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,
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.

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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

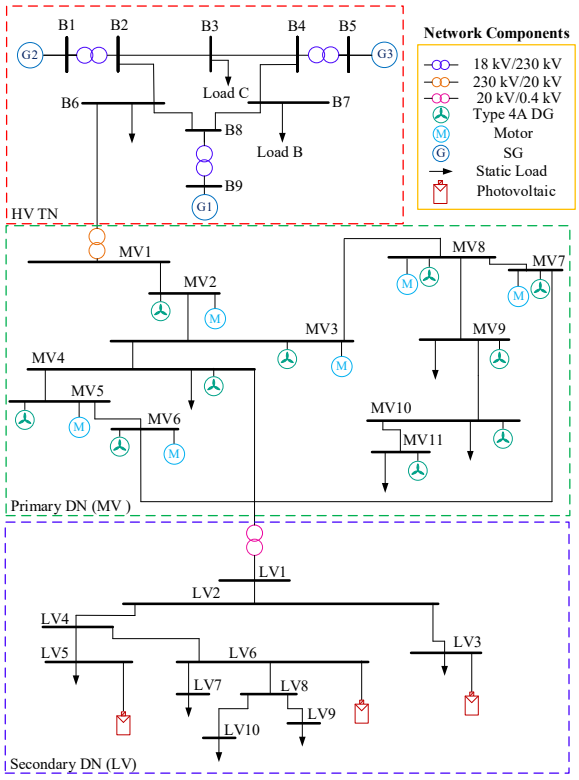
Project Progress So Far

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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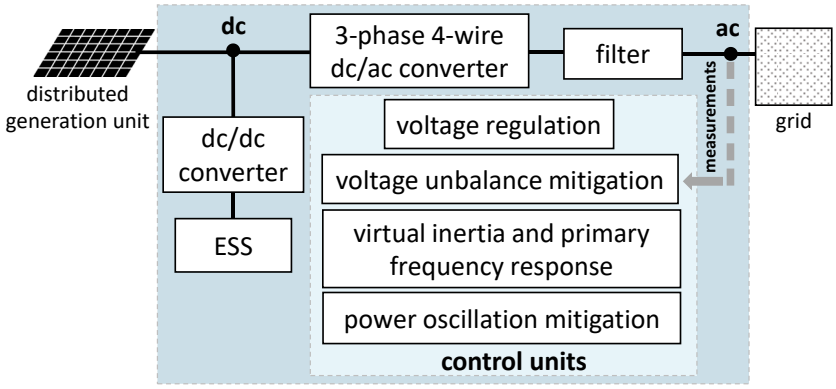
Power converter design

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.

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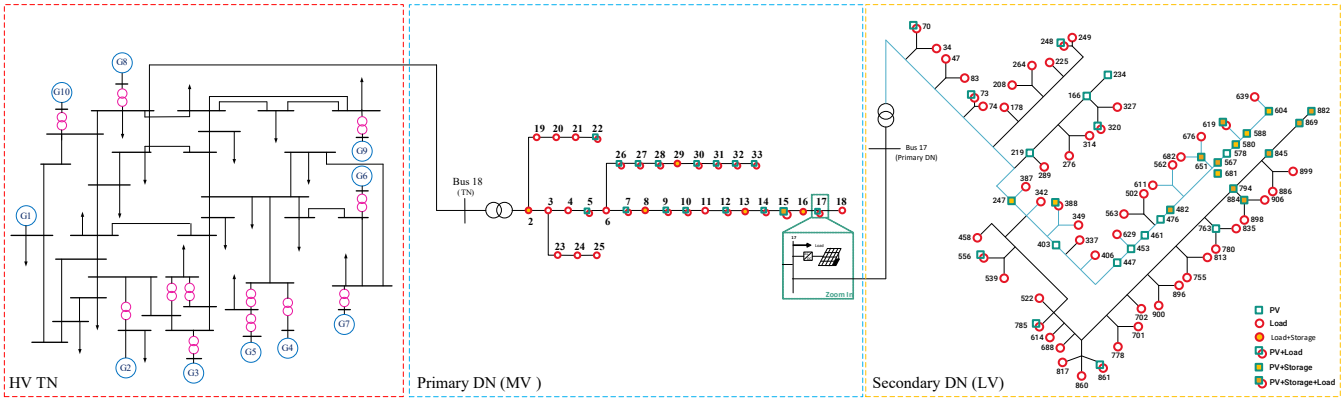
Project Progress So Far

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.

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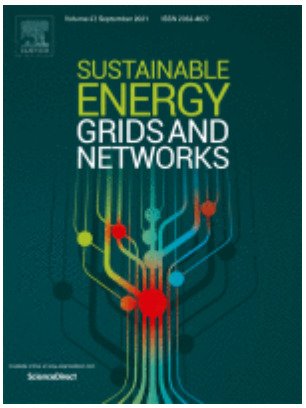
Communication & Dissemination activities

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*

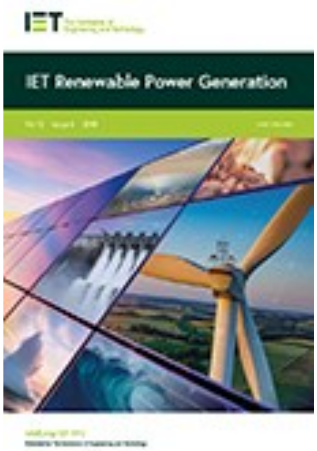
Journal publication



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

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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POWER SYSTEMS LABORATORY
ARISTOTLE UNIVERSITY OF
THESSALONIKI

Aristotle University of Thessaloniki (AUTH)

The Power Systems Laboratory (PSL) of AUTH is running since 1980 and has been involved in 140+ European, bi-lateral and national projects (http://power.ee.auth.gr/). The PSL and the team members involved in this project have significant experience in all topics related to power systems analysis, operation and control, modelling, distributed generation and smart grids and renewable energy sources.

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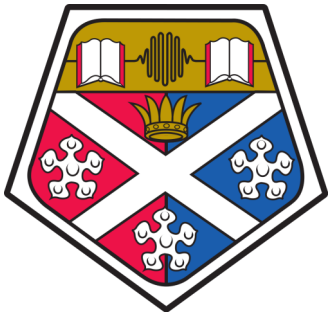

University of Strathclyde (UoS)

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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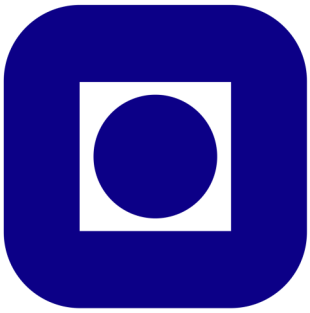

Norwegian University of Science and Technology (NTNU)

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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