INSTITUTE FOR SYSTEMS
AND COMPUTER ENGINEERING,
TECHNOLOGY AND SCIENCE

INESCTEC 35 1985 TRINTA E CINCO ANOS 2020

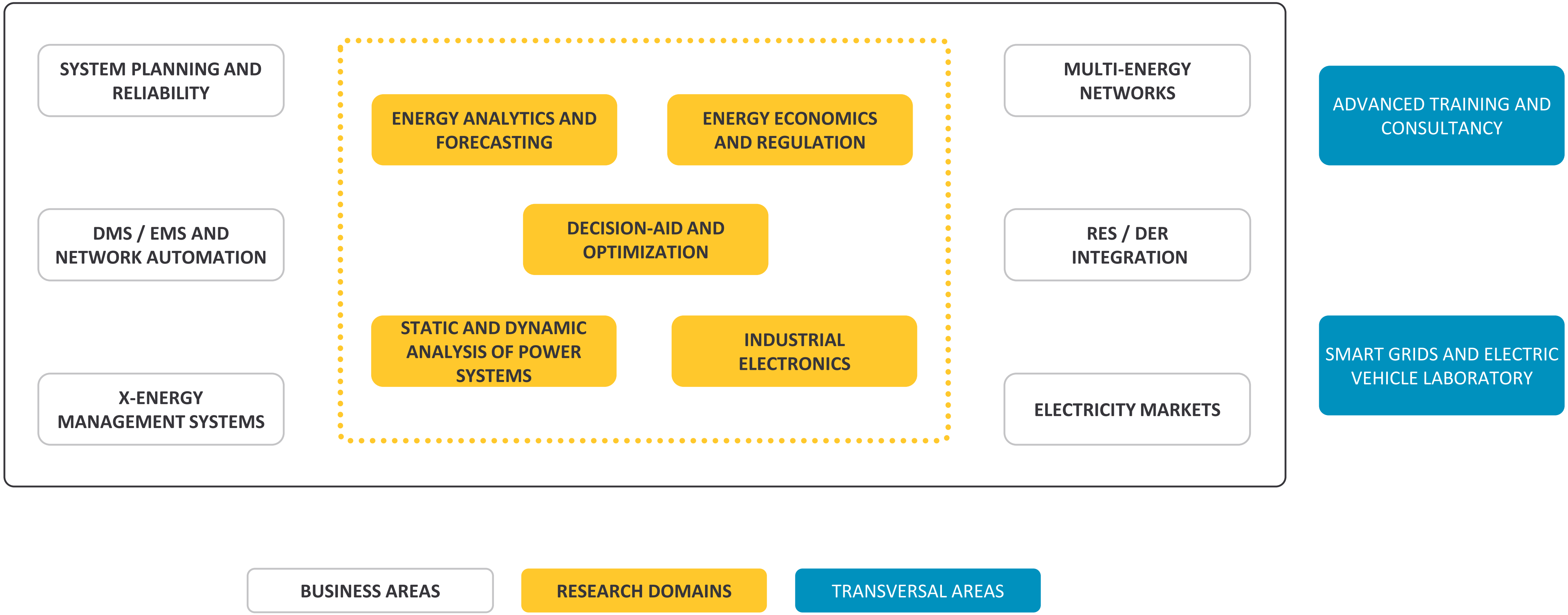
CPES

SCOPE AND ACTIVITY FOR 2021

C C I / 2 0 2 1 - 0 7 - 2 7

from knowledge
generation to
science-based
innovation

CPES RESEARCH LINES



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RESEARCH ACTIVITIES AND CLUSTERS

	COMPUTER SCIENCE	POWER AND ENERGY	NETWORKED INTELLIGENT SYSTEMS	INDUSTRIAL AND SYSTEMS ENGINEERING
Energy Analytics and Forecasting	POTENTIAL	ACTIVITY		
Energy Economics and Regulation		ACTIVITY		POTENTIAL
Decision-aid and Optimization	POTENTIAL	ACTIVITY		POTENTIAL
Static and Dynamic Analysis of Power Systems		ACTIVITY		
Industrial Electronics		ACTIVITY		POTENTIAL

INNOVATION ACTIVITIES AND APPLICATION AREAS

	TEC4AGRO	TEC4ENERGY	TEC4HEALTH	TEC4 INDUSTRY	TEC4SEA
System Planning and Reliability		ACTIVITY			
DMS/EMS and Network Automation		ACTIVITY			
X-Energy Management Systems	POTENTIAL	ACTIVITY	POTENTIAL	ACTIVITY	
Multi-energy Networks		ACTIVITY		POTENTIAL	POTENTIAL
RES and DER Integration	POTENTIAL	ACTIVITY		ACTIVITY	ACTIVITY
Electricity Markets	POTENTIAL	ACTIVITY		POTENTIAL	

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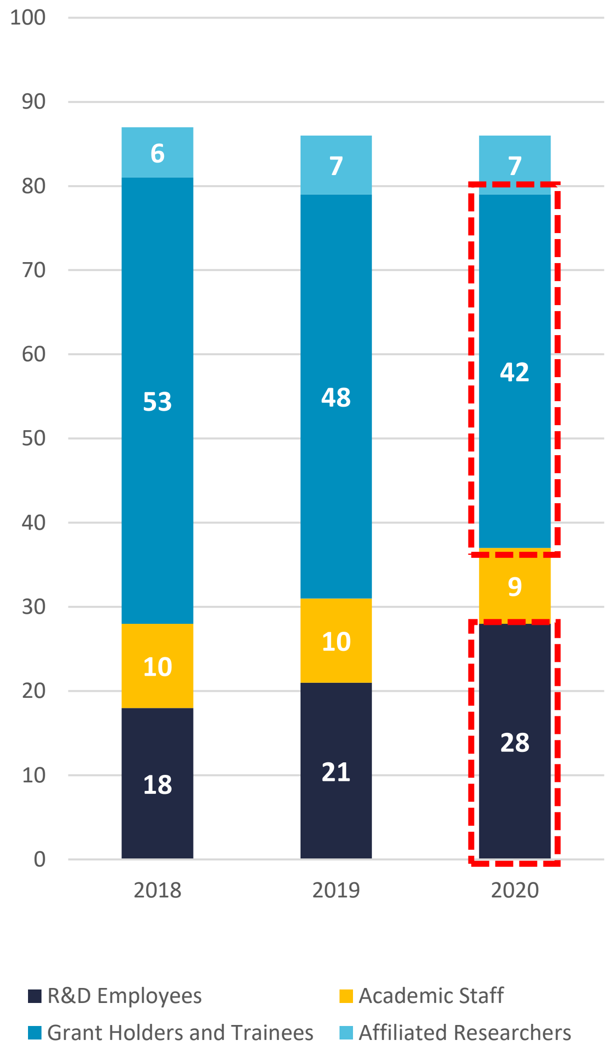
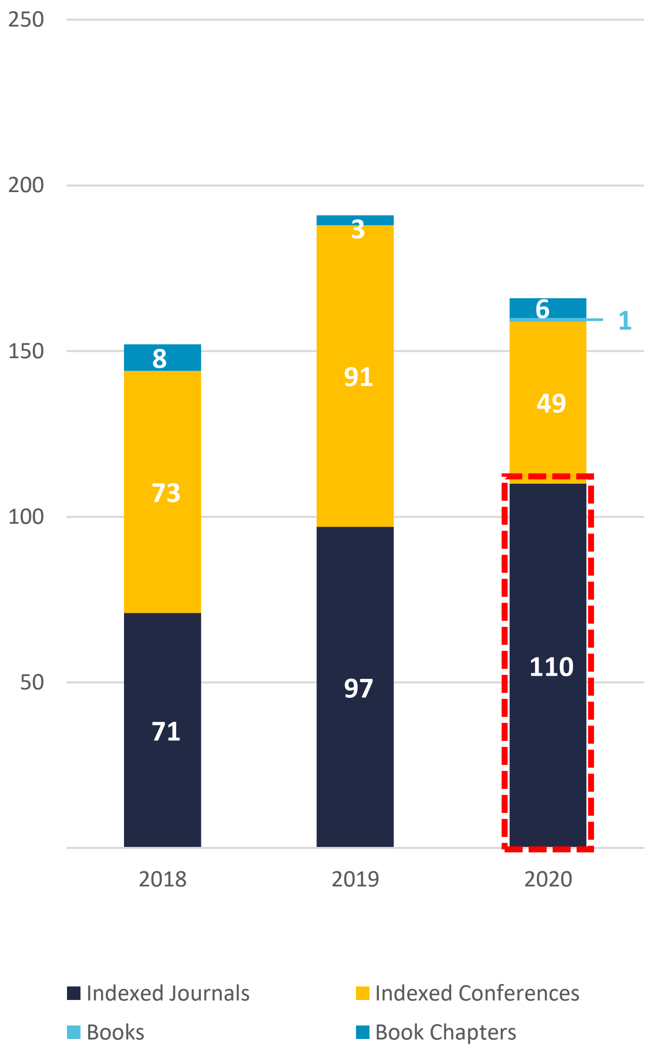
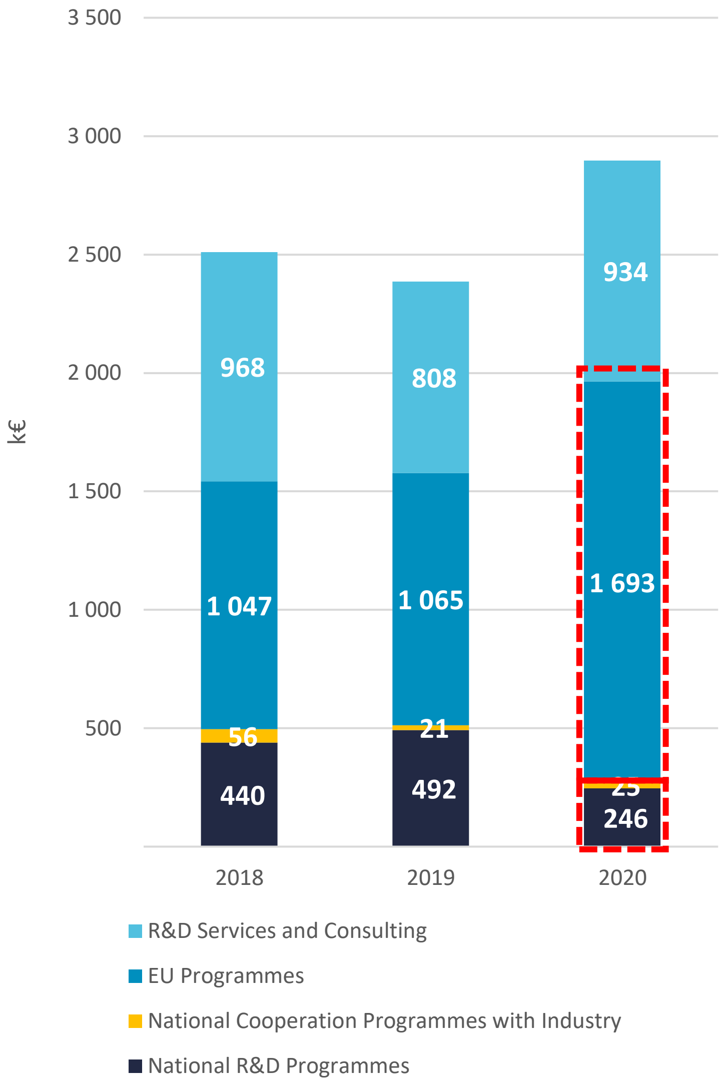
CPES - TEAM AND ACTIVITY







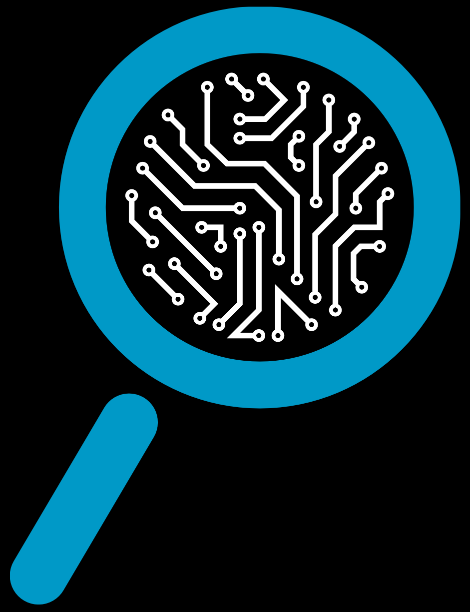
OBJECTIVES IN 2021

- R&D solutions for future scenarios with near-100% renewable energy
- Novel methods to maximize energy efficiency and conservation in multi-energy networks
- Computational solutions to integrate new flexibility services and improve grid resilience
- Privacy-preserving analytics and data markets for energy systems
- Improve electricity market modelling tools
- Develop models for emerging power system reliability problems
- Develop a modular and computationally efficient energy optimization algorithms

MAIN ACTIONS IN 2021

- Development of simulation tools for converter-dominated grids
- Security of supply evaluation for multi-area power systems with distributed computing architectures
- MIBEL market simulator improvement: EU interconnected markets, H2 economy
- Digital and interoperable solutions for energy management: SAREF extensions, micro-services
- Development of operational and planning tools for multi-energy networks
- Field demonstration (Portugal, Germany) of TSO-DSO coordination schemes
- Development of new approaches for multi-voltage level coordination and resilience in smart grids
- New contributions to data-driven modelling of energy systems
- Create conditions for a solid research team in industrial electronics: + 2 Contracted post-docs & +1 R&D Engineer + 1 Academic Staff + 1 Contracted post-doc (in 2022) (existing: 2 R&D Engineers and 1 Academic Staff)

FLAGSHIP PROJECTS



FLAGSHIP PROJECTS UNDER WAY IN 2021

interconnect

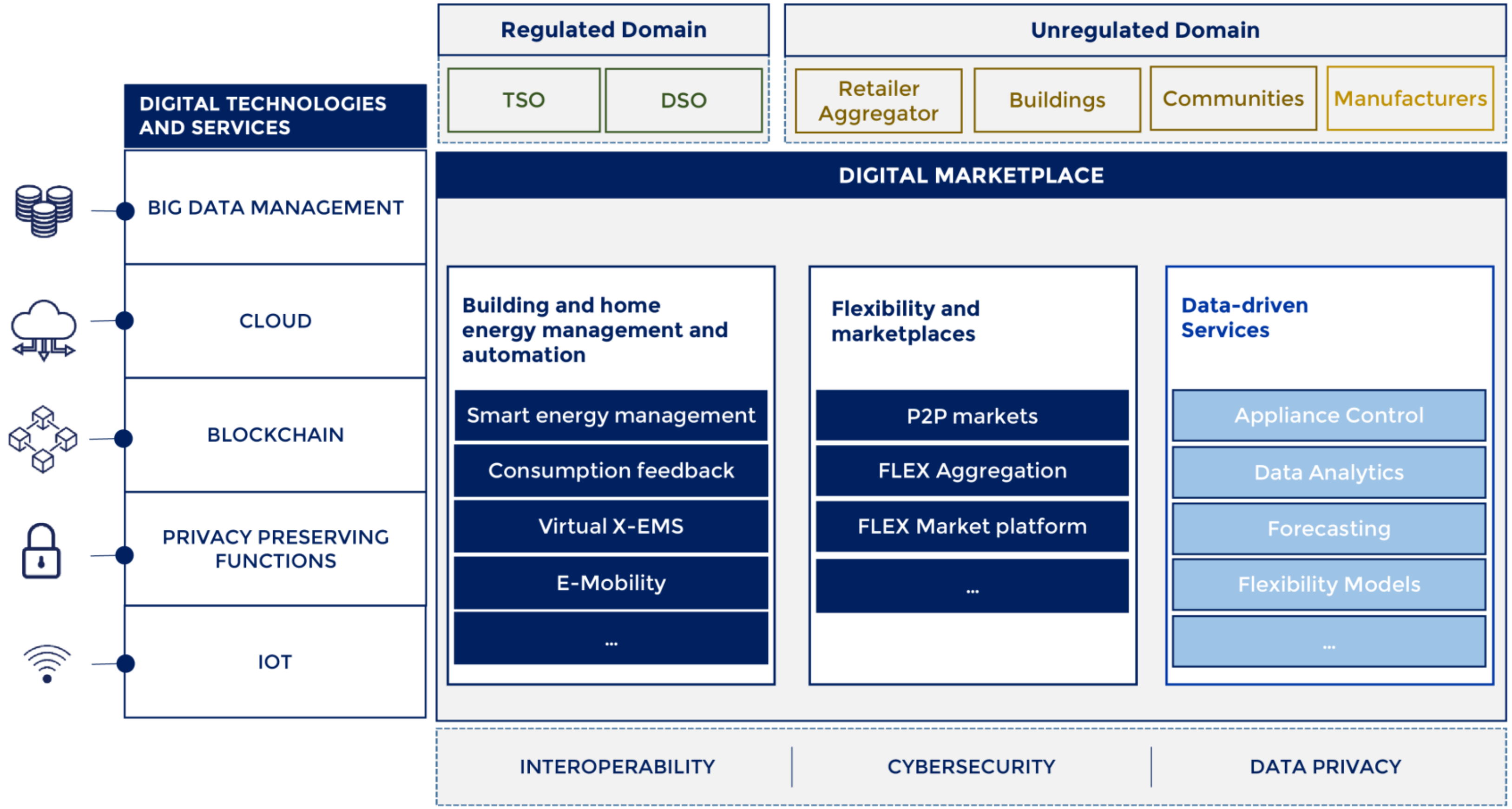
Innovation Action [IA]

Coordinator
INESC TEC

Duration
2019-2023

Budget
~36M€

52 Partners



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FLAGSHIP PROJECTS UNDER WAY IN 2021

ATTEST

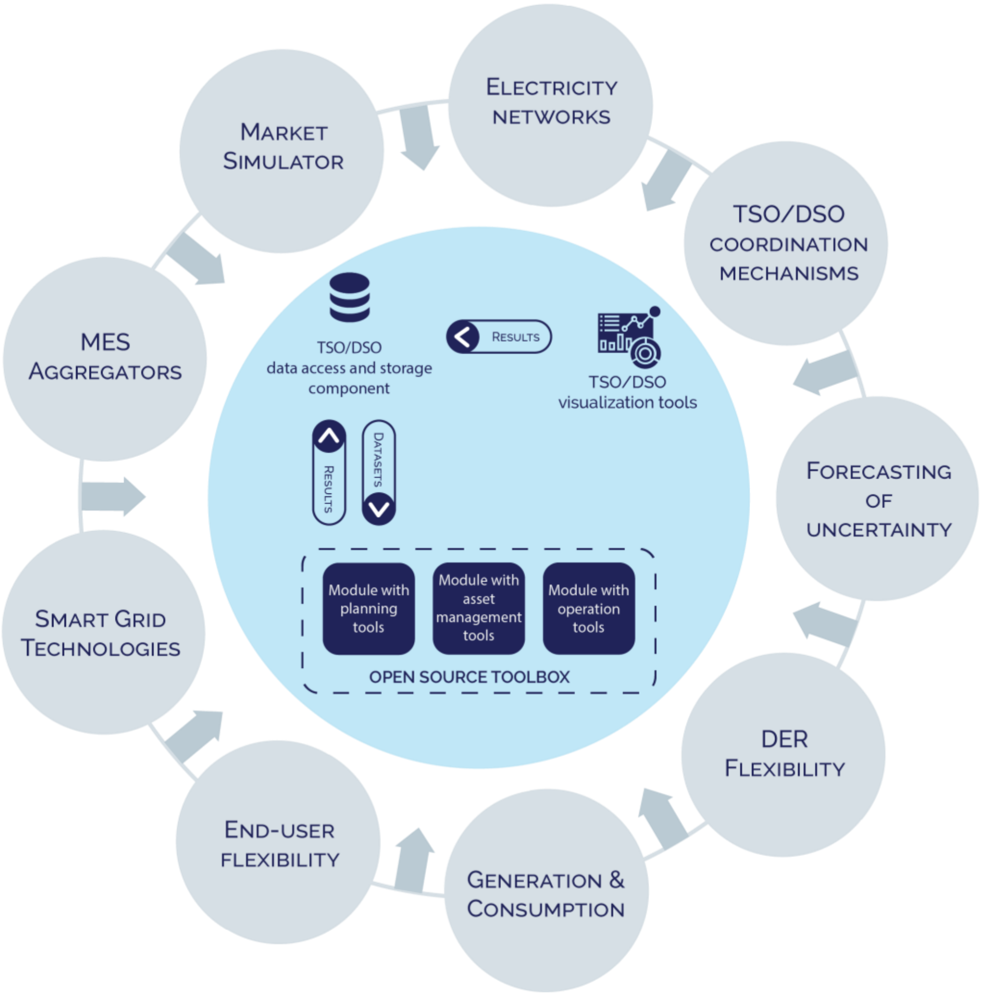
Research and Innovation Action [RIA]

Coordinator
INESC TEC

Duration
2020-2023

Budget
4M€

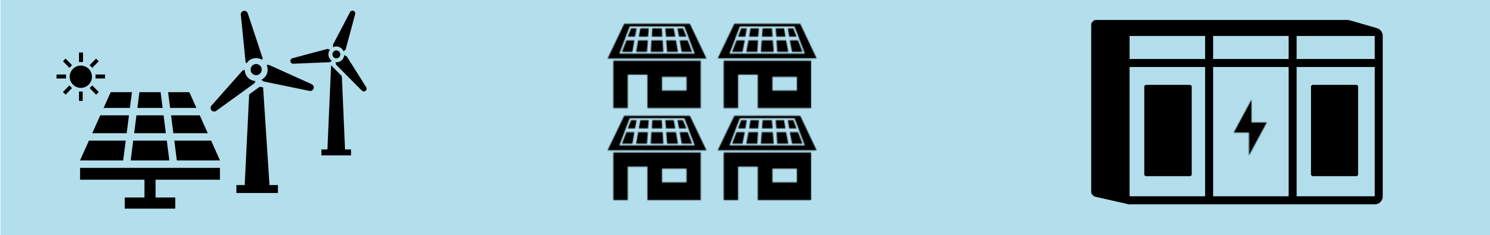
9 Partners [6 countries]



FLAGSHIP PROJECTS CLOSED IN 2021

FLEXERGY

efacec



Hybrid Parks

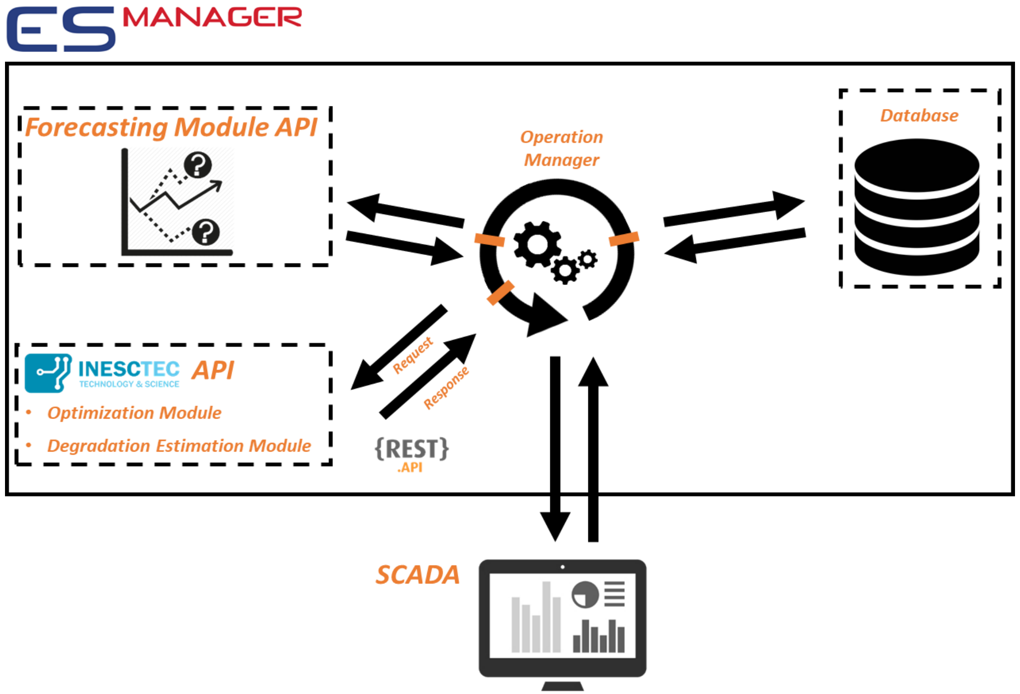
Technical and economic optimization supported by BESS

Microgrids

Holistic optimization integrating energy storage

BESS*

Fundamental dynamics modeling and life cycle assessment



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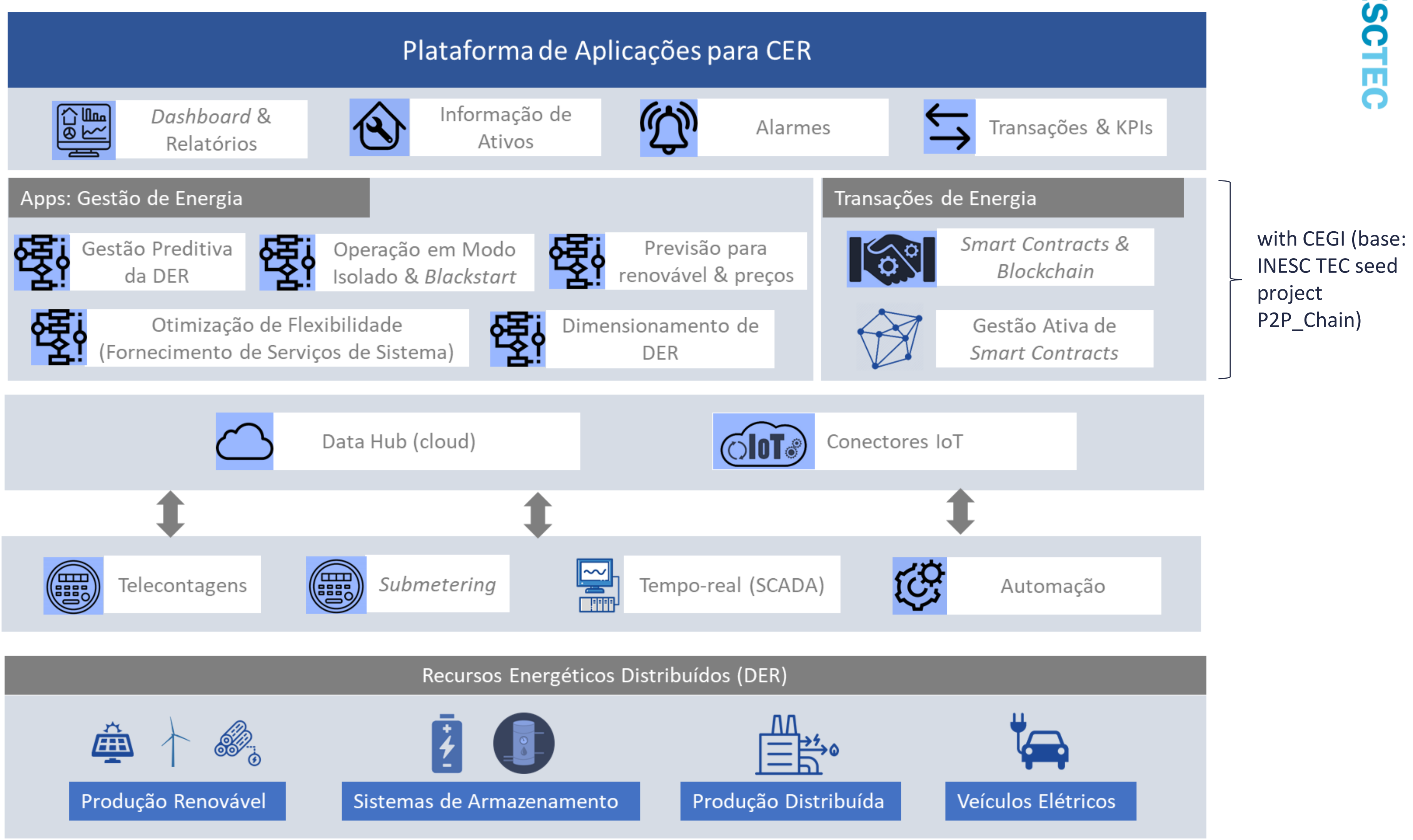
FLAGSHIP PROJECTS TO BEGIN IN 2021

Digital platform for renewable energy communities (CER) in industrial sites



FLAGSHIP PROJECTS TO BEGIN IN 2021

- **Powered by renewable energy**
- **Energy management solutions**
- **Energy and non-energy services hub**
- **E-mobility**

Buildings In Motion by Casas Em Movimento

PIPELINE TO MAXIMIZE RESEARCH IMPACT

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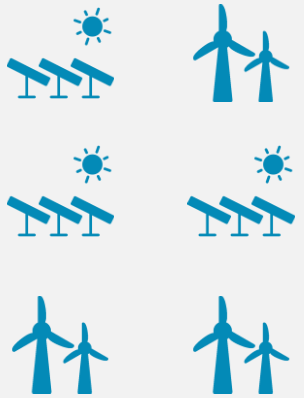
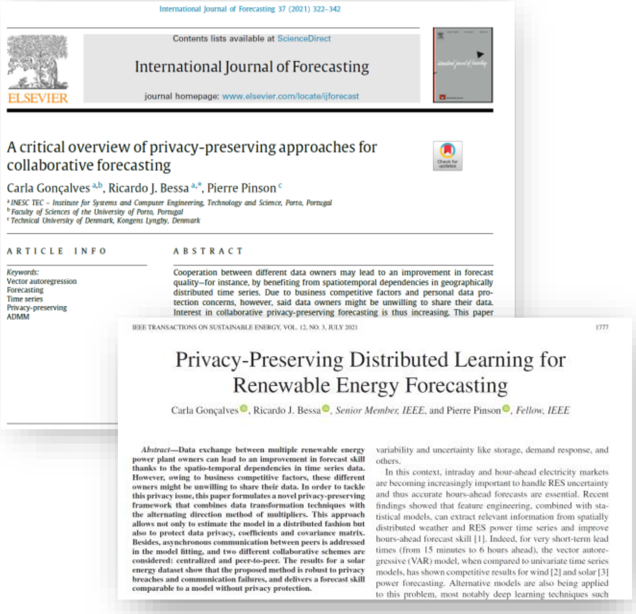
Data privacy issues

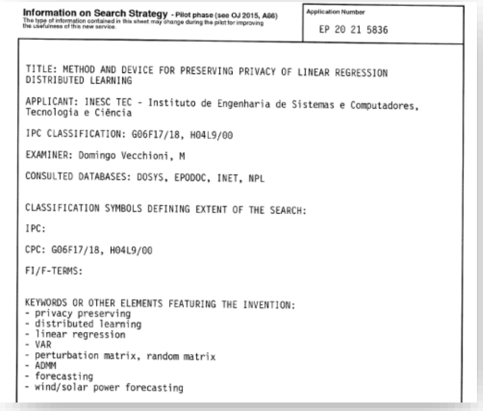
Forecasting with geographically distributed data



since in 2015…



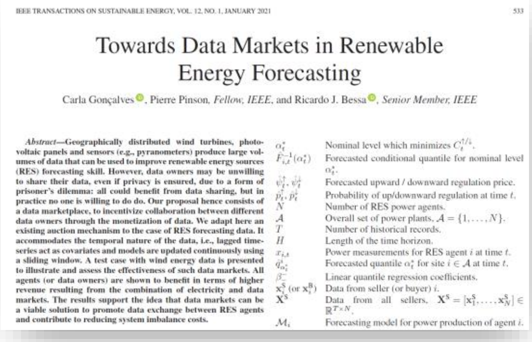
Patent application



New use case

voltage control in microgrids and communities

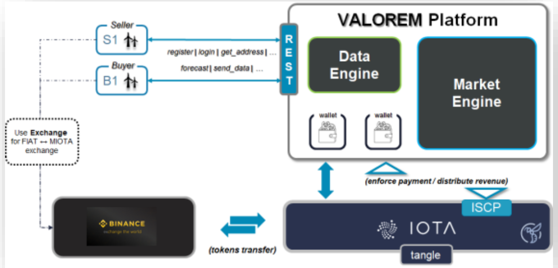
ENEIDA.IO



Data privacy guarantees are not enough

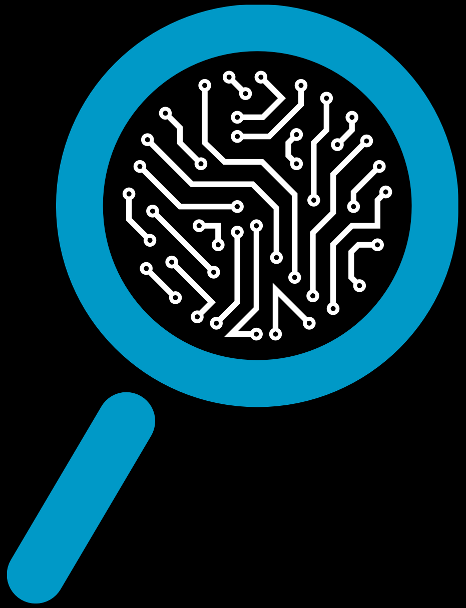
Proof-of-concept INESC TEC seed project (VALOREM)

eit | JUMPSTARTER



AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

COLLABORATIONS WITH OTHER CENTERS



COLLABORATIONS WITH OTHER CENTERS – RESEARCH

in 2017…

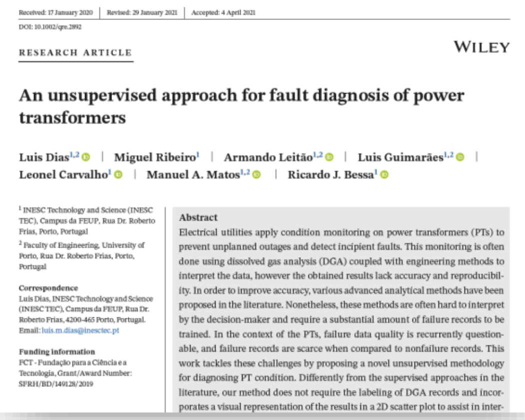
CEGI
Condition assessment
Predictive maintenance

Domain knowledge on
Industrial engineering

now in 2021…

CPES
Reliability analysis
Energy analytics

Domain knowledge on
Power systems



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DOI: 10.1002/qre.2892

RESEARCH ARTICLE

WILEY

An unsupervised approach for fault diagnosis of power transformers

Luis Dias[1,2] | Miguel Ribeiro[1] | Armando Leitão[1,2] | Luis Guimarães[1,2] | Leonel Carvalho[1] | Manuel A. Matos[1,2] | Ricardo J. Bessa[1]

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FCT - Fundação para a Ciência e a Tecnologia, Grant/Award Number: SFRH/BD/149128/2019

Abstract
Electrical utilities apply condition monitoring on power transformers (PTs) to prevent unplanned outages and detect incipient faults. This monitoring is often done using dissolved gas analysis (DGA) coupled with engineering methods to interpret the data, however the obtained results lack accuracy and reproducibility. In order to improve accuracy, various advanced analytical methods have been proposed in the literature. Nonetheless, these methods are often hard to interpret by the decision-maker and require a substantial amount of failure records to be trained. In the context of the PTs, failure data quality is recurrently questionable, and failure records are scarce when compared to nonfailure records. This work tackles these challenges by proposing a novel unsupervised methodology for diagnosing PT condition. Differently from the supervised approaches in the literature, our method does not require the labeling of DGA records and incorporates a visual representation of the results in a 2D scatter plot to assist in inter-

HIP – Health Index for Power Transformers

edp produção

HEAD – Heath index for assets of the distribution network

E-REDES

Predictive maintenance of pump power storage

XFLEX HYDRO

EU-SCORES (Green Deal – **NEXT SLIDE**)

AI4PV

Data sharing in asset management with collaborative analytics and data markets

iPTransfer (under evaluation)

FCT Fundação para a Ciência e a Tecnologia

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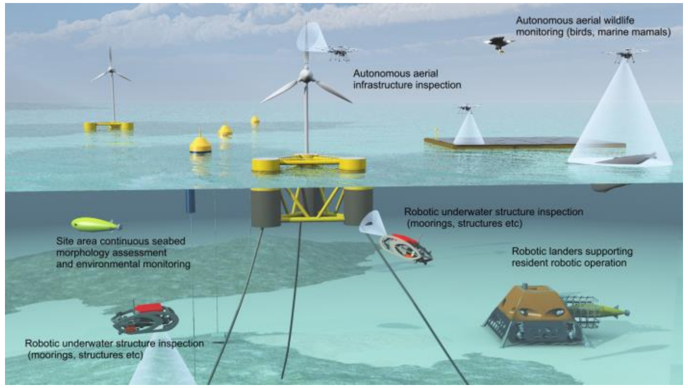
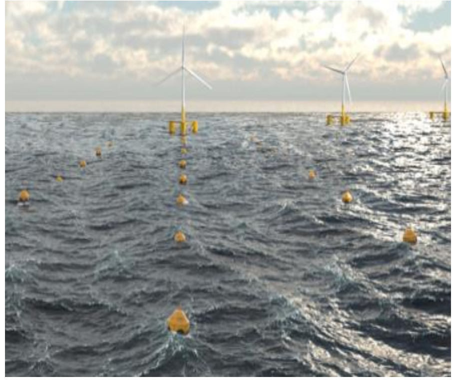
COLLABORATIONS WITH OTHER CENTERS - INNOVATION

EU-SCORES: EUropean - Scalable and Complementary Offshore Renewable Energy Source





2.2 M€ budget [INESC TEC]

Offshore wind + floating PV: **Belgium DEMO**

Offshore wind + wave: **Portuguese DEMO**

CPES – Electrical infrastructure design, energy management, provision of system services, electricity market design and simulation

CRAS – Marine robots & sensor integration for environmental and condition monitoring

CEGI – Development of O&M tools for multi-technology offshore power plants

CAP – Sensors for environmental monitoring

COLLABORATIONS WITH EXTERNAL PARTNERS

WORK WITH EXTERNAL PARTNERS - RESEARCH

E-REDES

Challenge

Operation complexity rising on a fast pace
(RES, prosumers, grid maintenance, etc.)

Large volume of real-time and historical alarms data

High Cognitive Load!

Alarms!

Decisions!

Data!

IEEE TRANSACTIONS ON POWER DELIVERY 1

Data-driven Anomaly Detection and Event Log Profiling of SCADA Alarms

J. R. Andrade, C. Rocha, R. Silva, J. P. Viana, R. J. Bessa, *Senior Member, IEEE*, C. Gouveia, B. Almeida, R. J. Santos, M. Louro, P. M. Santos, A. F. Ribeiro

***Abstract*—Decision-making during grid outages requires significant attention and the ability to perceive real-time feedback from multiple information sources to minimize the number of control actions and service interruption time. Presently, the high complexity of events, the data semantics, and the large variety of equipment and technologies translate into very few AI applications developed in SCADA. This work describes two novel data-driven applications based on SCADA data: (i) identification of anomalous behaviors regarding the performance of the protection relays of primary substations, during circuit breaker tripping alarms in HV and MV lines; (ii) unsupervised learning to identify similar events in HV line panels and supervised learning to classify new events and detect rare events. Important aspects associated with data handling and pre-processing are also covered. The results for real data from a Distribution System Operator show a very promising potential of applying AI-based approaches to SCADA data, enhancing the role of the human operators and helping them make better and more informed decisions.**

***Index Terms*—SCADA, power system protection, data-driven, digital substation, alarm message, contextual knowledge.**

I. Introduction

THE the evolution of the energy utility digital ecosystem led to the generation of large volumes of data that must be analyzed to extract actionable insights. Artificial Intelligence (AI) is quickly redefining how utilities manage their infrastructures and is being applied to different use cases with positive effects [1].

In the control center, human operators depend on the alarm events generated in substations (SS) and network equipment for grid supervision, outage detection and diagnosis. However, the evolution of protection relays, the quick adoption and growing monitoring capacity of internet-of-things assets and new devices (e.g., Phasor Measurement Unit) has exponentially increased the volume of data that human operators need to analyze in short periods of time [2], [3]. As an example, in E-REDES, the Portuguese Distribution System Operator (DSO), historical data from 2020 shows that a daily average of 295,000 events were registered on the Supervisory Control and Data Acquisition (SCADA) system, considering only assets in the High Voltage (HV) and Medium Voltage (MV) grid. On days with extreme weather conditions, the number of events exponentially increased to nearly one million and, in a single day of 2020, the SCADA database registered more than 2,200,000 new events. This makes real-time analysis of network state very complex and time-consuming.

Intelligent alarm processing in power systems is not new; the first works were mainly rule-based expert systems that filtered and prioritized alarms to provide information to human operators [4]. As indicated in [5], the majority of said early works were essentially fault location systems. In order to address this issue, expert systems have been widely applied at the research and industry levels [6], but more recent works focus on artificial neural networks [7], rough set theory [8], Petri Nets [9] and Bayesian networks [10], among others. Nevertheless, alarm data can be exploited for other use cases. Miao et al. described a logic-based methodology to identify malfunctioning relays and breakers [11], where the logic expressions are not learned from data (i.e., built with domain knowledge). Hor and Crossley proposed an unsupervised rough classification technique to select the reference Intelligent Electronic Devices for each fault type and reduce the volume of information displayed to the operator [12]. This method also showed the ability to assess the operating performance of the protection system. However, the extracted rules only covered a limited number of simulated fault scenarios. Wang et al. combined spiking neural P systems with rough set theory for fault equipment identification of SS, including uncertainties regarding the status information of protective devices [13]. An alternative approach, named analytic model-based methods, was proposed in [14] to measure the mismatch between the expected and actual alarm event, employing time constraint networks to capture the temporal logic among event occurrences; it was used to cluster alarms into related groups, identify abnormal or missing alarms and relate causes with alarm events. A similar principle was applied in the mixed integer linear programming model formulated in [15], focusing on detecting malfunctioning circuit breakers or relays.

The aforementioned approaches presume that alarm data is available in a structured format and is fully readable by data-driven methods. However, despite the adoption of the IEC 61850 standard, a major challenge identified in [16] is to turn semi/unstructured alarm information into algorithm-readable semantic, without neglecting its hierarchical and topological structure of data. In this context, recent advances in Natural Language Processing (NLP), such as Word2vec combined with Convolutional Long Short-Term Memory Networks [17], are

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under review

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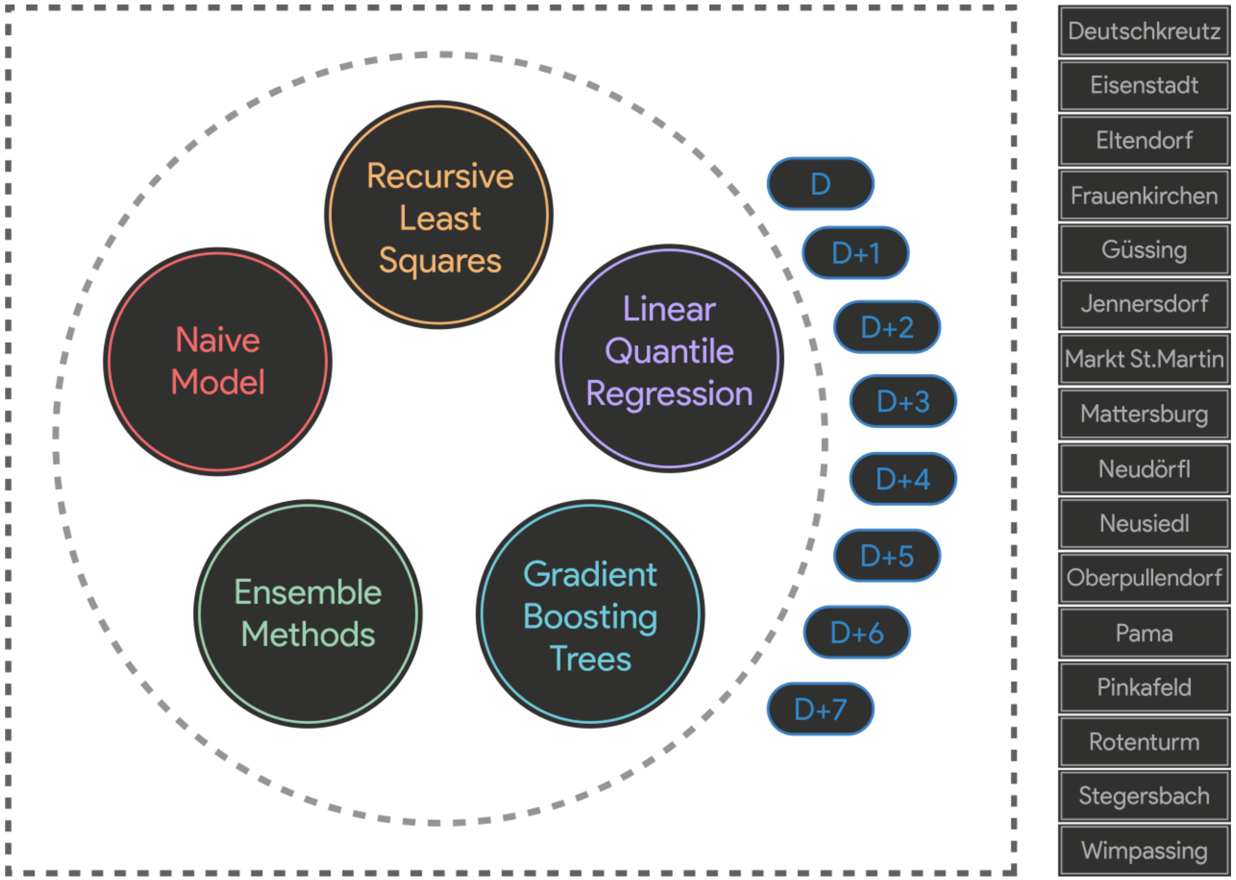
WORK WITH EXTERNAL PARTNERS - INNOVATION

Improve the electrical energy consumption model of the Transmission System Operator of Austria



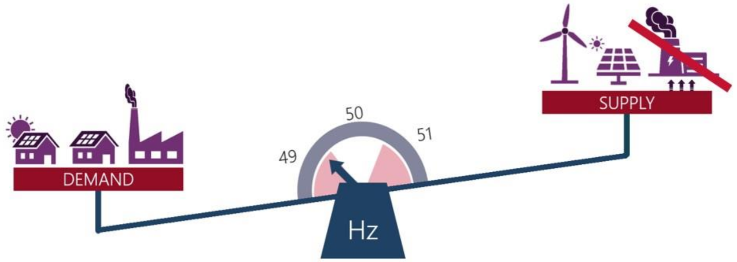
WORK WITH EXTERNAL PARTNERS - INNOVATION

EDP anuncia meta para descarbonização mais ambiciosa até 2030 em linha com ciência climática

SEXTA-FEIRA 30, OUTUBRO 2020

PRODUÇÃO | ENERGIAS RENOVÁVEIS | SUSTENTABILIDADE

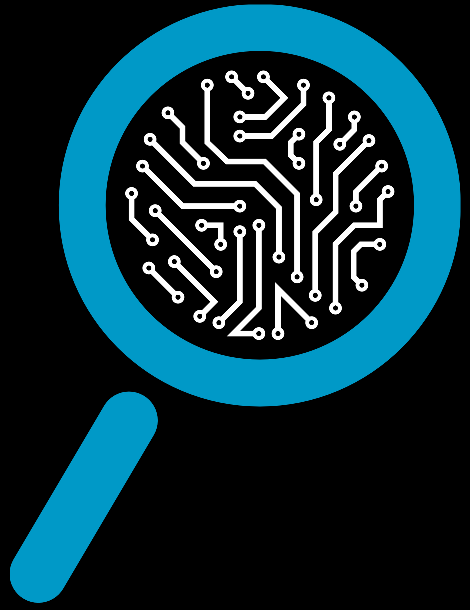
Nova meta da EDP de redução em 90% das emissões de CO2 até 2030, face aos níveis de 2015, foi reconhecida pela Science Based Target initiative BTi como estando alinhada com as exigências da ciência climática. Estratégia é mais um contributo relevante da empresa para conter o aumento da temperatura média global a 1,5°C.

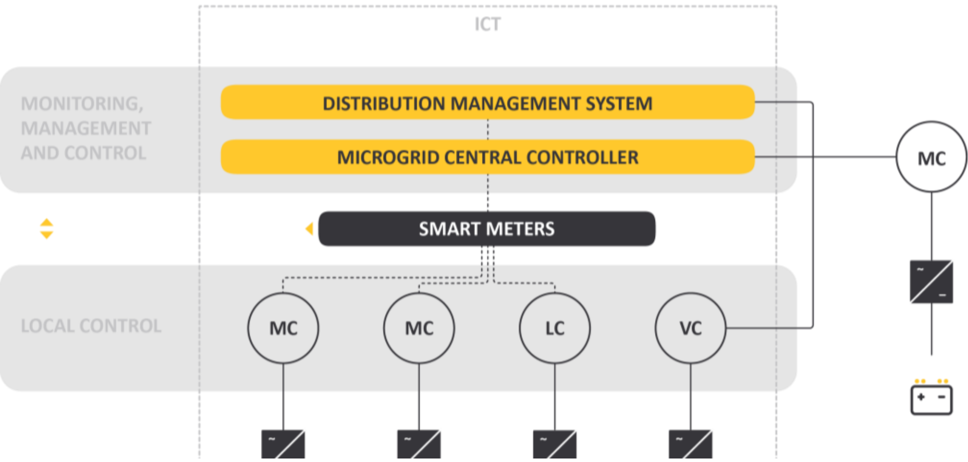


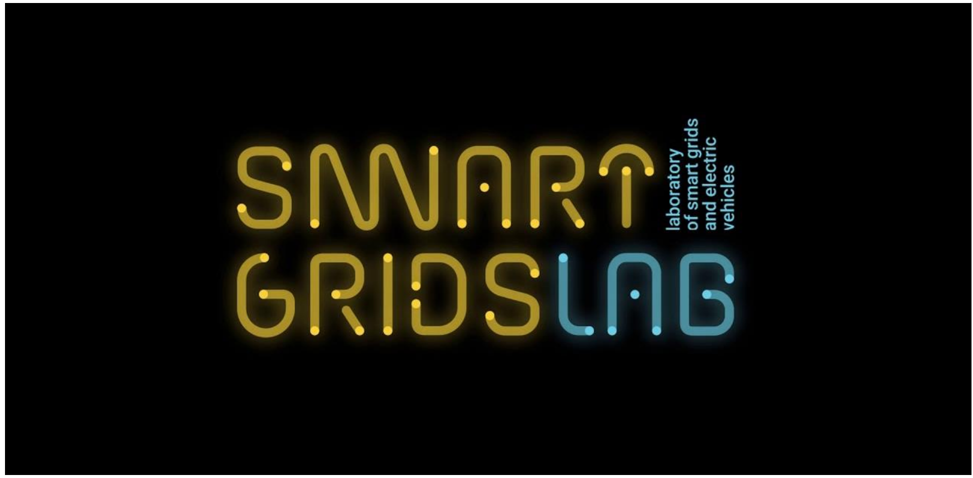
New role in the power system & alternative sources of revenues?

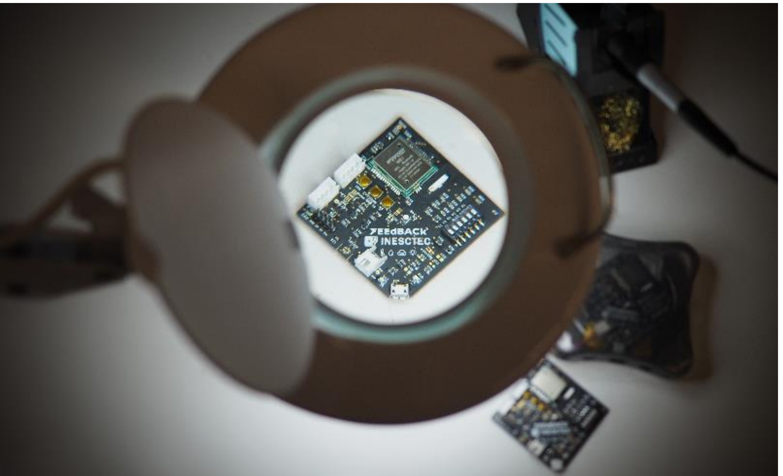
- ❑ Evaluate market opportunities for **current** system services
- ❑ Study potential for **new** system services, e.g. inertia

LABORATORIAL INFRASTRUCTURE

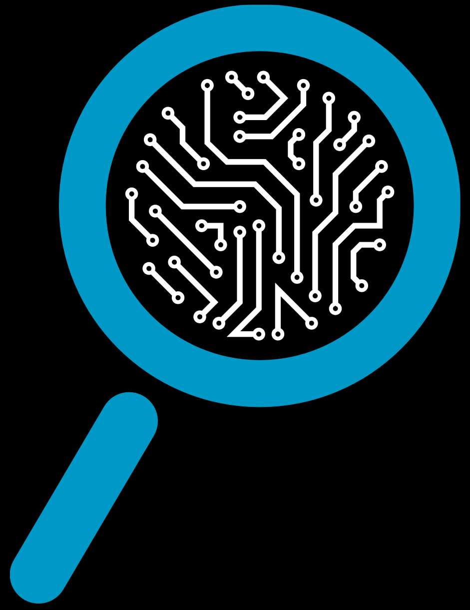



ICT
MONITORING, MANAGEMENT AND CONTROL
DISTRIBUTION MANAGEMENT SYSTEM
MICROGRID CENTRAL CONTROLLER
SMART METERS
LOCAL CONTROL
MC
MC
LC
VC
MC


SMART GRIDS LAB
laboratory of smart grids and electric vehicles



BUT...



FRAGILITIES / THREATS

- Low attractivity (and availability) of HR with power systems background
- Difficulties in retaining senior researchers
- Changes in the board and strategy of energy companies (EDP, GALP,...)
- Unidimensional perspective of sustainability (margin)
- Risk of low scientific literacy from young researchers (no access to b-on/ IEEE)
- Lack of visibility on the website and dissemination material for INESC TEC energy domain