European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	**HOLISTICA**
Title	**Holistic Optimization of Losses using an Improved Synergy of Technologies under an Innovative Coordination Algorithm**
ERIGrid Reference	**05.008-2018**
TA Call No.	**05**

HOST RESEARCH INFRASTRUCTURE			
Name	**Department of Electrical Engineering, Technical University of Denmark (DTU)**		
Country	**Denmark**		
Start date	**17/06/2019**	**Nº of Access days**	**6**
End date	**20/09/2019**	**Nº of Stay days**	**16**

USER GROUP	
Name (Leader)	**Daniel Morales Wagner**
Organization (Leader)	**Ingelectus Innovative Electrical Solutions SL**
Country (Leader)	**Spain**
Name	**Adolfo Gastalver Rubio**
Organization	**Ingelectus Innovative Electrical Solutions SL**
Country	**Spain**
Name	**David Señas Sanvicente**
Organization	**Ingelectus Innovative Electrical Solutions SL**
Country	**Spain**
Name	**Luis del Rio Etayo**
Organization	**Ormazabal Corporate Technology**
Country	**Spain**
Name	**Alena Ulasenka**

Organization	**Ormazabal Corporate Technology**
Country	**Spain**
Name	**Eder Arroyo Muñoz**
Organization	**Ormazabal Corporate Technology**
Country	**Spain**
Name	**Pablo Cirujano Ballesteros**
Organization	**Ormazabal Corporate Technology**
Country	**Spain**
Name	**Álvaro Ortiz Gil**
Organization	**Ormazabal Corporate Technology**
Country	**Spain**

1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

Objectives

The HOLISTICA (**H**olistic **O**ptimization of **L**osses using an **I**mproved **S**ynergy of **T**echnologies under an **I**nnovative **C**oordination **A**lgorithm) project will be the first to physically test an innovative proposal (control algorithms) for the holistic technical management of the Low Voltage Cell (from the *"Web-of-Cells*" architecture), proposing the MV/LV Transformer Substation as a control and communication hub for the Low Voltage Grid.

Voltage rise is the most critical constraint for the integration of DG in rural electric distribution networks. The DSO is responsible for maintaining voltage limits, however DSO does not have direct access to the DGs.

Coordinated voltage control concepts, as the proposed for research in the HOLISTICA project, can delay expensive and long-term grid reinforcement while increasing the DG hosting capacity of electric distribution networks.

The scope of the proposed research is to test different voltage control concepts allowing a cost-efficient integration of high shares of DG. These concepts have to maintain a high level of quality of supply while achieving economic benefits in comparison to network reinforcement. This project proposes a coordinated voltage control architecture between MV/LV distribution transformer with OLTC, solar inverters and distributed storage units (EV with V2G capabilities or batteries).

First, a conventional control will be tested with a local voltage control for the distribution transformer with OLTC, the PV-inverters and the distributed storage units. There is no communication between the grid controller and the mentioned electric resources. Each local resource works on his own, taking into account local available voltage measurements and try to balance it with the help of a local controller.

Afterwards, the integration of voltage measurements (smart meters and/or remote sensors) along the LV network with a simple optimization algorithm for distribution transformer tapping will be tested. PV-inverters and distributed storage units will be working on their own.

Next step will be to test an integrated coordination between the distribution transformer with OLTC and the inverters. Distributed storage units will be still working on their own.

Finally, a holistic coordination algorithm will be tested with the aim to enhance the renewable hosting capacity of the LV distribution grid and to reduce losses, whilst reducing inverters curtailment and enhancing health-index of distributed resources. In this case there will be a coordinated voltage control architecture between MV/LV distribution transformer with OLTC, solar inverters and distributed storage units (EV or batteries).

Test setup

As SYSLAB is a LV laboratory, a back-to-back connection of a conventional transformer plus a distribution transformer with OLTC, inside a ship container, is proposed. LV enters to the container and it is elevated to MV by means of the conventional transformer. Then, a grounded connector is used to join the MV of the conventional transformer with the MV of the distribution transformer with OLTC, that reduces voltage to LV out of the container. Therefore, MV is confined inside the container.

The smart distribution transformer can be connected to the following resources:

- Distributed Energy Resources: 2 wind turbines (11kW and 10kW), 3 PVplants (10kW, 10kW and 7 kW), Diesel generator set (48 kW / 60 kVA).
- Energy storage: 15 kW / 120 kWh vanadium redox flow battery.
- Energy loads: Controllable loads (75 kW, 3 x 36 kW). Connected to the PowerFlexHouse facility, an intelligent office building as well as two domestic houses with controllable loads (10 to 20 kW). The SYSLAB facility is further interconnected with the NEVIC electrical vehicle test facility at DTU/Risø. The NEVIC facility includes chargers for electrical vehicles and has access to an increasing fleet of electrical vehicles used for test purposes and internal transport between PowerLabDK facilities.

Layout: Distributed energy sources and load are all connected in one distributed control and measurement system that enables very flexible setup with respect to experimental configuration.

Test cases

The coordination of MV/LV distribution transformer with OLTC, solar inverters and distributed energy storage units (batteries or EV with V2G capabilities) will be assessed under different coordination levels.

Different control algorithms (normal, advanced) will be checked under a set of different operation conditions.

In addition, reverse power flow conditions, in the case that distributed DG excess the LV loads, will be tested along with remote sensors devices.

Besides, the relation between voltage, LV load characteristics (ZIP model) and power consumption will be assessed.

<u>Levels of coordination:</u>

1. First, a conventional control will be tested with a local voltage control for the distribution

transformer with OLTC, the PV-inverters and the distributed storage units, including electric vehicles with V2G capability. There is no communication between the grid controller and the mentioned electric resources. Each local resource works on his own, taking into account local available voltage measurements and try to balance it with the help of a local controller.

2. Afterwards, the integration of voltage measurements (smart meters and/or remote sensors) along the LV network, with a simple optimization algorithm for distribution transformer tapping, will be tested. PV-inverters and distributed storage units will be working on their own.
3. Next step will be to test an integrated coordination between the distribution transformer with OLTC and the inverters. Distributed storage units will be still working on their own.
4. Finally, a holistic coordination algorithm will be tested with the following objectives:
   - To reduce LV losses.
   - To improve the hosting capacity (RES and EV) of the LV distribution grid.
   - To reduce the curtailment of inverters.
   - To reduce the number of the operations and/or the operating times, in order to improve the health-index of the distributed devices.

   In this case, there will be a coordinated voltage control architecture between MV/LV distribution transformer with OLTC, solar inverters and distributed storage units (EV and/or batteries and EV with V2G capabilities).

Further test specifications must be defined with the proposed Lab.

Expected Outcomes

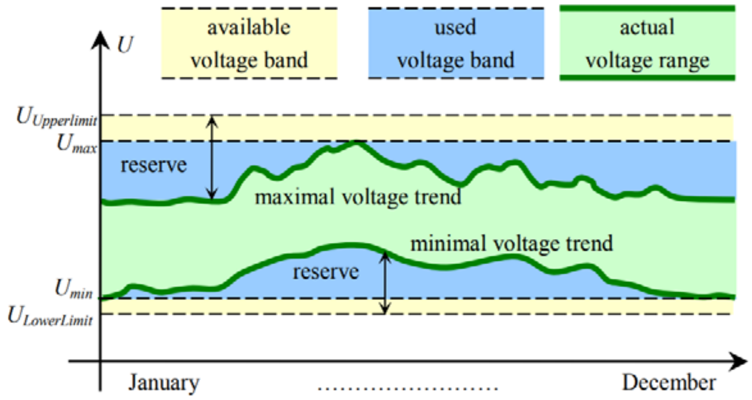
A reliable and flexible solution that is able to control a series of different element present in the LV grid to achieve TSO or DSO requirements at the POI (Point of Interconnection) of the LV with the MV, i.e. the Transformer Substation.

A system that is capable of meeting the international requirements for grid stability management using closed loop controls offering the following functionalities:

- Active Power Reference, with or without ramp rate limiter (increase or decrease if its possible).
- Active Power Curtailment, with or without ramp rate limiter.
- Frequency response depending on the frequency deviations.
- Voltage Control. AVR (Automatic Voltage Regulator)
- Reactive Power control.
- Power factor control

Besides, it is expected that a higher coordination control concept will use less voltage band than a less coordinated control concept (f.i. conventional control).

The ‘voltage band’ that is used by a control strategy is defined as maxt(Umax(t)) – mint(Umin(t)) where t covers all timespans this control strategy was active in the grid.



Used voltage band concept.

The reduction in the voltage band will increase the renewable hosting capacity of the tested network under different configurations preventing overvoltages.

The research will purpose a hierarchy in the using of the technologies. It is expected that the distribution transformer with OLTC will act as the main voltage controller in the LV grid, other voltage regulators will be grid following units. Power curtailment will be the last option.

Fundamental Scientific/Technical value

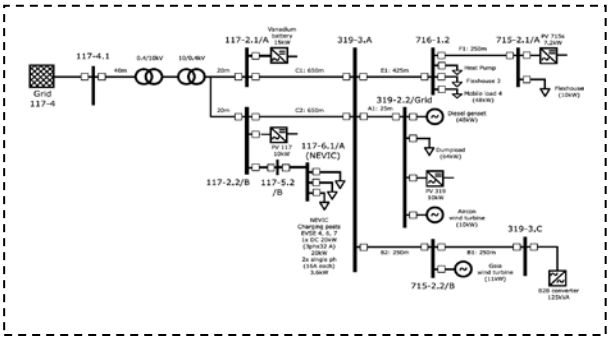
The HOLISTICA project will be the first to physically test an innovative proposal (control algorithms) for the holistic technical management of the Low Voltage Cell (from the *"Web-of-Cells*" architecture), proposing the MV/LV Transformer Substation as a control and communication hub for the Low Voltage Grid.

The proposed research will improve the current knowledge regarding the coordination of the technologies capable of providing a distributed voltage balance in the LV distribution network, avoiding technologies miscoordination that can cause undesired additional losses and curtailment, the limitation of the hosting capacity of electrical networks and the over operation of distribution transformers with OLTC, distributed batteries or inverters.

2. MAIN ACHIEVEMENTS (results, conclusions, lessons learned)

Background

In previous projects, some technical restrictions were encountered, openning the opportunity for further research with the idea to include not only PV inverters but also distributed storage units (batteries) and EV charging control in an unbalanced LV network with dynamic loads and a higher reactive power presence.



The HOLISTICA project, carried out at Syslab of DTU, takes into account all the above technologies and more advanced characteristics of the network.

Test scenarios and control strategies

Rural and urban grid scenarios using four voltage control strategies based on real-time measurements from different nodes are considered: no control (NC), tap control (T-control), reactive power control (Q-control) and holistic combinated tap and reactive power control (QT-control).

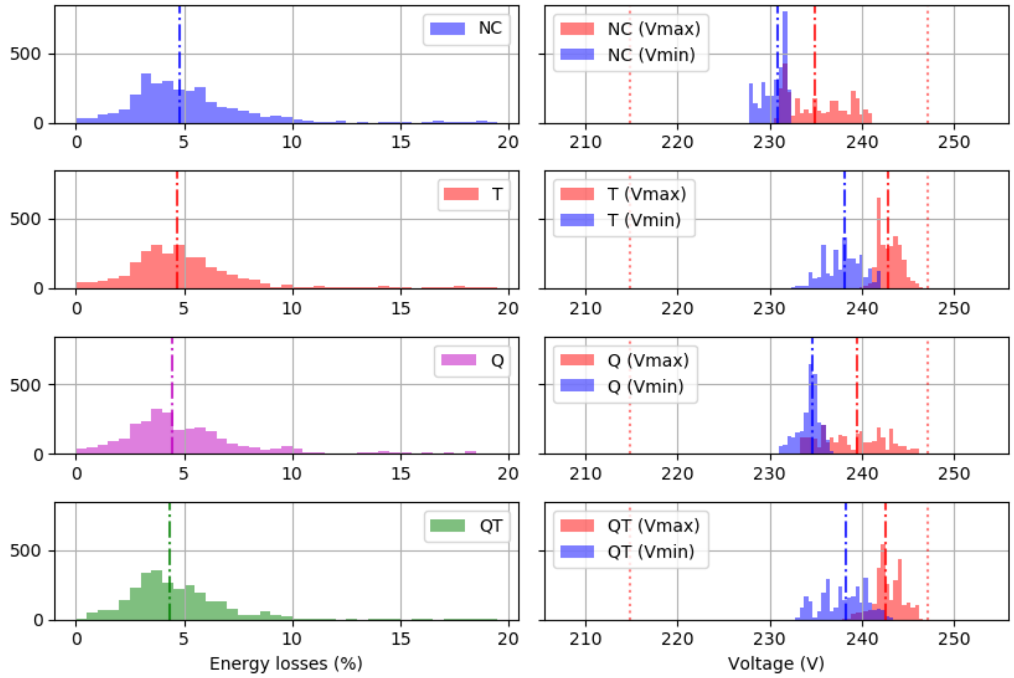
Results comparison

The impact of each approach is evaluated by comparing the hosting capacity of the network, the reduction of power losses and the increment of grid stability, whilst streamlining the number of OLTC operations.

Control strategy	Hosting capacity (pu)	Energy losses (%)	Losses reduction (%)	Number of operations
NC	1.93	4.78	0.00	0
T	3.12	4.66	2.56	19
Q	3.05	4.42	6.31	0
QT	3.16	4.33	9.35	20

Comparison results between the different control strategies

The table above shows the performance of the control strategies. While enabling a better voltage and overloading contraint management, the application of OLTC operation increases up to 61.65 % the nominal hosting capacity; and, by adding a centralized reactive power control of distributed generation, the efficiency of the electrical grid can improve a 9.35 %.



Losses and voltage profiles

Conclusions and future work

Results show that the smart distribution transformer with OLTC can be considered an essential element of distribution networks that provides optimal grid flexibilities and reliability, thus maximizing the integration of renewables whilst delaying expensive and long-term grid reinforcement - especially when it is coordinated with existing distributed generation, batteries and EV.

In previous works, the control system included an optimal power flow implementation using the topology and measurments from all the devices in the network. This information is not usually available or it is difficult to ensure in a real production environment. Thus, additionally to the inclusion of batteries and EV, the topology of the network was ommited in the control system, and the optimal power flow was reduced to follow simpler and closer to real-time control rules. The latest assumption resulted in a reduction of the benefit in energy losses savings with respect to the complete (OPF) version of the control system.

In the near future, we intent to take the control a little further by ommiting also the availability of measurements on the feeder, thus, estimating the voltages and current limits based on the transformer or secondary substation measurements. Moreover, including new functionality to the control system, such as flexibility, secondary services, or energy optimization using energy storage systems.

3. PLANNED DISSEMINATION OF RESULTS (journals, conferences, others)

The project results will be presented at the CIRED 2020 Berlin Workshop on 4-5 June 2020, both as a presentation and as a paper in the conference proceedings.

The CIRED paper reference:

A. Ulasenka, A. Gastalver-Rubio, et al., “Coordinated Operation of Distributed Energy Resources to Enhance Local Flexibility”, in *CIRED 2020 Berlin Workshop*, paper 130, 2020.

4. PLANNED DISSEMINATION OF RESULTS THROUGH ERIGRID CHANNELS

Contact erigrid-ta@list.ait.ac.at to organise promotion of your results

Project results presented at ERIGrid final event. An ERIGrid “Success Story” has been published on the ERIGrid website.

Once the paper has been published in CIRED, we plan to contact the email above to disseminate the results within ERIGrid channels.