SGTech Europe 2017

All-IP telecom network supporting Utility process evolution

Sérgio Pinto, EDP Distribuição S.A.

29th March 2017
Agenda

1. EDP in brief

2. Network transformation drivers

3. Core Network transformation
   • Ownership Model
   • Main technical challenges
   • Design and architecture
   • Service focus and Operational efficiency

4. Wrap up
1. EDP in brief

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4. Wrap up
From a local electricity incumbent, EDP has grown into a global energy player with strong presence in Europe, Brazil and considerable investments in the USA.

EDP Group – overview

United Kingdom
21 Employees
2015 651 Electricity Customers
1 874 Installed Capacity (MW)
8 043 Net Generation (GWh)
100% Generation from renewable sources

Poland/ Romania
51 Employees
475 Installed Capacity (MW)
6 211 Net Generation (GWh)
100% Generation from renewable sources

Spain
2 048 Employees
1 015 543 Electricity Customers
787 869 Gas Customers
6 087 Installed Capacity (MW)
15 331 Net Generation (GWh)
37% Generation from renewable sources

Portugal
34 Employees
363 Installed Capacity (MW)
705 Net Generation (GWh)
100% Generation from renewable sources

France/ Belgium
36 Employees
271 576 Gas Customers
10 992 Installed Capacity (MW)
34 364 Net Generation (GWh)
51% Generation from renewable sources

Italy
14 Employees
7 138 Gas Distribution (GWh)

Brazil
7252 Employees
6 053 509 Electricity Customers
27 1576 Gas Customers
10 992 Installed Capacity (MW)
34 364 Net Generation (GWh)
51% Generation from renewable sources

Angola
46 508 Electricity Distribution (GWh)
7 138 Gas Distribution (GWh)

USA/ Canada
260 Employees
3 422 Installed Capacity (MW)
9 330 Net Generation (GWh)
100% Generation from renewable sources

Mexico
2 635 Employees
2 831 651 Electricity Customers
1 874 Installed Capacity (MW)
8 043 Net Generation (GWh)
100% Generation from renewable sources

USA Canada
104 544 Electricity Distribution (GWh)

Top position in Electric Sector in Dow Jones Sustainability Indexes

#3 World wind energy company

#1 Europe hydro project (+3.5 GW under development)

#1 Portugal industrial group

Countries in which EDP has Distribution activities
The National Electricity System includes EDP Distribuição as the regulated electricity distribution company, acting under a public service concession. EDP Distribuição in the National Electricity Sector.

**Value chain**
- Production
- Transportation
- Distribution
- Retail Market

**Agents**
- EDP
- FORTIA
- endesa
- IBERDROLA
- REN

**EDP D drivers**
- Production market integrated at an Iberian level

**Value drivers**
- Grid concessions from HV till LV and meters
- Agreed network investments remunerated at the IRR of Portuguese bonds

**Operations management**
- Efficient network operations & guarantee of service continuity and energy quality
- Controllable costs baseline recovered until a certain price cap (pressure for costs decrease)

**Information management**
- Information broker and settlement between market players and consumers
- Monitor energy balance and minimize energy losses (technical and commercial)
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4. Wrap up
The electricity grid of the future will be digital - higher level of control and supervision, greater volume of information and ubiquitous connectivity

Current and future challenges of Electricity DSOs

**Past** | **Electricity grid** | **Present & Future**
--- | --- | ---
HV | Solar generation | Wave energy | Additional power control
| Cogeneration | Biomass | Energy Data Mgmt
| Eolic generation | Substation Automation | Improved cyberattack protection (ciber-security)
| B2B | Small hydric | 
MV | Grid Automation | Energy storage | 
| B2B | Energy Data Mgmt | 
| Grid utomation | Distributed Energy Resources | 
| Secondary substations | Spot pricing | 
| B2B | Micro-generation | 
LV | Grid Automation | Electric vehicles | 
| B2C | Smart appliances | 

**More complex electricity grid (k#)**
- 2010: 10
- 2014: 29
- 2018: 87
- DER
- Minigeneration
- Electric Vehicles

**Higher level of control and supervision (k#)**
- 2010: 5
- 2014: 8
- 2018: 33
- Secondary Substations
- OCR
- DTC

**Greater vol. of information to manage (k#)**
- 2010: 75
- 2014: 178
- 2018: 2,630
- Smart Meters
To sustain the increase in quality of service, EDP D will have to direct investment & focus towards it’s communications’ infrastructure, which creates new challenges.

Evolution of operations at EDP Distribution and challenges for the communications infrastructure.

To further improve QoS metrics …

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SAIDI - System Average Interruption Duration Index

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Focused investment & increase in automation are key for improving the quality of service.

… communications will become more complex …

<table>
<thead>
<tr>
<th>Nº of assets with communications at EDP Distribuição</th>
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<tbody>
<tr>
<td>Critical Services</td>
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<tr>
<td>Grid Switches¹</td>
</tr>
<tr>
<td>Automated Transformer Stations²</td>
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<tr>
<td></td>
<td>3.0</td>
<td>6.0</td>
<td>8.0</td>
<td>23.5</td>
<td>39.0</td>
<td>54.5</td>
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<tbody>
<tr>
<td>Business Services</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>14</td>
<td>24</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nº of assets with communications at EDP Distribuição</th>
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<tbody>
<tr>
<td>Smart-meters³ (transformer stations and consumers)</td>
</tr>
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<tr>
<td></td>
<td>150.7</td>
<td>205.3</td>
<td>275.3</td>
<td>360.3</td>
<td>449.3</td>
<td>540.4</td>
</tr>
</tbody>
</table>

… create new challenges

New ways of planning and managing the grid (e.g. DG, bidirectional energy flows...)

More information to customer energy efficiency

New technologies (e.g. energy storage) and new business models (e.g. dynamic energy prices)

Increased exposure to cybersecurity incidents

1. 10,000 switches in the grid until 2020 (2016-2020 with linear growth); 2. Transformer stations automation until 2020 (2016-2020 with linear growth); 3. Roll-out assumes current proportion of Smart-Meters with SIM in comparison to the total number of Smart-Meters.
To address this increasing connectivity challenge, EDP has rolled-out a fiber optic infrastructure, with SDH & PDH technology that now face Service limitations

**90’s - 00’s Vision...**

- Digitalization will increase beyond analog and NB current systems (Analog radio UHF/VHF; Powerline HV)
- More control and management capabilities will be necessary
- QoS metrics will be more demanding

**...led to Fiber and PDH/SDH investments...**

- **>6.500 km**
- PDH / SDH

**...with several limitations**

- EoL technology
- Several TDM legacy Islands
- Static and dedicated bandwidth allocation
- Service BW < E1
- Point-to-Point
- Limited/Complex Multi point setup
- IP over TDM as a start
Use Case growth, multipoint requirements and IP as the established convergence dominant protocol, motivates the evolution into a Packet Data Network.

**Evolution to Packet Data Networks**

### Service Growth
- Teleprotection
- Outage Management Systems
- ADMS
- SCADA
- Energy Management Systems
- Energy metering
- Event recorders
- Switchover of services between control centers
- Disturbance recorders
- Real-time PMU
- Operational Voice Services
- General site alarms, supervision and surveillance
- Time distribution using IEEE 1588
- Video services
- Physical site security using access control mechanisms
- Smart Metering communications.
- IEC 61850 based communications.
- Dynamic Line Rating
- Weather Monitoring & Lightening Detection

### Packet Data Network
- Multipoint Services
- Dynamic BW sharing
- Scalability
- Policing and QoS
- TDM emulation
- Traffic segregation (VPN, ...)
- Traffic delay
- Deterministic quality
- Jitter
- Backup path switching
- Path/delay symmetry

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**IP as interoperability enabler**

**BW Demand**

**Multipoint Uses Cases**
EDP as developed an integrated approach to its connectivity transformation within a managed service and competitive landscape – The Connect Program

Connect Program Scope

<table>
<thead>
<tr>
<th>Digital Networks</th>
<th>Core Network</th>
<th>Access Network</th>
<th>Local Network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Private fiber optics infrastructure, IP-MPLS</td>
<td>- Wireless communications over Public and private networks</td>
<td>- Last mile communication technology portfolio</td>
</tr>
<tr>
<td></td>
<td>- Critical services support on primary substations</td>
<td>- Critical services support on SS1, sensors and <em>field teams</em></td>
<td>- Business services support to the end customer</td>
</tr>
<tr>
<td></td>
<td>- Maximum resilience</td>
<td>- <em>Backhaul smart metering</em></td>
<td>- LV Grid services support</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Capabilities</th>
<th>Monitoring &amp; Control</th>
<th>OT Cybersecurity</th>
<th>OT Platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Supervision center transformation</td>
<td>- Monitoring, Control &amp; Assurance of cybersecurity in the operational platforms</td>
<td>- Operational support systems architecture</td>
</tr>
<tr>
<td></td>
<td>- Monitor and service tools implementation</td>
<td>- OT cybersecurity strategy implementation</td>
<td>- Digital platform governance</td>
</tr>
<tr>
<td></td>
<td>- Staffing with specific competences</td>
<td>- International standards alignment</td>
<td>- New digital technologies enabling (ex:IoT)</td>
</tr>
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</table>

1 – Secondary Substations
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4. Wrap up
Within EDP D’s approach, the new Core network constitutes an important project addressing communications for mission critical services (primary substations)

Connect Program – Core Network

Critical services support on primary substations (HV)

Main requirements

➢ Multiple services support
➢ Low Latency
➢ High Availability
➢ Scalability
➢ Secure

Decision

1. Fully owned Private Network
2. IP/MPLS Technology
3. Lean design and architecture
4. Improved management capabilities
Leveraging on existing fiber, a fully owned private network is able to assure more control over the network and services

<table>
<thead>
<tr>
<th>Private Network</th>
<th>Network-as-a-Service</th>
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<tbody>
<tr>
<td><strong>Reliability, availability and security</strong></td>
<td>Tailored design for requirements, protection and backup, O&amp;M and network accessibility</td>
</tr>
<tr>
<td><strong>Control over SLA</strong></td>
<td>High control of the value chain and associated technical infrastructure</td>
</tr>
<tr>
<td><strong>Technology life cycle</strong></td>
<td>More than 10 years (total control)</td>
</tr>
<tr>
<td><strong>Technology control</strong></td>
<td>Technology evolution dependent of Energy business and process requirements and priorities</td>
</tr>
<tr>
<td><strong>Implementation</strong></td>
<td>&gt; 12 months depending on scope and internal team capabilities</td>
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Legend: + Level of Benefit/compliance -

Control over Cost, Network and Services + Governance / Control under Force Majeure conditions - Complexity due to implementation

DAT – Dept. of Automation and Telecontrol
Fully owned Private Network

From the cost perspective, a private network ownership on a 5Y TCO basis is a competitive choice for EDP, complemented with flexible O&M sourcing models.

➢ 5Y TCO analysis revealed that a Private Network Ownership is an economic competitive scenario when compared to outsource models.

➢ O&M should rely on flexible models:
  • To insource or train existing resources
  • To outsource on/off premises, capturing market knowhow strength
Chosen technology, IP-MPLS, provides state-of-the-art capabilities to support present and future business and technical requirements

2 IP/MPLS Technology

MPLS is a scalable IP based telecom network that sends signals based on labels which identify paths between nodes, instead of a network address or dedicated circuit.

- **Service Flexibility** – SCADA, Voice, Metering
- **Interface Flexibility** – E1, E3, E&M
- **Protocol Flexibility** – Legacy, IPv4, IPv6
- **Consolidate traffic on a unified connection to provide effective bandwidth usage and lower cost**

- **QoS** provides traffic prioritization
- **VPNs** provide traffic segmentation

- **Topology Flexibility** - (Ring, Mesh, Hub & Spoke)
- **Resiliency** – No single point of failure

- **Simplified E2E Network Management**
The Network uses EDP’s fiber infrastructure, laid along its aerial powerlines, imposing a physical restriction on topology.

3 Lean design and architecture

Theoretical MPL Design

Topology ruled by existing fibers
High Level Design much addresses main topology constrains and key quality and performance targets

3 Lean design and architecture

Iterative process

- Geographical coverage
- Power Budget
- Rings & Mesh

Availability

- Component Reliability
- System Reliability
- Improve Topology and/or System

Latency/Delay

- E2E Edge to Core
- Edge and Regional Rings
- BW requirements

Network Intrinsic Quality

- Ensure required redundant Fiber and IP-MPLS trunk routes
- E2E Availability better than 99.99%
- E2E Delay
  - Edge – Core < 10 ms
  - (Regional) Edge – Edge < 8 ms
Component MTBF, HW redundancy, route Topology and operational preparedness (MTTR) drive Core and E2E availability objectives

Availability

- Availability is a key quality factor for overall Utility Services
- Equipment high availability config.
- Fiber routes
- Worst Case better than 99.99%

Core Layer, better than 99.999 .... (9 nines)
E2E, better than 99.99% (4 nines)

Much dependent on fiber time-to-restore
Deterministic traffic flow requirements can be addressed by a toolset of traffic engineering capabilities

Lean design and architecture

**IP PERFORMANCE**

- Delay
- Delay – Jitter
- Packet Loss
- Throughput
- Availability
- Per flow sequence preservation

**Data Plane**

- Traffic Classification
- Traffic Marking
- Rate enforcement
- Prioritization
- Minimum rate assurance

**Control Plane**

- RSVP – per flow resource reservation and admission control
- RSVP – traffic engineering, admission control and MPLS traffic engineering tunnels
Delay objectives can be met for worst case of Edge to Core (Data Center) and regional edge/aggregation rings for Substation to Substation services

**Lean design and architecture**

**Farthest Edge to Core**
- 20µs x NE #50 NE
- 1 ms
- 5µs x km
- 600 km
- 3 ms
- Optical propagation
- 100 B, 2 Mbps
- 1 ms

**Regional Ring**
- 20µs x NE #30 NE
- 6 ms
- 5µs x km
- 200 km
- 1 ms
- Serialization BW Impact
- Serialization
- 100 B, 2 Mbps
- 1 ms

**Important mechanisms for multiservice and heterogeneous time sensitiveness:**
- Policing CIR & Burst
- WFQ
- Scheduler
- Shaping
Differential Protection Relays represent one of the most sensitive services to delay and jitter, requiring adequate diffServ QoS consideration.

Lean design and architecture
Capacity planning and traffic management with DiffServ/QoS enable service SLA delivery in a sustained deterministic way

Lean design and architecture

Service Definition → Routing Model
Demand Forecast → Capacity Simulation
Traffic Matrix → Logical Topology

Network provision

Physical Topology

IP-MPLS Network

Account for probability of queuing with trunk utilization per hop
Operational capability is essential for Service Assurance, Cybersecurity and improved global awareness

Improved management capabilities

**Initial state**

**Desired end-state**

**Integrated Management of Network Support Services**
- Ensure availability of the support services
- Separate the complexity of support services from the core business (i.e. integrating and autonomizing the various service components)
- 24x7 operations – teams sizing in accordance with business needs

**Management and operations of the electricity grid**
- Ensure availability of the electricity supply
- Guarantee compliance with quality of service and quality of energy requirements

**Monitoring of the provided quality of service and energy supply**
- Service continuity and stability requirements
- Quality of energy requirements

**Single point of contact**
- End-to-end awareness
- Improved reaction capacity
EDP Distribuição realized the opportunity and need, moving to capitalize its knowledge and tools, promoting an integrated NOC/SOC

Improved management capabilities

Functions/ responsibilities

- Professionalized relationship with the clients with a single point of contact
- Services' predictive & integrated monitoring
- Trouble-shooting & management of incidents & service requests
- End-to-end service & priority management
- Integrated vision of multiple technologies
- Services' performance analysis, catalogue mgmt. & predictive analysis & reporting
- Back-office support for technical operations execution
- Monitoring with event and replenishment mgmt., and swift incident resolution (or avoidance preventive action)
- Capabilities for incident and root cause analysis identifying and executing corrective actions
- Contact and coordination of suppliers' operational involvement
- Availability and capacity mgmt.
- Technical security mgmt., implementation & supervision of security processes, policies and rules
- Access mgmt. (IAM & PAM)
- Intrusion tests
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**Final Remarks**

**Main Challenges and Concerns**

1. **Data communications are critical for DSO overall operations**, namely taking in consideration the new market landscape and new central facilitator role.

2. **All-IP QoS enabled Networks lead the way to service convergence** across networks and technology platforms.

3. **IP-MPLS is a well established technology** able to address scalability and strict service requirements.

4. **It’s not “just” about technology**, we’ve to address skills, set-up and dimensioning, Security, sourcing options and operation capability.

5. **Traffic / Service profile / Bandwidth / QoS setting and ongoing operations are essential** for service deterministic delivery and performance KPIs.
Thank you for your attention

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