ΕΛΙΔΕΚ
Ελληνικό Ίδρυμα Έρευνας & Καινοτομίας

Ancillary services in aCTIVe distribution networks bAsed on moniToring and control tEchniques

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1. Executive summary

Deliverable **D6.3 entitled "Newsletters"** includes the 7 newsletters launched every 6 months during the project duration. The 7 newsletters are included in the Appendix

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2. Appendix

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 1 **June 2020**

Dear Reader,

*It is our pleasure to introduce you to **ACTIVATE** - Ancillary services in active distribution networks, based on monitoring and control techniques and to welcome you to this first project newsletter which will inform you about the progress of our project activities. ACTIVATE is our new and ambitious research project funded by the Hellenic Foundation for Research & Innovation, and is being implemented by a consortium of 4 highly capable and well established Universities.*

If you would like to keep up with all the latest developments of our project follow us on Facebook, LinkedIn & Researchgate.

Kind Regards,
The ACTIVATE Research Team

About ACTIVATE

ACTIVATE will propose the design of *hybrid control strategies*, combining features of centralized and decentralized concepts to improve the performance of the network operation. In order to extend the applicability of the proposed hybrid strategy also a *virtual inertia* scheme will be incorporated to modify the control strategies of DRES converters. To enhance further the adaptability of the provided virtual inertia and to modify the overall dynamic response of the power system, *energy storage systems* will be used with novel congestion management techniques.

Additionally, an innovative *network monitoring architecture* will be proposed to determine the converter virtual-inertia parameters and coordinate the hybrid control strategy operation.

Finally, to facilitate the implementation and application of the proposed scheme in existing distribution grids, a *prototype three-phase converter* will be developed

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Scope and expected outputs

Project Scope and Objectives

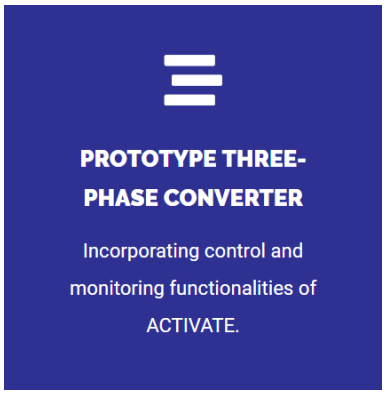
The objective of **ACTIVATE** is to develop novel DSO-oriented and TSO-oriented ancillary service solutions. These solutions aim to address the emerging grid operation challenges caused by the increased Distributed Generation (DG) penetration and especially by the intermittent nature of Distributed Renewable Energy Sources (DRESs). The **ancillary services** to be developed will be based on exploiting the functionalities the network assets offer including:

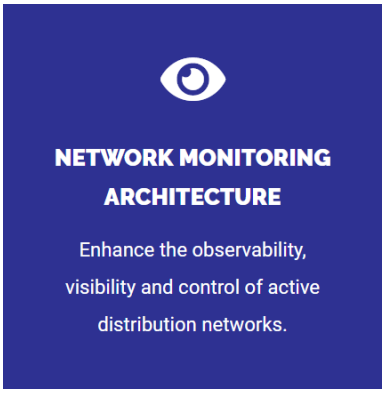
a) Energy Storage Systems (ESSs)

b) Novel operational features of the grid-interfaced converters of ESSs and DRES units

c) A new monitoring system architecture for active distribution networks (ADNs) based on measurements acquired locally at the point of common coupling of the DRES units.

This project will contribute to the increase of supply reliability and RES penetration, in an attempt to meet the targets European Union has set to improve sustainability, flexibility, and efficiency in the electricity sector.





Key Outputs expected by the ACTIVATE project

1. **Innovative control strategies** to provide ancillary services aiming to regulate network voltages and mitigate congestion issues
2. **Coordinated** strategies to achieve **optimal** distribution grid **operation**
3. TSO-oriented ancillary services, focusing on **frequency control**
4. New **network monitoring** architecture, enhancing the visibility of ADN operation
5. **Three-phase converter**, incorporating all new control strategies and monitoring techniques

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The project is funded by the Hellenic Foundation for Research & Innovation

Progress over the first semester

Progress so far

During the first part of the project, a lot of effort has been placed on studying the existing situation on:

→ **ancillary services,**

→ electrical **network monitoring** technologies and

→ **power converter implementations**.

This study is the basis for the design of the technical solutions and key outputs of ACTIVATE.

Over the Project's first 6 months, significant progress has been observed

- Overview of the **state-of-the-art** regarding:
  - → Ancillary services solutions for DSOs and TSOs
  - → Network monitoring technologies and techniques
  - → Power converter implementations
- **Benchmark transmission and distribution networks** were developed to perform steady-state and dynamic analysis.
- **Control strategies** to tackle network operational issues were designed. In particular:
  - → Local controller to coordinate the response of end-users with ESSs and DRESs to tackle overvoltages and undervoltages in LV networks
  - → Local controller to coordinate the response of MV large scale ESS and DRES systems to tackle overvoltages and undervoltages in MV networks
  - → One day analysis was performed using consumption and generation data with one-minute resolution
- **System identification techniques evaluation** to identify system modes by using ringdown data

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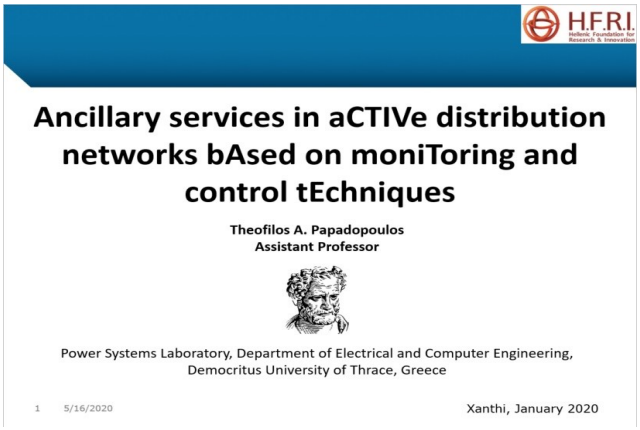
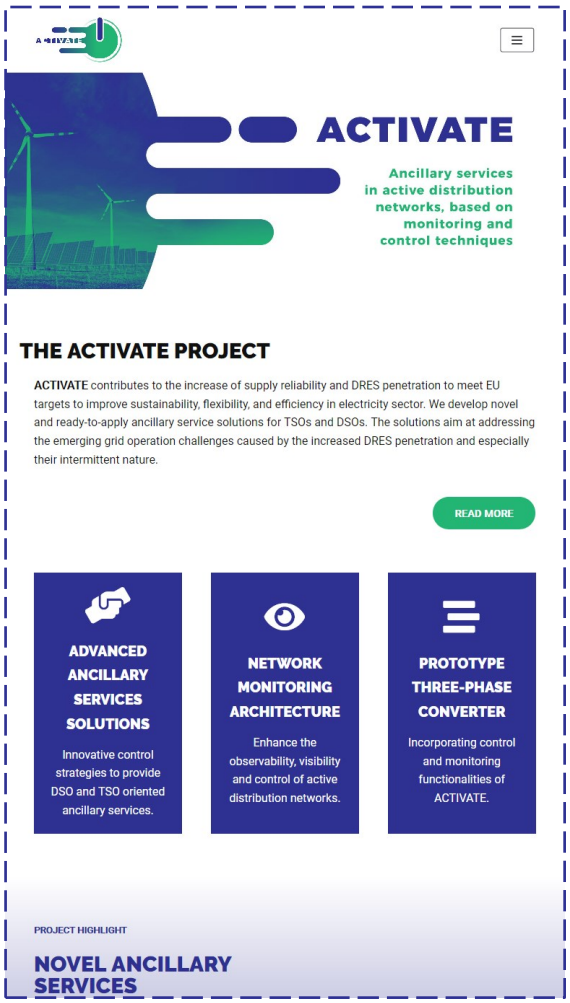
Communication & Dissemination activities

Kick-Off Meeting

The Kick-off meeting of the project was held in January 2020, in Xanthi, Greece. It was the first opportunity after the preparation of the project application for members of Democritus University of Thrace and Aristotle University of Thessaloniki to meet in person and to acquaint themselves in detail with all the project tasks and the timelines. At the meeting the partners agreed on a common work plan and methodology in order to achieve the project objectives.





Project Website

Everything you need to know about ACTIVATE can be found on our webpage:

https://activate.ee.duth.gr/

Make sure that you receive our Newsletter, so that you are kept informed regularly about the ongoing progress and results of the project.

Social Networking

Stay informed on the ACTIVATE Project progress and news via its LinkedIn, Facebook and ResearchGate accounts.

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Project Consortium

Democritus University of Thrace (DUTH)

Power Systems and Electrical Machines laboratories are involved in ACTIVATE. DUTH is proud to be one of the largest Universities in Greece. In this context, it has attracted a significant number of research programs funded by the EU as well as national and private resources. The research team of ACTIVATE consists from two DUTH academics, three PhD candidates and two MSc students..

Theofilos A. Papadopoulos thpapad@ee.duth.gr

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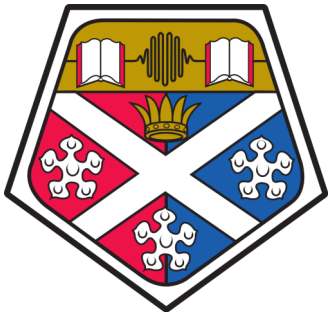

University of Strathclyde (UoS)

The D-NAP laboratory of the Institute for Energy and Environment provides an environment for research, development and testing of smart grid functions incorporating PHIL functionalities with real-time simulators. Also, experts in the topics related to power systems modeling and near real-time dynamic security assessment from UoS, will participate in the development of ACTIVATE network monitoring techniques.

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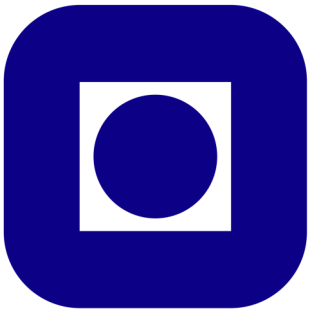

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Experts from Department of Electric Power Engineering of NTNU will contribute on the development and testing of the three-phase converter. NTNU experts are specialized in the area of wide band gap power converters design, gate and base driver designs for WBG devices, as well as dc-breaker concepts for MV and HVDC systems.

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 2 December 2020

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Current Project Progress

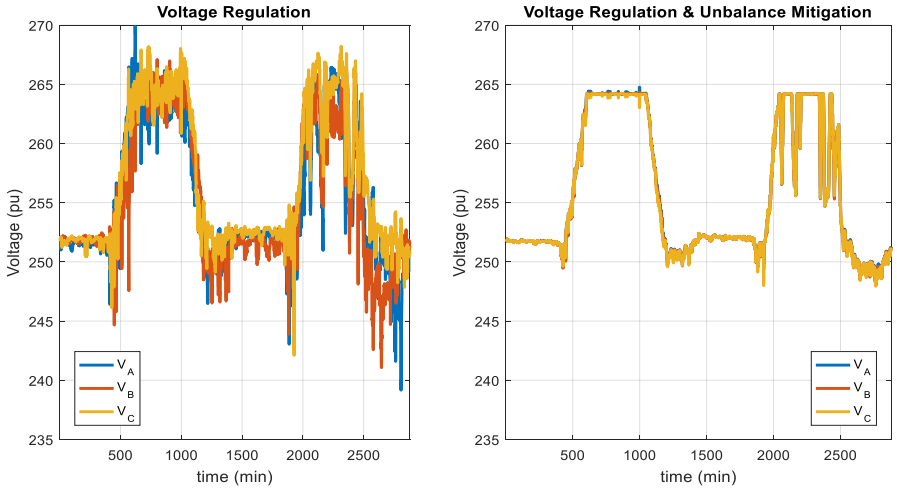
Ancillary services solutions for DSOs and TSOs

In the context of ACTIVATE, **enhanced decentralized control strategies** have been developed, tackling on a local level technical issues related to the penetration of DRESs into the existing distribution grids, such as **overvoltages, voltage unbalances,** and **overloading of network equipment**. In particular:

a) A local controller has been designed to determine the response of battery energy storage (BES) systems and DRES to electrical system changes, by using only parameters available at the point of connection of each unit with the grid. The controller exploits the reactive power capability of DRESs and the storage capacity of the ESSs to **tackle under-** and **overvoltages** in distribution networks.

b) A **voltage unbalance mitigation** control scheme for the inverters of DRES and BES units has been developed. The proposed method introduces a virtual conductance for the negative and zero sequence that affects the level of voltage unbalance mitigation capability of each inverter.

c) A **congestion management scheme** has been designed to tackle the overloading of network equipment. The developed scheme uses the available active and reactive power of BES systems to maintain the line and transformer currents within permissible limits. It is worth mentioning that priority is given to the reactive power to reduce the stress on the BES.



Main lessons learnt

1. The performance of the **local controller** has been evaluated by means of quasi-static simulations. Comparisons with the well-established decentralized solutions, $Q(V)$, $\cos\varphi(P)$, revealed its superiority in terms of voltage regulation and losses.

2. The developed **voltage unbalance control** can efficiently mitigate voltage unbalance, acting in cooperation with the local controller voltage regulation strategy without affecting its performance.

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Real-time network monitoring and operating techniques

A main task of the project is to examine online monitoring techniques for the analysis of Active Distribution Networks (ADNs). Towards this objective, a measurement-based multi-channel identification method has been developed constituting the core of a three-level monitoring architecture that will be designed within ACTIVATE. In detail:

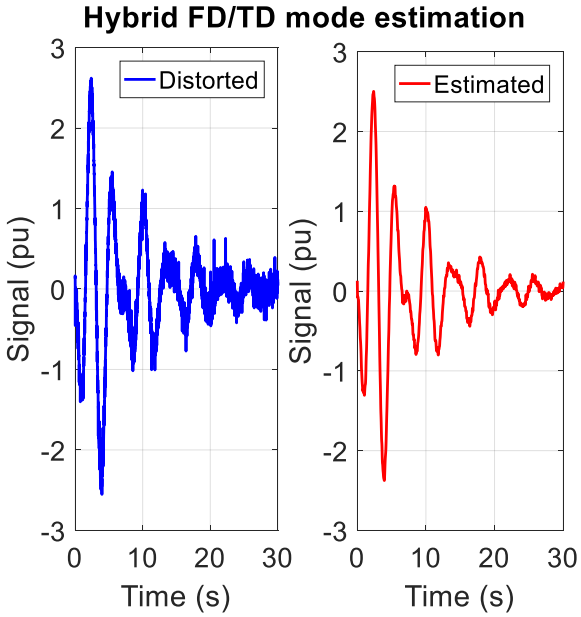
a) Several real-time **measurement-based identification techniques** for the estimation of the network **modal parameters** at the LV/MV/HV levels have been examined. Among them, the Prony, Matrix Pencil (MP), Vector Fitting (VF), Hybrid FD/TD, etc..

b) Different **signal pre-processing methods** have been tested to facilitate the application of system identification models to real-field conditions. The analysis included the investigation of different types of filtering techniques, types of noise, event-detection techniques, and time alignment and signal synchronization methods

c) A **multi-channel** measurement-based identification method based on the Hybrid FD/TD technique has been developed. Several measurements, acquired from different network buses are processed together to derive network modal estimates and to develop reduced order equivalent models, describing the dynamic behavior of the power system.

Main lessons learnt

1. Initial results revealed that the **Hybrid FD/TD**, **VF** and **MP** methods provide the most accurate mode estimates when stable or sustained oscillations are examined. They are also very robust considering noisy conditions, the type and the level of the examined response.
2. The Hybrid FD/TD can be efficiently used for cases where in the recorded signal missing data or outliers exist. The method also filters out automatically noise very efficiently.
3. **Multi-channel** techniques present higher accuracy compared to single-channel analysis, reducing significantly the impact of noise, canceling also out erroneous mode estimates that may occur.



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Communication & Dissemination activities

55th International Universities Power Engineering Conference, UPEC 2020

Initial results obtained from the ACTIVATE project were presented in the paper entitled '*Viability Assessment of PV Systems in University Campuses Under the Net-Metering Policy*' presented in UPEC 2020 on 1-4 September 2020. In this paper, the techno-economic assessment of the net-metering policy in medium-voltage (MV) prosumers is discussed. Results from various scenarios are analysed and remarks are drawn regarding the cost-efficiency of net-metering policy of MV prosumers in Greece. In the future steps, the effect of the ACTIVATE voltage regulation techniques on the cost-efficiency of MV prosumers under the net-metering scheme will be investigated.

12th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion, MEDPOWER 2020

In MEDPOWER 2020 our paper entitled '*Impact Assessment framework of PV-BES Systems to Active Distribution Networks*' was presented, proposing a framework for the assessment of the impact of PV and BES systems on voltage profiles and power losses of active distribution networks as well as of the utilization of battery BES. The proposed framework will be used to evaluate the developed project decentralized voltage regulation techniques, as well as the proposed holistic approach within ACTIVATE. Our paper received the best paper award taking into account both the content of the paper and the quality of the presentation!

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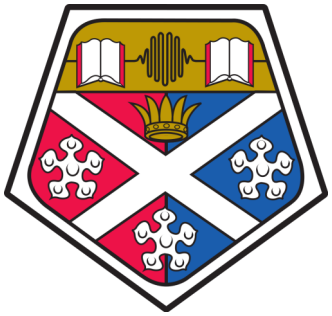

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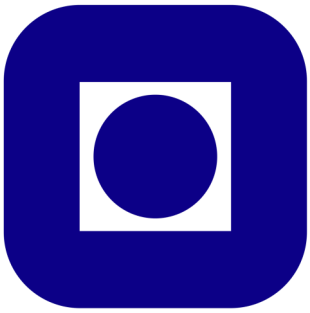

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Issue No 3 **June 2021**

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Project Progress So Far

Ancillary services solutions for DSOs and TSOs

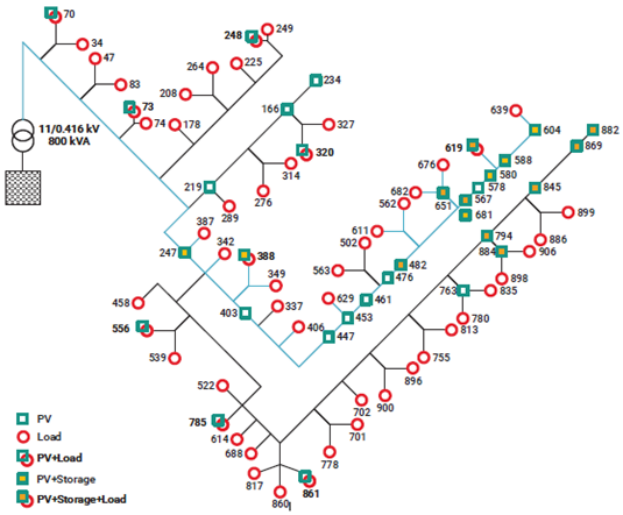
A **unified control strategy for voltage regulation (VR), voltage unbalance mitigation (VUM) and congestion management** (CM) has been developed in ACTIVATE. The proposed architecture uses the reactive power of DRESs and the active/reactive power of distributed battery energy storage systems (DBESSs). The distinct characteristic of the proposed approach is that the implemented algorithms are decoupled allowing the individual handling of VR, VUM, and CM issues. The performance of the proposed control strategy has been tested in the IEEE LV European benchmark network and was compared against well-established control schemes proposed in the literature, including:

a) A control scheme dealing with a consensus algorithm for voltage regulation using only the positive-sequence active power of DBESSs.

b) A control scheme implementing droop-based *Q*(*V*) - *P*(*V*) method proposed to control the output power of both PVs and DBESSs.

c) A phase-based implementation of the consensus algorithm for VR using only the active power of DBESSs.

d) A droop-based *P*(*V*) solution with and without VUM capabilities



Main lessons learnt

1. The developed algorithms are characterized by **low-complexity**, **reduced monitoring needs** and **limited exchange of information**, facilitating their integration to the real distribution grids
2. The proposed approach outperforms the existing solutions in terms of **reduced network losses**, **improved DBESS utilization** and ability to **concurrently address VR, VUM, and CM issues**

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Project Progress So Far

Power smoothing techniques

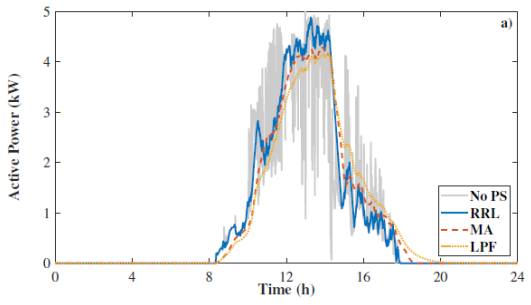
The vast majority of DRESs consists of photovoltaics and wind turbines. Their common characteristic is the highly variable output power depending mainly on the availability of the primary energy source. This variability affects the reliable operation of distribution networks, since voltage fluctuations may occur affecting the performance of voltage-sensitive devices. Generally, the power smoothing capability can be provided by adopting at least one of the following solutions:

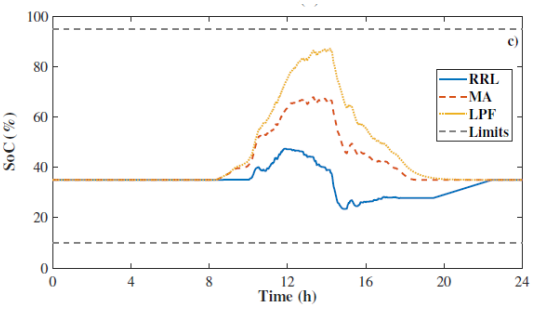
- control of DRESs to operate below the MPP
- active participation of loads to mitigate the variable output power of DRESs
- utilization of ESSs by applying smoothing techniques as **filtering-based algorithms**, e.g., moving-average (MA) and low-pass filtering (LPF), where the output power is filtered to reduce the frequency spectrum of the injected power or use **ramp rate controls** (RRC), where the output power saturates when the calculated ramp rate reaches a specific limit.

In ACTIVATE in order to develop an efficient **power smoothing control strategy** the impact of the most well-established power smoothing techniques (LPF, MA, and RRC) on the long-term performance of BESS has been investigated systematically. In the examined studies, **BESS aging** has been also considered by applying the rainflow cycle-counting algorithm to estimate the cycle aging, and thus BESS capacity degradation.

Main lessons learnt and future work

1. The most critical parameters that affect the **power smoothing** capability and the **BESS aging** have been identified by applying parametric analysis with high-resolution measurements.
2. At least one **BESS replacement** is needed with the PV lifetime.
3. **RRC outperforms** MA and LPF-based methods in terms of required BESS sizing, achieved smoothing, and capacity degradation.
4. In future **work** additional parameters that may affect the BESS capacity degradation, e.g., BESS temperature will be investigated. Furthermore, the impact of recently proposed sophisticated Kalman-filter and wavelet techniques will be examined.





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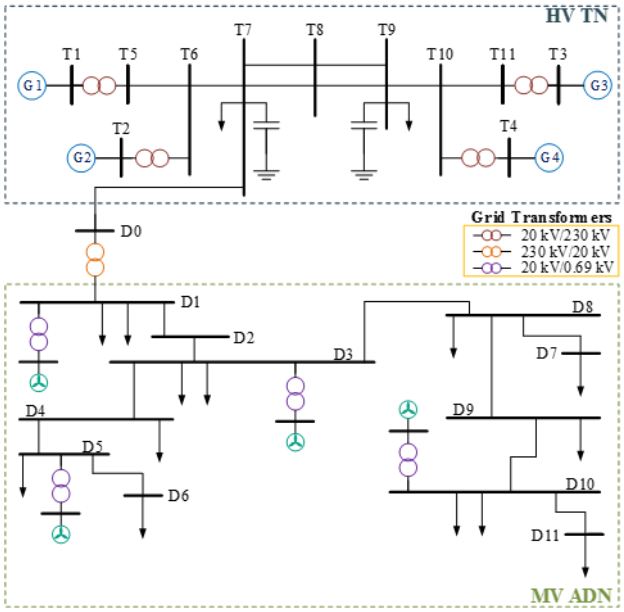
Project Progress So Far

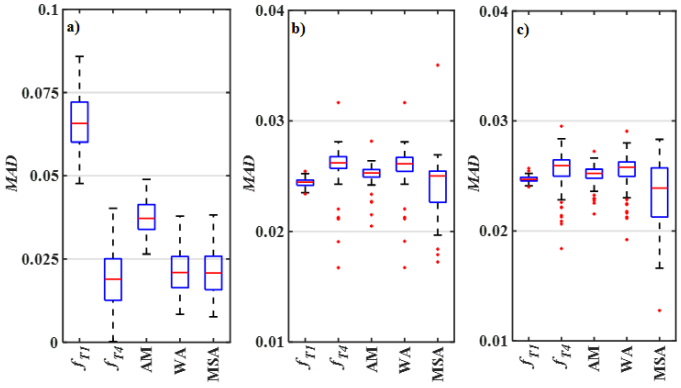
Multi-channel measurement-based identification methods

Vital information regarding grid oscillations and stability margins of the power system can be provided by mode estimation. Mode estimation can be implemented in terms of **single-channel analysis** (system responses are analyzed as single entities) and **multi-channel analysis** (a set of measured signals is processed). Generally, multi-channel analysis results into more accurate and generic results, by either analyzing **multiple signals simultaneously** (multi-signal fitting) or single-channel analysis is applied to each of the signals to derive modal estimates and the final estimates are calculated by **means of arithmetic mean** or **weighted averaging**. In this context, within ACTIVATE the following tasks have been done:

- The applicability and performance of different **multi-channel identification** approaches has been evaluated
- The analysis has been implemented in a **combined transmission-active distribution network (ADN)** to investigate mode propagation as well as the applicability of multi-signal architectures for the analysis of complex **TN - ADN** interactions
- Comparative analysis between **single-** and **multi-channel** approaches has been performed



Main lessons learnt



1. **Inter-area modes** can be identified by using responses from both the TN and ADNs
2. **Multi-channel techniques** are more accurate, significantly reducing the impact of noise, canceling out also erroneous mode estimates (single channel analysis)
3. All multi-channel techniques present similar accuracy. **VF** and **MP** provide the most accurate estimates and are practically not affected from SNR .
4. **VF** is the most suitable for **close to real time applications**, presenting **low computational burden** and **high immunity to noise**.

H.F.R.I. Hellenic Foundation for Research & Innovation
http://www.elidek.gr
The project is funded by the Hellenic Foundation for Research & Innovation

Communication & Dissemination activities

Conference on Power System Transients, IPST 2021

In our conference paper entitled '***Multi-channel measurement-based identification methods for mode estimation in power systems',*** the applicability and the performance of the most known multi-channel measurement-based identification approaches for the modal analysis of modern power systems incorporating active distribution networks was analysed. The paper was presented in the IPST 2021 on 6-10 June 2021. The paper has been also accepted for publication in **Electric Power Systems Research journal** as part of the Special Issue "*Proceedings of the 15th International Conference on Power Systems Transients (IPST 2021)*".

URL: *https://doi.org/10.1016/j.epsr.2021.107157*

Journal publication

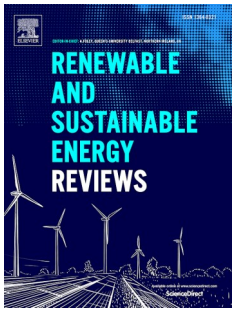
The project paper entitled '***Methodology for the Techno-Economic Assessment of Medium-Voltage Photovoltaic Prosumers Under Net-Metering Policy***' was published in IEEE Access. The paper presents a techno-economic assessment methodology to evaluate the viability of net-metering policy in medium-voltage prosumers, incorporating different decentralized voltage regulation techniques contained in the PV systems of the prosumers.

URL: *https://doi.org/10.1109/ACCESS.2021.3073780*

Journal publication

As a results of our D1.1 "Review of the state-of-the-art and technical solutions" the review paper '*Ancillary services in active distribution networks: A review of technological trends from operational and online analysis perspective*' was published in **Renewable and Sustainable Energy Reviews** of **Elsevier**.

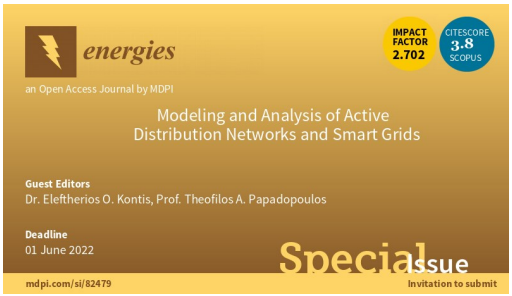
URL: *https://doi.org/10.1016/j.rser.2021.111198*



Special Issue

Within the frame of **ACTIVATE** we are guest editing the Special Issue entitled "*Modeling and Analysis of Active Distribution Networks and Smart Grids*", which will be published in ***Energies MDPI***.

URL: *https://www.mdpi.com/journal/energies/special_issues/Active_Distribution_Networks*



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Project Consortium

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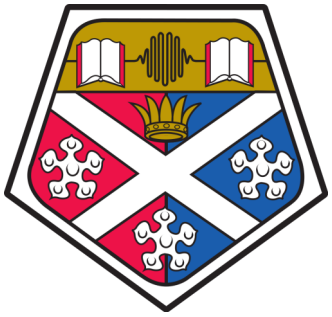

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The D-NAP laboratory of the Institute for Energy and Environment provides an environment for research, development and testing of smart grid functions incorporating PHIL functionalities with real-time simulators. Also, experts in the topics related to power systems modeling and near real-time dynamic security assessment from UoS, will participate in the development of ACTIVATE network monitoring techniques.

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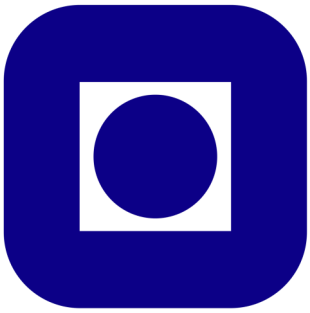

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Experts from Department of Electric Power Engineering of NTNU will contribute on the development and testing of the three-phase converter. NTNU experts are specialized in the area of wide band gap power converters design, gate and base driver designs for WBG devices, as well as dc-breaker concepts for MV and HVDC systems.

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 4 December 2021

Dear Reader,

It is our pleasure to welcome you to the fourth edition of the ***ACTIVATE*** **Newsletter!**
"ACTIVATE—Ancillary services in active distribution networks, based on monitoring and control techniques" is an ambitious research project funded by the Hellenic Foundation for Research & Innovation, and is being implemented by a consortium of 4 highly capable and well established Universities.

If you would like to keep up with all the latest developments of our project follow us on Facebook, LinkedIn & Researchgate.

Kind Regards,
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About ACTIVATE

ACTIVATE will propose the design of *hybrid control strategies*, combining features of centralized and decentralized concepts to improve the performance of the network operation. In order to extend the applicability of the proposed hybrid strategy also a *virtual inertia* scheme will be incorporated to modify the control strategies of distributed renewable energy sources (DRES) converters. To enhance further the adaptability of the provided virtual inertia and to modify the overall dynamic response of the power system, *energy storage systems* will be used with novel congestion management techniques.

Additionally, an innovative *network monitoring architecture* will be proposed to determine the converter virtual-inertia parameters and coordinate the hybrid control strategy operation.

Finally, to facilitate the implementation and application of the proposed scheme in existing distribution grids, a *prototype three-phase converter* will be developed.

H.F.R.I. Hellenic Foundation for Research & Innovation
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This project has received funding from the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant (Project Number: HFRI-FM17-229).

DEMOCRITUS UNIVERSITY OF THRACE

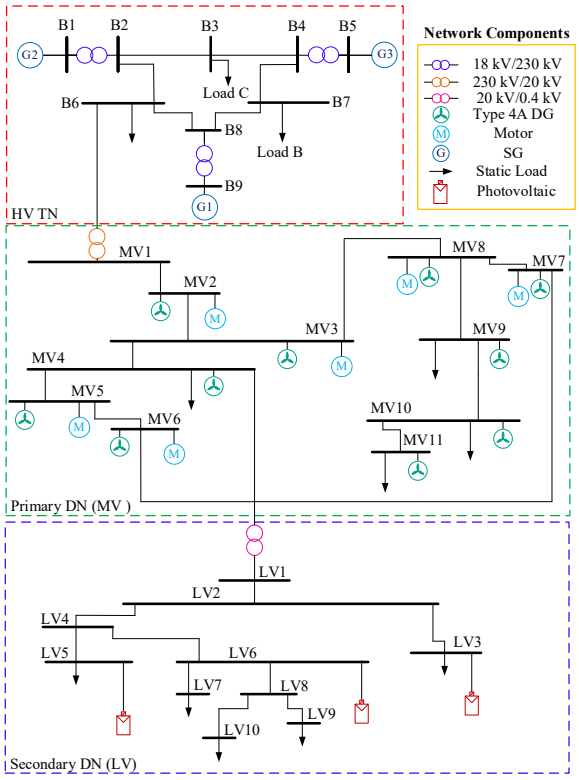
Project Progress So Far

Three-level Distributed Architecture for the Real-time Monitoring of Modern Power Systems

A **three-level distributed architecture** has been developed in ACTIVATE for the coordinated dynamic analysis and evaluation performance of the transmission, primary and secondary distribution networks (DNs), by exploiting ambient and transient response measurements. The proposed architecture supports several online and offline applications, including:

1. small-signal stability analysis
2. transient stability analysis
3. frequency stability analysis as well as system inertia estimation and
4. dynamic equivalencing

A set of **measurement-based analysis tools** are incorporated, consisting of an event triggering and classification algorithm, a signal processing procedure and a unified **autoregressive-moving-average with exogenous inputs (ARMAX)**-based methodology by using measured data.



Main lessons learnt

1. The proposed ARMAX modelling approach can accurately estimate the dominant modes of oscillation and mode shapes by using measured data recorded both at the **transmission** and also at the **distribution network**.
2. The developed ARMAX models can be applied to **ambient** and **transient response** data to estimate the **inertia** of synchronous generators and of the overall system.
3. A **multi-channel cluster analysis method** based on k-medoids has been proposed to calculate representative modal parameters.
4. ARMAX modelling can be used to derive **dynamic equivalent models** of DNs from both ambient data and transient responses.
5. The proposed architecture has extended the application of stability indices to analyze the dynamic behavior of active distribution networks.

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The project is funded by the Hellenic Foundation for Research & Innovation

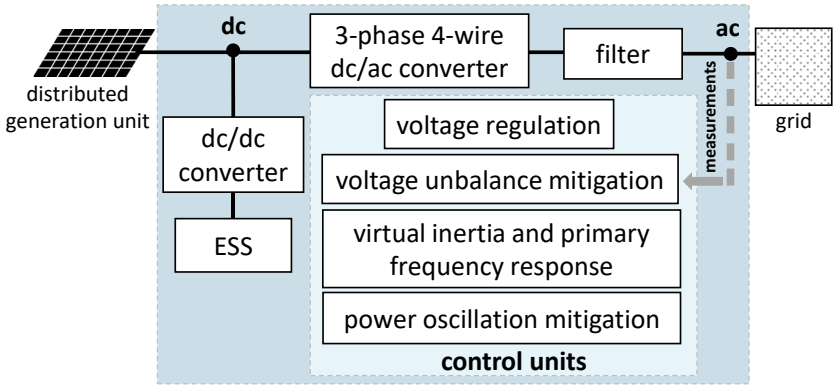
Project Progress So Far

Power converter design

A novel 3-phase converter system has been designed consisting of a three-phase four-wire dc/ac converter, a series dc/dc converter, a battery storage system (BSS), an output filter and four control units enabling the provision of the following **ancillary services** to DSOs:

- voltage regulation
- voltage unbalance mitigation
- virtual inertia and primary frequency response
- power oscillations mitigation at the output of the converter

The prototype converter incorporates not only **control** but also **monitoring functions**, similarly to distribution phasor measurement units (D-PMUs). In the first stops of the prototype converter development, the converter performance has been evaluated under different operating conditions, through simulations in simple test network configurations.



Main lessons learnt and future work

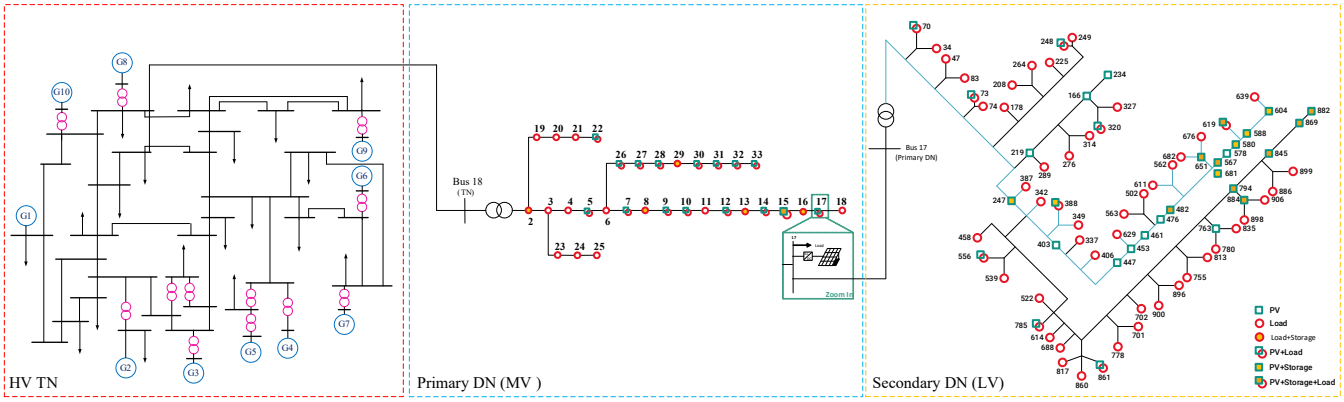
1. The various control units of the converter are **decoupled**, removing any interference among them. This subsequently facilitates their accurate and efficient handling.
2. The converter can mitigate voltage unbalance even for low levels (<1%) of negative- and zero-sequence voltage.
3. Next steps include the development and performance evaluation of the converter by conducting laboratory experiments and power hardware in the loop simulations in benchmark test systems.

The project is funded by the Hellenic Foundation for Research & Innovation
http://www.elidek.gr

Project Progress So Far

Validation of the proposed architecture with simulation and experimental results

The **control strategies**, the **monitoring architecture** and the **prototype converter** developed in ACTIVATE will be validated by means of **simulation and laboratory tests**. Towards this objective, different scenarios for both **steady-state** and **dynamic analysis** have been implemented in terms of simulations. Results have been obtained from a **combined transmission and distribution (T&D) network,** exploiting well-known benchmark electrical networks. The power system under study consists of a high voltage (HV) transmission network (TN), as well as a primary medium voltage (MV) and a secondary low voltage (LV) distribution network (DN). Topologies and main conclusions drawn from the aforementioned analysis will be used for the preparation of the **PHIL laboratory experiments**, planned to take place in the partner University of Strathclyde.



Future work

1. The performance of the **voltage regulation** and **congestion management** techniques on the LV and the MV DNs will be assessed. Technical problems such as overvoltages, overloading of equipment, etc., will be recorded and analyzed.
2. Simulated dynamic responses acquired from specific network buses will be used to **estimate modal parameters** and derive reduced order **equivalent models**, in order to validate the performance of the proposed three-level distributed architecture.
3. A portfolio of base case **laboratory test scenarios** will be defined, by exploiting the main conclusions drawn from the simulation results.
4. The performance of the proposed three-level distributed architecture and the functionalities of the prototype converter will be tested using **experimental results** acquired at a dynamic power system laboratory.

H.F.R.I. Hellenic Foundation for Research & Innovation
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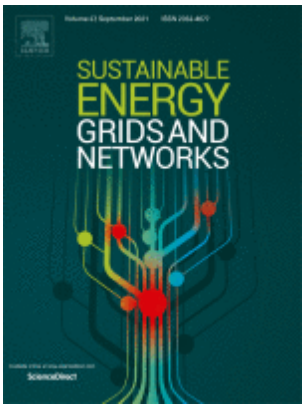
Communication & Dissemination activities

56th International Universities Power Engineering Conference, UPEC 2021

In our conference paper entitled "***Impact of Power Smoothing Techniques on the Long-Term Performance of Battery Energy Storage Systems,'*** the impact of the most well-established power smoothing techniques on the long-term performance of battery energy storage systems focusing on capacity degradation has been investigated. The paper was presented in the **56th International Universities Power Engineering Conference** held virtually and hosted by TEESSIDE UNIVERSITY, UK. Between 31/08 – 03/09/2021.

URL: *https://10.1109/UPEC50034.2021.9548172*

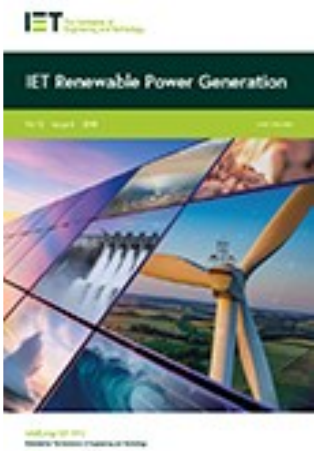
Journal publication



The project paper entitled "***Assessment of load and generation modelling on the quasi-static analysis of distribution networks***" was published in **Sustainable Energy, Grids and Networks**. The paper investigates the effect of different load and generation modelling approaches on the quasi-static analysis of distribution networks .

URL: *https://doi.org/10.1016/j.segan.2021.100509*

Journal publication



Our MEDPOWER 2020 conference paper entitled ***"Impact Assessment framework of PV-BES Systems to Active Distribution Networks"*** was selected for a special issue and was published in the *IET Renewable Power Generation journal*. The paper proposes a framework for the assessment of the impact of PV and BES systems on voltage profiles and power losses of active distribution networks as well as of the utilization of battery BES. The proposed framework is already used to evaluate the developed project decentralized voltage regulation techniques, as well as the proposed holistic approach developed within ACTIVATE.

URL: *https://doi.org/10.1049/rpg2.12313*

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Project Consortium

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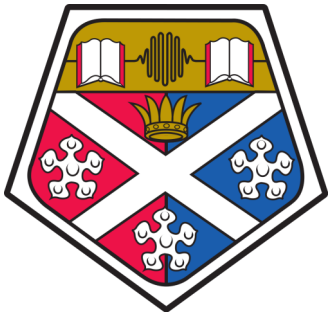

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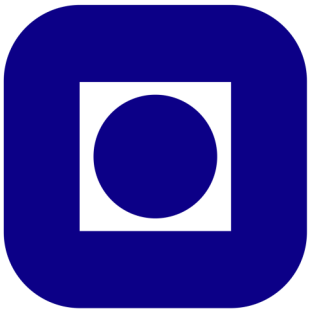

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 5 June 2022

Dear Reader,

It is our pleasure to welcome you to the fifth edition of the ***ACTIVATE*** **Newsletter!**
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Additionally, an innovative *network monitoring architecture* will be proposed to determine the converter virtual-inertia parameters and coordinate the hybrid control strategy operation.

Finally, to facilitate the implementation and application of the proposed scheme in existing distribution grids, a *prototype three-phase converter* will be developed.

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DEMOCRITUS UNIVERSITY OF THRACE

Project Progress So Far

Prototype power converter design

A power converter system has been designed consisting of a three-phase four-wire dc/ac converter, a series dc/dc converter, a battery storage system (BSS), an output filter and four control units enabling the provision of the following **ancillary services** to DSOs:

- voltage regulation
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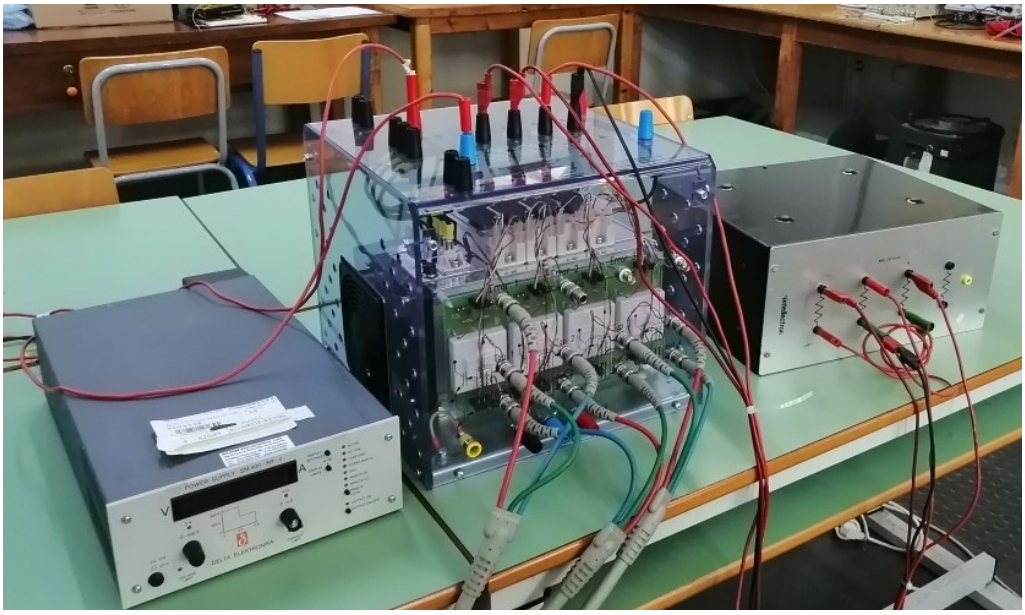
The converter incorporates not only **control** but also **monitoring functions**, similarly to distribution phasor measurement units (D-PMUs).



Main lessons learnt and next steps

1. Laboratory experiments carried out in DUTH have evaluated and verified the performance of the converter system.
2. We have applied for a **National Patent** for the proposed system design.
3. Next steps include the evaluation of the proposed system by conducting also **power hardware in the loop simulations**.

The project is funded by the Hellenic Foundation for Research & Innovation
http://www.elidek.gr

Project Progress So Far

Validation of the proposed control and monitoring architecture with simulation and experimental results

The **control strategies**, the **monitoring architecture** and the **prototype converter** developed in ACTIVATE will be validated by means of **simulation and laboratory tests**.

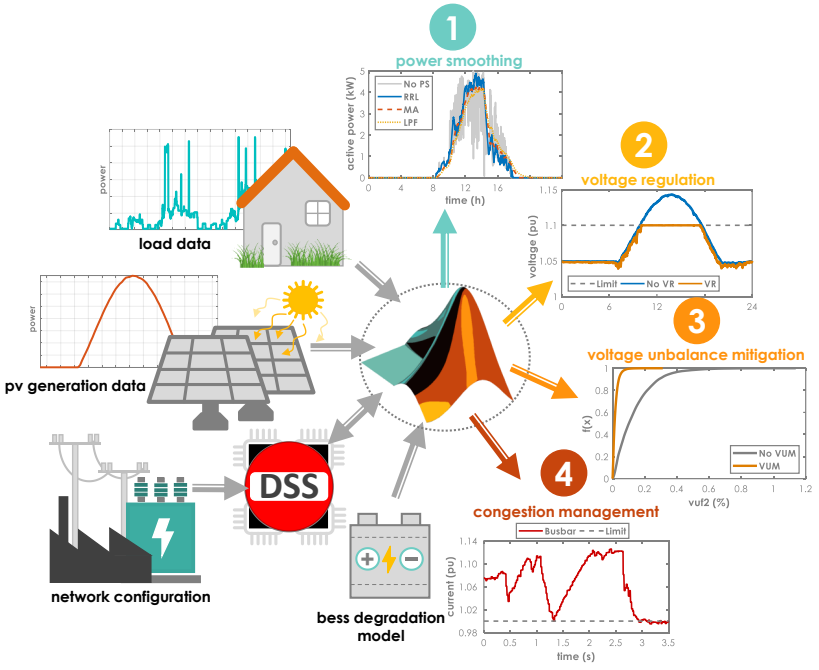
Towards this objective, the performance of the designed ACTIVATE **ancillary services (ASs)**, are tested by means of simulations in a combined transmission, primary and secondary distribution network, designed specifically for the needs of ACTIVATE. Some of the provided ASs include **(1) power smoothing**, **(2) voltage regulation**, **(3) voltage unbalance mitigation** and **(4) congestion management**. In the investigations, a calendar and cyclic battery degradation model is also incorporated into quasi-static simulations to replicate real operating conditions and assess the long-term impact of the ASs on the BSS lifetime.

Using the combined transmission, primary and secondary distribution network model, dynamic simulations were also conducted to test the features of the proposed three-level distribution architecture. At this step, our work focuses on the development of **digitally twin distribution network equivalent** models and the application of the proposed ARMAX method for the estimation of oscillatory modes in experimental results.

Lessons learnt

Investigations are ongoing. From the analysis conducted up to now it was shown that:

1. the proposed power smoothing, voltage regulation, voltage unbalance mitigation and congestion management ASs can be harmoniously combined and solve problems in active distribution networks,
2. the provision of multiple ASs does not necessarily lead to accelerated BSS capacity degradation compared to the case where less ASs are considered,
3. BSS aging is mainly influenced my the mean SOC operating value as higher mean SOC leads to accelerated BSS degradation,
4. the ARMAX method can accurately identify oscillatory modes by using measurements obtained at all levels of the grid.



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Communication & Dissemination activities

XXII Power Systems Computation Conference (PSCC)

Our paper "**A Multi-Signal Least-Squares-Based Optimization Technique for the Identification of Power System Oscillatory Modes**" has been accepted for presentation in the XXII Power Systems Computation Conference (PSCC) that will take place in June in Porto, Portugal. In this paper, a multi-signal identification technique is proposed to estimate oscillatory modes contained in power system responses. The proposed technique utilizes least-squares optimization to analyse simultaneously several system measurements and determine close-to-real-time the modal parameters of the examined power system.

5th International Conference on Smart Energy Systems and Technologies (SEST)

Our paper "**Assessing the Provision of Ancillary Services Considering BSS Capacity Degradation**" has been accepted for presentation in the 5th International Conference on Smart Energy Systems and Technologies (SEST) that will take place in September in Eindhoven, the Netherlands.

In this paper, a methodology for the assessment of the provision of voltage regulation and power smoothing services by PV-BSS systems is presented, by taking into account the capacity degradation of BSS. The proposed framework involves quasi-static simulations incorporating the operating conditions of the distribution network. A battery aging model is used to estimate the BSS capacity loss caused by both the calendar and the cyclic aging mechanisms.

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Communication & Dissemination activities

Journal publication

The project paper entitled '**A Three-Level Distributed Architecture for the Real-Time Monitoring of Modern Power Systems**' was published in IEEE Access. The paper is the result of the research effort within WP3 and describes the ACTIVATE three-level distributed architecture for the monitoring and analysis of modern power systems.

URL: *https://doi.org/10.1109/ACCESS.2022.3159340*

Journal publication

ACTIVATE has also contributed to the development of a methodology for identifying the applicability range in terms of accuracy and generalization capability of several conventional and newly developed equivalent models for the dynamic analysis of modern distribution networks. The results of this work were published in the journal paper entitled '***Methodology for Evaluating Equivalent Models for the Dynamic Analysis of Power Systems***' in IEEE Trans. On Power Delivery

URL: *https://10.1109/TPWRD.2022.3167136*

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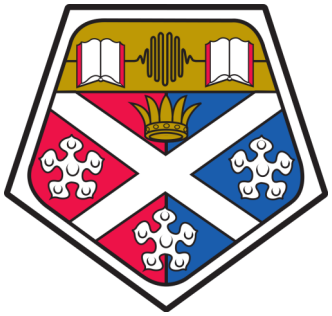

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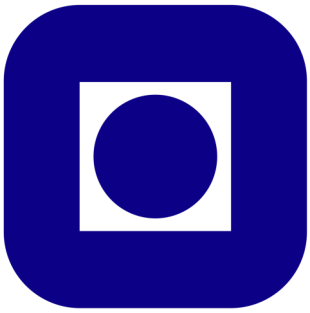

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 6 December 2022

Dear Reader,

One step before the end of ***ACTIVATE*** *"Ancillary services in active distribution networks, based on monitoring and control techniques"* it is our pleasure to welcome you to the sixth edition of the ***project*** **Newsletter!**
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The ACTIVATE Research Team

About ACTIVATE

ACTIVATE will propose the design of *hybrid control strategies*, combining features of centralized and decentralized concepts to improve the performance of the network operation. In order to extend the applicability of the proposed hybrid strategy also a *virtual inertia* scheme will be incorporated to modify the control strategies of distributed renewable energy sources (DRES) converters. To enhance further the adaptability of the provided virtual inertia and to modify the overall dynamic response of the power system, *energy storage systems* will be used with novel congestion management techniques.

Additionally, an innovative *network monitoring architecture* will be proposed to determine the converter virtual-inertia parameters and coordinate the hybrid control strategy operation.

Finally, to facilitate the implementation and application of the proposed scheme in existing distribution grids, a *prototype three-phase converter* will be developed.

H.F.R.I. Hellenic Foundation for Research & Innovation
http://www.elidek.gr

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DEMOCRITUS UNIVERSITY OF THRACE

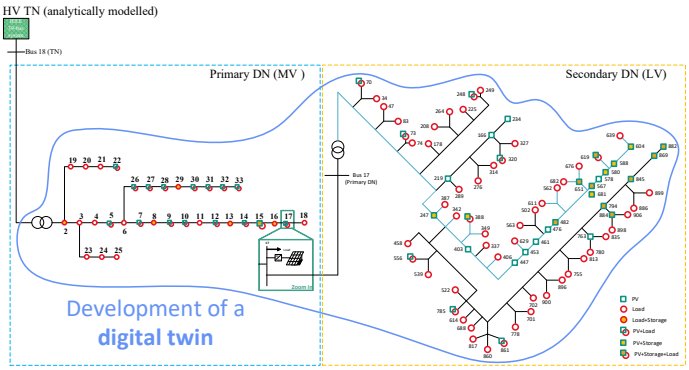
Project Progress So Far

Validation of the proposed control and monitoring architecture with simulation and experimental results

The **control strategies**, the **monitoring architecture** and the **prototype converter** developed in ACTIVATE are validated by means of **simulation and laboratory tests**.

Towards this objective, the performance of the designed ACTIVATE **ancillary services (ASs)**, are tested by means of simulations in a combined transmission, primary and secondary distribution network, designed specifically for the needs of ACTIVATE. Some of the provided ASs include **(1) power smoothing**, **(2) voltage regulation**, **(3) voltage unbalance mitigation** and **(4) congestion management**.

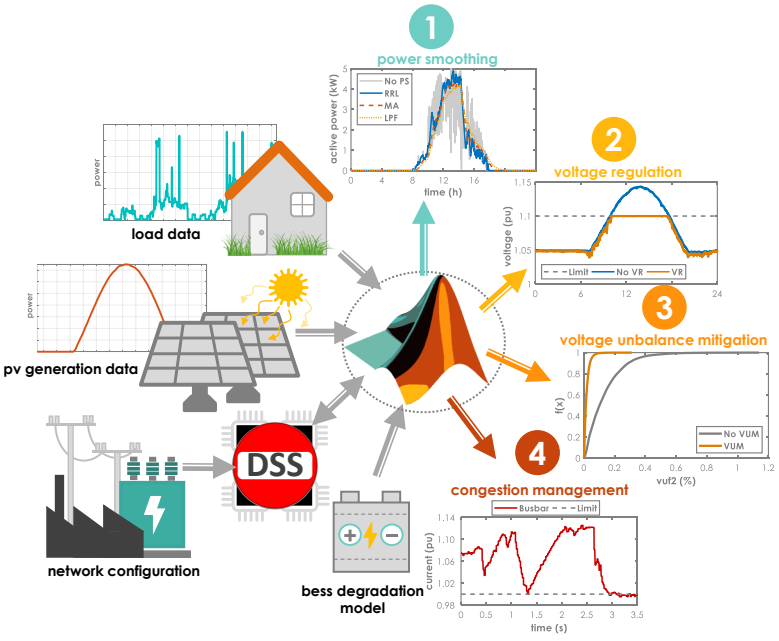
Using the combined transmission, primary and secondary distribution network model, dynamic simulations were also conducted to test the features of the proposed three-level distribution architecture. At this step, our work focuses on the development of **digitally twin distribution network equivalent** models in experimental results.



Lessons learnt

Investigations are ongoing. From the analysis conducted up to now it was shown that:

1. the proposed power smoothing, voltage regulation, voltage unbalance mitigation and congestion management ASs can be applied to both primary and secondary distribution networks and solve the corresponding problems,
2. the designed three-phase four-wire DC/AC converter can be efficiently operate in unbalanced low-voltage distribution networks. Its performance has been evaluated both in terms of software simulations and also of hardware-in-the-loop (HIL) simulations in the partner University of Strathclyde,
3. by selecting an appropriate equivalent model, a digital twin for the analytically modelled primary and secondary distribution networks, which accurately replicates their dynamic behavior, can be developed.



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57th International Universities Power Engineering Conference, UPEC 2022

Our paper "**Combined Transmission and Distribution Test System for Small-Signal Stability Analysis: Initial Results**" was presented in UPEC 2022 on 30 August—2 September 2022. In this paper, a combined transmission and distribution network synthetic model is developed to investigate the dynamic performance of an overall power system and analyse the interactions between its constituent parts. Conventional and modern power system configurations are considered. The small-signal stability of the power system is investigated by means of eigenvalue analysis and by applying the matrix pencil algorithm to identify the dominant modes contained in the dynamic responses.

URL: *https://doi.org/10.1109/UPEC55022.2022.9917807*

5th International Conference on Smart Energy Systems and Technologies (SEST)

Our paper "**Assessing the Provision of Ancillary Services Considering BES Capacity Degradation**" was presented in the 5th International Conference on Smart Energy Systems and Technologies (SEST) that took place in September 2022 in Eindhoven, the Netherlands. In this paper, a methodology for the assessment of the provision of voltage regulation and power smoothing services by PV-BES systems is presented, by taking into account the capacity degradation of BES. The proposed framework involves quasi-static simulations incorporating the operating conditions of the distribution network. A battery aging model is used to estimate the BES capacity loss caused by both the calendar and the cyclic aging mechanisms. **Our paper was one out of the total three papers that received the best paper award!**

URL: *https://doi.org/10.1109/SEST53650.2022.9898493*

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Communication & Dissemination activities

2nd International Conference on Energy Transition in the Mediterranean Area (SYNERGYMED)

Two of our papers were presented in the 2nd International Conference on Energy Transition in the Mediterranean Area (SYNERGYMED) that took place in October 2022 in Thessaloniki, Greece.

The first paper is entitled "**Identification of Closed-spaced and Poorly-damped Oscillatory Modes in Ringdown Responses of Power Systems**" investigating the performance of Prony, eigenvalue realization, matrix pencil and vector fitting methods in the identification of closely spaced in frequency and poorly damped modes by using synthetic signals.

URL: *https://doi.org/10.1109/SyNERGYMED55767.2022.9941458*

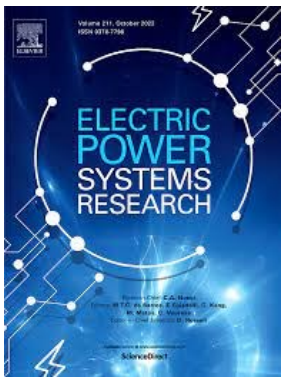
In the second paper entitled "**Wavelet-based Automatic Processing of Dynamic Responses for the Development of Dynamic Load Models**" an efficient method for event detection and noise reduction of dynamic responses based on Wavelet Transform is proposed, aiming to improve this way the quality of data used for the derivation of load models.

URL: *https://doi.org/10.1109/SyNERGYMED55767.2022.9941470*

Journal publication

The project paper entitled "**A unified control strategy for voltage regulation and congestion management in active distribution networks**" was published in Elsevier's Electric Power Systems Research Journal. The paper is the result of the research effort within WP2 and describes the ACTIVATE unified control strategy for unbalanced low voltage distribution grids to providing ancillary services of voltage regulation, voltage unbalance mitigation and congestion management control.

URL: *https://doi.org/10.1016/j.epsr.2022.108648*



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Project Consortium

Democritus University of Thrace (DUTH)

Power Systems and Electrical Machines laboratories are involved in ACTIVATE. DUTH is proud to be one of the largest Universities in Greece. In this context, it has attracted a significant number of research programs funded by the EU as well as national and private resources. The research team of ACTIVATE consists from two DUTH academics, three PhD candidates and two MSc students..

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ARISTOTLE UNIVERSITY OF
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Grigoris Papagiannis gpapagia@ece.auth.gr

University of Strathclyde (UoS)

The D-NAP laboratory of the Institute for Energy and Environment provides an environment for research, development and testing of smart grid functions incorporating PHIL functionalities with real-time simulators. Also, experts in the topics related to power systems modeling and near real-time dynamic security assessment from UoS, will participate in the development of ACTIVATE network monitoring techniques.

Graeme Burt graeme.burt@strath.ac.uk

Norwegian University of Science and Technology (NTNU)

Experts from Department of Electric Power Engineering of NTNU will contribute on the development and testing of the three-phase converter. NTNU experts are specialized in the area of wide band gap power converters design, gate and base driver designs for WBG devices, as well as dc-breaker concepts for MV and HVDC systems.

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ACTIVATE

Ancillary services in active distribution networks, based on monitoring and control techniques

Issue No 7 June 2023

Dear Reader,

One step before the end of ***ACTIVATE*** *"Ancillary services in active distribution networks, based on monitoring and control techniques"* it is our pleasure to welcome you to the seventh and last edition of the ***project*** **Newsletter!**
ACTIVATE is an ambitious research project funded by the Hellenic Foundation for Research & Innovation, and is being implemented by a consortium of 4 highly capable and well established Universities.

If you would like to keep up with all the latest developments of our project follow us on Facebook, LinkedIn & Researchgate.

Kind Regards,
The ACTIVATE Research Team

About ACTIVATE

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Additionally, an innovative *network monitoring architecture* is proposed to determine the converter virtual-inertia parameters and coordinate the hybrid control strategy operation.

Finally, to facilitate the implementation and application of the proposed scheme in existing distribution grids, a *prototype three-phase converter* has been developed.

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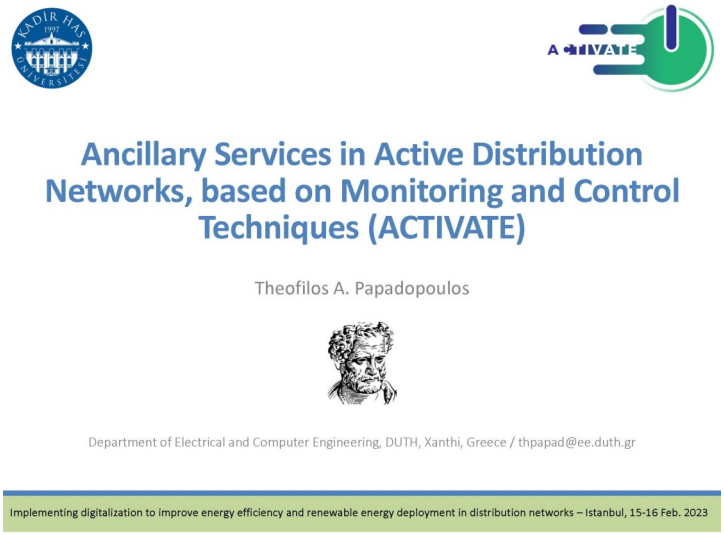
DEMOCRITUS UNIVERSITY OF THRACE

Communication & Dissemination activities

Participation at workshop “Implementing digitalization to improve energy efficiency and renewable energy deployment in distribution networks”

An overview and results of ACTIVATE were presented in the international workshop “**Implementing digitalization to improve energy efficiency and renewable energy deployment in distribution networks**”, organized in Kadir Has University in Istanbul, 14/02/2023-16/02/2023.

Researchers for academia and industry from Turkey UK, Greece and Kazakhstan were met and shared their experiences on issues related to active distribution networks, services and modelling.



DUTH Idea Accelerator Info Day

ACTIVATE participated in the **DUTH Idea Accelerator Info Day** presenting results of the project and most importantly the ACTIVATE prototype converter to the Democritus University of Thrace community

The workshop was organized in Xanthi during 28/02 – 03/03/2023.

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Communication & Dissemination activities

IPST2023
International Conference on Power Systems Transients
THESSALONIKI | 11-15.06.2023

International Conference on Power Systems Transients, IPST 2023

Our papers "**Application of a performance assessment method to identify the applicability range of distribution network equivalent models**" and "**Transient performance of a unified control system for the provision of ancillary services in low-voltage distribution networks**" were presented in IPST 2023 on 11 – 15 June 2023. Both papers have been also selected as journal papers in the Special Issue of the conference in Electric Power Systems Research (EPSR).

Scope of the **first paper** is to evaluate the applicability range of conventional equivalent models for the dynamic analysis of modern DNs by using a recently proposed performance assessment method.

In the **second paper** the ACTIVATE unified control system for the provision of ancillary services by distributed RES-BES systems is validated via tie-domain simulations.

Journal Publication

The results of WP5 have been published in the paper entitled "**Validation of a Holistic System for Operational Analysis and Provision of Ancillary Services in Active Distribution Networks**" in *Energies*, *MDPI*.

Scope of the paper and this WP was to present a validation of the overall ACTIVATE system, which is performed by using simulation and power-hardware-in-the-loop results in combined transmission and distribution network models.

energies

URL: https://doi.org/10.3390/en16062787

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Communication & Dissemination activities

ACTIVATE International workshop

As a closing event of **ACTIVATE,** an international workshop was organized on 19/05/2023 in the Department of Electrical & Computer Engineering in Democritus University of Thrace.

In the workshop, members of the research group from Democritus University of Thrace and Aristotle University of Thessaloniki presented the results of the project. Moreover, an invited speaker, Prof. **Emrulah Fatih Yetkin** from Kardir Has University, Istanbul Turkey gave a talk on topics relevant to ACTIVATE.

Students from DUTH and guest academics from Klaipėdos valstybinė kolegija / Higher Education Institution (KVK) also attended in the workshop.

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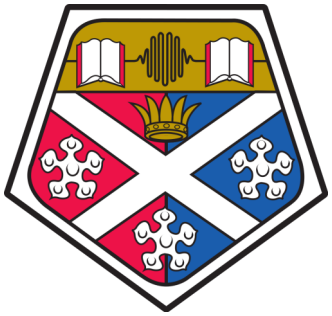

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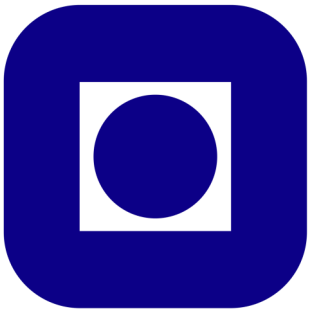

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