utility architecture has also exponentially grown to meet new technical requirements and consumer expectations about Automation to Sustainability demanding a fresh approach in design of utility infrastructure and business processes.
- It is imperative to apply system thinking to this evolving utility paradigm and developing a unified digital architecture for sustainable digital transformation of distribution utilities.
- It should facilitate a seamless integration of all the business processes with diverse technical systems/ solutions coming from different energy sectors and relevant ecosystems like Cities, Buildings and Homes in resilient & cyber secure manner.

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Digital Distribution Utilities

- The hugely complex nature of a utility infrastructure projects creates a very real risk that oversights in the planning phase can cause the sub-optimization of sub-systems, which can severely impair the overall success of the project.
- Designing the future proof sustainable digital distribution utilities needs a comprehensive and granular architectural and systems approach.
- The question we need to ask ourselves is, are we ready to embrace disruptive innovation to change the way utilities operate today.

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The Digital Transformation

The society, the business, the infrastructure, the services and all other aspects of the civilization on the planet Earth are going through a paradigm shift in the wake of technological advancements, especially in the field of ICT

All the ecosystems, be it Smart Cities, Smart Grid, Smart Buildings or Smart Factories now find themselves making three classes of transformations:

- Improvement of Infrastructure – to make it resilient & sustainable…
- Addition of the Digital Layer- which is the essence of the *smart paradigm*; and
- Business Process Transformation - necessary to capitalize on the investments in smart technology.

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The genesis of Digital Transformation

In digital transformation in any paradigm, domain or ecosystem

- ‘Sustainability is the *True* Destination’
- ‘Resilience is the *Core* Characteristic’
- ‘Smart is *merely* the Accelerator’

Standards are the Chromosomes of Digital Infrastructure

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Digital Transformation Constituents

- Information Technologies
- Operational Technologies

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Digital Transformation Constituents

- Information Technologies
- Operational Technologies
- Network Technologies

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Digital Transformation Constituents

- Information Technologies
- Operational Technologies
- Network Technologies
- IoT Technologies

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Digital Transformation Constituents

- Information Technologies
- Operational Technologies
- Network Technologies
- IoT Technologies
- Artificial Intelligence

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Digital Transformation Constituents

- Information Technologies
- Operational Technologies
- Network Technologies
- IoT Technologies
- Artificial Intelligence
- SUSTAINABILITY ???

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Digital Transformation

is not a technology,

it's a complex paradigm

with domain-specific implications

We are living in an ephemeral world

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Disruptive Technologies on the Radar

- Artificial Intelligence/ Machine Learning
- Blockchain
- Internet of Things/ Everything
- Big Data
- 5G/6G
- AR/VR/XR
- Web 3.0
- Robotics & Drones
- Data Centers
- Digital Twin
- Metaverse….

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5G Foundation

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Future Architecture

One Network – Diverse Use Cases

A common network platform with Dynamic and Secure Network Slices

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5G – Only the Beginning…
The Carl Benz Automobile for the Internet

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Projecting a Path- towards Universal Autonomy

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The moot Question

Are our Utilities geared up to embrace and leverage these innovative disruptive digital technologies

Typical view of Distribution Utility…

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Typical view of Transmission Utility…

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Technical Solutions in Utilities

- Supervisory Control and Data Acquisition (SCADA) and Distribution Management Systems
- Distribution Automation
- Substation Automation
- Advanced Metering Infrastructure (AMI) or Smart Metering
- Geographical Information System (GIS)
- Distribution Transformer Monitoring System
- Smart Street Lights (with noise and pollution sensors)
- Energy Storage
- Electric Vehicles
- Distributed Energy Resources and Renewable Energy Integration
- Enterprise IT Systems

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Enterprise/Business Process Solutions in Utilities

- Application Integration
- Peak Load Management
- Power Quality Management
- Outage Management System
- Mobile Crew Management System
- Customer Care Centre
- Customer Engagement
- Social Media
- Cyber Security
- Analytics
- Smart Homes, Buildings Energy Management Systems /Home Energy Management Systems (BEMS/HEMS)

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Functional Architecture

Customer Segment

- Disaggregation
- community energy manager
- Incentive price calculation
- Smart Home Gateway
- Smart Device Control using Rule Engine
- Voice control

API MGMT

Demand

- Dashboard (operational view)
- Frequency Stabilizing
- Voltage Stabilizing
- Congestion management

Indicators

- Balancing Group Manager
- TSO (System+ Grid)
- DSO (Grid)
- Price arbitrage Aggregator / retailer

Enablers

- Energy optimizer (Intra Day, Spot, Forward)
- Load Forecasting
- Supply & Demand Matching
- Manageability
- Incentive price calculation

Supply

- GIS
- DMS
- DERMS

Indicators

- Location
- Time
- Telemetry

Actors: Prosumer, TSO/DSO, Utility, Aggregator, Industry, Appliances, Ecarss

Service Orchestration

- CRM
- EMS
- OMS
- MDMS
- EDM
- ERP
- Billing((I/SU)

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DESIGNING A SUSTAINABLE & RESILIENT FUTURE

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Growing Complexity with P2P integrations & new use cases

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AMI – Adaptation Architecture

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AMI – Adaptation Architecture

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E & RESILIENT FUTURE

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AMI – Adaptation Architecture

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AMI – Adaptation Architecture

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High Level Service Delivery Architecture…

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High Level Service Delivery Architecture…

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High Level Service Delivery Architecture…

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AMI Systems are complex

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AMI Reference Architecture…

PREBUILT DATA PIPELINES
(INTEROPERABLE, CIM COMPLIANT)

AI-FIRST APPROACH
(FASTER AVAILABILITY OF DATA FOR BUSINESS USE)

READY FOR "BEYOND THE METER" STORY
(GEN-AI FABRIC, PREBUILT AI USE CASES)

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Current Utility Solutions work in “Silos”

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Common Understanding is a Big Deal

- To map out the scope of the utility
- To clarify the universal values of Utility
- To reach consensus on the core capabilities of Utility
- To indicate commonalities between different utility systems
- To provide the reference for integration & interoperability
- To smooth the collaboration of SDOs and other utility stakeholders
- ……

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The big challenge:

Building a smart, sustainable, secure n resilient Utility is a big challenge

"The same way of thinking that got you into trouble won't get you out of it."

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Systems Approach: Holism

Aristotle (300 B.C.)

"The Whole is Greater than the Sum of its Parts"

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System and Systems Approach

- System: *A group of interacting, interrelated, or interdependent elements forming a purposeful 'WHOLE' of a complexity that requires specific structures and work methods in order to support applications and services relevant to the stakeholders.*
- Systems Approach: *A holistic, iterative, discovery process that helps first defining the right problem in complex situations and then in finding elegant, well-designed and working solutions. It incorporates not only engineering, but also logical human and social aspects.*

Systems Approach demystified…

- Identify and understand the relationships between the potential problems and opportunities in a real-world situation.
- Gain a thorough understanding of the problem and describe a selected problem or opportunity in the context of its wider system and its environment.
- Synthesize viable system solutions to a selected problem or opportunity situation.
- Analyze and trade off between alternative solutions for a given time/cost/quality version of the problem.
- Measure and provide evidence of correct implementation and integration.
- Deploy, sustain, and apply a solution to help solve the problem (or exploit the opportunity).
- All of the above, are considered within a life cycle framework which may need concurrent, recursive and iterative applications of some or all of the systems approach.

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Systems Approach imperatives

- The multiplicity of technologies and their convergence in many new and emerging markets, however, particularly those involving large-scale infrastructure demand a top-down approach to standardization starting at the system or system-architecture rather than at the product level.
- Therefore, the systemic approach in standardization work can define and strengthen the systems approach throughout the technical community to ensure that highly complex market sectors can be properly addressed and supported.
- It promotes an increased co-operation with many other standards-developing organizations and relevant non-standards bodies needed on an international level.
- Further, standardization needs to be inclusive, top down and bottom up; a new hybrid model with a comprehensive approach is needed.

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SYSTEMS APPROACH PROCESS FLOW

Sys Market Analysis

Analyze and identify the the market/industry trends and needs?

Sys Stakeholders

Who are the key stakeholders of the system and what are their needs and objectives?

Sys Use Cases

What are the different use cases for the system and how do they interact with the system?

Sys Architecting

What is the reference architecture of the system and its boundaries?

Sys Standards

What are the existing standards and SDOs that pertain to this system?

Sys Gaps

What are the standards that are missing in the system?

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Smart Grid Conceptual Model

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Evolved Smart Grid Conceptual Model

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Smart Grid Architecture Model （SGAM）

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Enterprise Architecture

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Levels of Architecting

A few scenario reference architectures may be derived from the reference architecture
AAL: personal telehealth, home
Smart Cities: megalopolis, city, village, island

Problem space

Solution space

A 3 Step approach for Systems of Systems Architecture Design

Utilities comprise of several teams with intertwined processes to manage their assets, operations, and customers. The IEC SGAM framework provides a robust foundation to analyze relationships between multitude of utility domains, their information exchanges, and interoperability aspects.

Figure 4 – Enterprise Architecture (EA)

The multiplicity of technologies and their convergence in many new and emerging markets, however, particularly those involving large-scale infrastructure demand a top-down approach to standardization starting at the system or system-architecture rather than at the product level.

Figure 3 – The SGAM Framework

Enterprise Architecture is the definition and description of an enterprise from the combined viewpoints of its strategy, business structure, business processes, information systems and technology, both from present standpoint, and how to support future needs.

Figure 5 – Levels of Architecting

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Strategy Framework for Unified Digital Infrastructure

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Utility ICT Architecture - Simplified View

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Seven Layers of Information Flow

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Mapping the Digital Infrastructure Philosophy to High-level Utility Solutions

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Mapping the Digital Infrastructure Philosophy to High-level Utility Solutions

- Advanced Metering Infrastructure
- SCADA DMS
- Distributed Energy Resources
- EV Charging Infrastructure

The application needs **change** (as part of the users' requirement) to derive value from different utility solutions, **but** the ICT and IoT **backbone remains (or should remain) the SAME !!!**

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Interoperability Imperatives

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The way forward: Unified Architecture

Horizontally and Vertically Scalable

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Unified Architecture…

- Mapping the Information Flow stack in the digital infrastructure in any technical solution of the utilities shows that different utility applications need changes as part of the solution requirements to derive value from different infrastructure pillars, but the ICT (and IoT) backbone remains the same.
- This implies that across diverse infrastructures and/or technical solutions utilities can leverage one common ICT Backbone (Digital Infrastructure).
- This leads to the evolution of a new Architecture Model for the Unified ICT Architecture of the Digital Infrastructure aptly called the Classic Saucer Champagne Glass Architecture Model developed initially during the Pre-standardization study in 2017 by Smart Infrastructure Standards Committee in Bureau of Indian Standards, India.

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Utility Applications & Consumer Services

UTILITY DATA RESERVIOR

Utility Middleware

Common Service Layer

Standardized GATEWAYS

Unified Last Mile Communication

Sensors, Controllers & Field Devices

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Classic Saucer Champagne Glass Architecture Model

The evolved Comprehensively Unified ICT Architecture can be modelled as a "Classic Saucer Champagne Glass" with a wide Flat Bottom Base depicting the multitude of Field Devices & sensors etc. The Saucer Shaped Bowl on the Top depicting being filled with an ever-increasing spectrum of Utility Applications and Consumers' Services.

The Long Stem depicts all the Common Layers viz.: the Unified Last Mile Communication, Common Standardized Gateways (application or Vertical Agnostic), Common Service layer representing the Common Service Functions in the Gateways, as well as, in the Cloud… and the Smart Utility Middleware & Utility Data Reservoir in the Cloud.

It is the "Long Stem" of the "Champagne Glass Model" instead of the Short & Narrow Neck in the "Hourglass Model" that brings the comprehensive harmonization, standardization & interoperability in the Architecture leading to optimization in operational efficiency & Life Cycle Cost of the ICT Infrastructure in any Utility.

This Architecture Model, beyond reducing significantly, the CAPEX, OPEX & Carbon Footprint of the Digital Infrastructure, enables a unified & well architected Infrastructure that can be easily designed to be comprehensively Resilient & Cyber Secure.

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The Unified Last Mile Communication Protocol Stack Reference Architecture

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ULMCPS – Application Layer

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IoT & OT Confluence…

It is evident that there is Glass Wall Barrier between the Communication Protocols & Standards for IoT applications and that for Infrastructure & Industrial popularly called OT applications. In spite of evident appreciation of strengths and weaknesses of both classes of standards, there has been NO initiative by any Global SDO or Industry Consortia.

This exercise is an effort in this direction with intent to break the Glass Wall Barrier and homogenize these Two siloed paradigms comprehensively by developing a Unified Last Mile Communication Protocol Stack Architecture leveraging the best of both the worlds and developing a Communication Technologies agnostic robust Stack Architecture that shall enable ubiquitous Data sharing seamless across domains, use cases and applications.

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Intended Outcomes / Changes / Benefits

To meet the vision of "Sustainable Digital Transformation of the Urban Landscape" in India, Bureau of Indian Standards (the National Standards Body of India) constituted a Sectional Committee LITD 28 on Smart Infrastructure in 2017 based on learnings and recommendations of the Pre-standardization Study Report - Technical Requirements Analysis of Unified, Secure & Resilient ICT Framework for Smart Infrastructure. This Committee is developing a Series of System Standards (IS 18000 to IS 18100) to address the gaps and challenges in the Smart Cities' Digital Infrastructure (including Critical/Civic Infrastructure) domain, Operations & Governance. First Ten Standards have already been released in December 2020 and June 2021:

- ⇨ IS 18000:2020 – Unified Digital Infrastructure – ICT Reference Architecture (UDI-ICT RA)
- ⇨ IS 18002-1: 2021 – Unified Digital Infrastructure — Data Layer Reference Architecture
- ⇨ IS 18003-1: 2020 – Unified Data Exchange Part 1 Architecture
- ⇨ IS 18003-2: 2021 – Unified Data Exchange - API Specifications
- ⇨ IS 18004-1: 2021 – Unified Digital Infrastructure - IoT System Reference Architecture
- ⇨ IS 18006-1: 2021 – Municipal Governance Reference Architecture
- ⇨ IS 18006-3-1: 2021 – Municipal Governance – Property Tax – Taxonomy
- ⇨ IS 18008-1: 2021 – Smart Cities GIS Reference Architecture
- ⇨ IS 18010-1: 2020 – Unified Digital Infrastructure – Unified Last Mile Communication Protocol Stack Part 1 Reference Architecture (UDI – ULMCPS – RA).
- ⇨ IS 18010-5-1: 2020 - Unified Digital Infrastructure – Unified Last Mile Communication Protocol Stack Part 5 Network Access Layer (IEEE 802.15.4) Section 1 Specification

The BIS Standards referred above are available in the following link: https://standardsbis.bsbedge.com/

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The way forward…

- The upper layer in Simplified Unified Architecture of Digital Utility is an explicit confirmation that Digital Utilities are not only about Information and Communication Technologies (ICT) and all various views must be considered and reviewed.
- ICT is mandatory but not sufficient to achieve sustainable, resilient, and cyber secure utilities
- The Architectural & Systems Approach proposed, if adopted by the Electricity Utilities including but NOT limited to Distribution Utilities, can drive comprehensive De-carbonization and Digitalization together, meeting current and future socio-techno-economic imperatives of the ecosystem stakeholders.
- Next steps are to develop the discussed 'Unified Digital Utility Reference Architecture' (UDURA) followed by a Granular 'Unified Digital Distribution Utilities Reference Architecture' (UDDURA) with 'Reference Solutions Architectures' of all its system components.
- The key feature of the UDURA needs to be a built-in capability to combine similarity and diversity. In other words, each utility may start from a standard solution and decompose it into smaller elements to adjust them to utility's particular needs. All of these can be done without compromising the quality characteristics of the solution.

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Neither an easy, nor a linear set of requirements but a complex and iterative process that requires careful consideration and cooperation with all the diverse stakeholders of the ecosystem

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Resilience....

Let us not pray to be sheltered from dangers but to be fearless when facing them

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Key Takeaways

Need to develop a Comprehensive approach to

- Sustainability
- Security & Resilience
- Leveraging Disruptive Technologies
- Ethically Aligned Designs

And adopt Systems approach to Design & Standardization in complex paradigms…

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Key takeaway from my Technology journey:

We humans need to radically change our relationship, not just with the planet, but with the objects with which we fill our lives.

We need to change how we think about technology and innovation.

Rather than allowing technological advancement to steer our narratives, innovation and technology should help us build bridges between the worlds we inhabit now and the ones we imagine for tomorrow.

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Thank you!

For a Sustainable & Resilient Future

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RACE TO ZERO

RACE TO RESILIENCE

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About me… N. KISHOR NARANG

Technology Philanthropist, Ethicist, Innovation, Standardization & Sustainability Evangelist…

Technology Advisor, Mentor & Design Strategist & Architect in Electrical, Electronics & ICT; running an Independent Design House – NARNIX since 1981

- Over 47 years of professional experience in education, research, design and advisory .
- Over 36 years of hardcore Research and Design Development Experience in Solutions, Systems, Products - Hardware, Software & Firmware (Embedded Software) in fields of Industrial, Power, IT, Telecom, Medical, Automotive, Aerospace, Defense, Energy and Environment. Over 10 years of Strategic Advisory Experience to different segments of business & industry.
- Over 500 Research & Design Mentees in the Electronics & ICT Ecosystems.
- **Mentoring many Deep Tech & Disruptive Tech Startups.**
- Leading & contributing to multiple National & Global Standardization Initiatives at BIS, Niti Aayog, TSDSI, IEC, ISO, ITU, IEEE etc….
- For the last 15 years, been deeply involved in standardization in the electrical, electronics, communications, information technology, digital infrastructure and cyber security domains with a focus on identifying gaps in standards to bring harmonization through system standards and standardized interfaces to ensure end-to-end Interoperability.
- **National Standards (INDIA) based on 10 years of Pre-Standardization Research Published Recently (December 2020) -**
  - Unified Digital Infrastructure ICT Reference Architecture – IS 18000:2020.
  - Unified Last Mile Communication Protocol Stack Reference Architecture – IS 18010:2020.

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- **Founding Chairman of the Smart Infrastructure Sectional Committee LITD 28 in BIS** (20 + standards on Unified Digital Infrastructure already published).
- **Vice Chair-Strategy, and Project Leader of two international standards in IEC SyC Smart Cities** – SCRAM: Smart Cities Reference Architecture Methodology IEC 63188 (published in September 2022) and SCRA: Smart Cities Reference Architecture IEC 63205 being developed jointly with ISO TC 268 & ITU-T SG 20.
- **Member IEEE SA Standards Board**
- **Chair, IEEE SA Working Group P2784 – Smart Cities Technology Framework.**
- Vice Chair, IEEE SA Working Group P 2872 - Standard for Interoperable and Secure Wireless Local Area Network (WLAN) Infrastructure and Architecture
- Convenor, Communication Technologies Work Group in IEC SyC Communication Technologies & Architectures,
- Convenor, IEC SyC SET, ahG 1: Systems Architecture for Sustainable Electrified Transportation
- Convenor, IEC TC 13/JahG 17 – Identifying Synergy & Interplay between TC 13 & TC 69
- Member, IEC SMB/SG 12 -Digital Transformation and Systems Approach,
- Member, IEC SMB/SG 14– All Electrified & Connected Society
- Member, IEC SMB/ahG 96 - Governance of Artificial Intelligence
- Member, IEC MSB/SWG 14 - SMART Standards – A Market & Industry perspective.
- OCEANIS - Chair of Advancing Research Work Group & member Steering Committee.
- ITU-T SG 20, ITU-T SG 17 & ITU-R SG 5 - Proactive Contributor.
- ITU-T SG 17 – Editor – X.cs-ra – Cyber Security Reference Architecture; Co-editor, X.arch-design: Design principles and best practices for security architectures.
- Member UL STP 3600 - ‘Measuring and Reporting Circular Economy Aspects of Products, Sites and Organizations’.
- ISO/IEC JTC1/WG11 - Co-Editor in Four Standards.
- **IEEE IoT Magazine** - Standards Column Editor.