# TRANSNATIONAL ACCESS
# USER PROJECT FACT SHEET

| USER PROJECT | |
|---|---|
| **Acronym** | VFG-VPP(AS) |
| **Title** | Validation of Flexibility to Generators - Offered by Virtual Power Plant (for Ancillary Services) |
| **ERIGrid Reference** | 05.003-2018 |
| **TA Call No.** | 5 |

| HOST RESEARCH INFRASTRUCTURE | | | |
|---|---|---|---|
| **Name** | OFFIS e.V. | | |
| **Country** | Germany | | |
| **Start date** | 30.09.2019 | **Nº of Access days** | 40 |
| **End date** | 28.11.2019 | **Nº of Stay days** | 60 |

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

The project relates to the flexibility a VPP can offer to conventional coal and combined cycle power plants. This puts the scope to the four relevant actors in power systems:

1-VPP as new actor in power system

2-TSO as operator for transmission level

3-DSO as operator for distribution level

4-Conventional power plants as supplier of real power and reactive power to TSO and DSO

The idea is to see how VPP can give flexibility to TSO, DSO, and power plants in terms of major ancillary services (voltage support, frequency support, and system protection). This overall gives flexibility to conventional power plants.

Use cases are developed w.r.t regulations of major European countries, and primarily Italy. The use cases discriminate amongst different ways these VPP interact with 2-4 Entities of the previous list in terms of ancillary services provision.

The use cases are validated in OPAL-RT with a HIL system, as described below.

The objectives include checking:

1- TSO needs fulfilled by power plants

2- TSO-DSO Interaction

It develops a validated VPP tool, which supports ancillary services provision to give flexibility to conventional generators, irrespective of the regulatory mechanism.
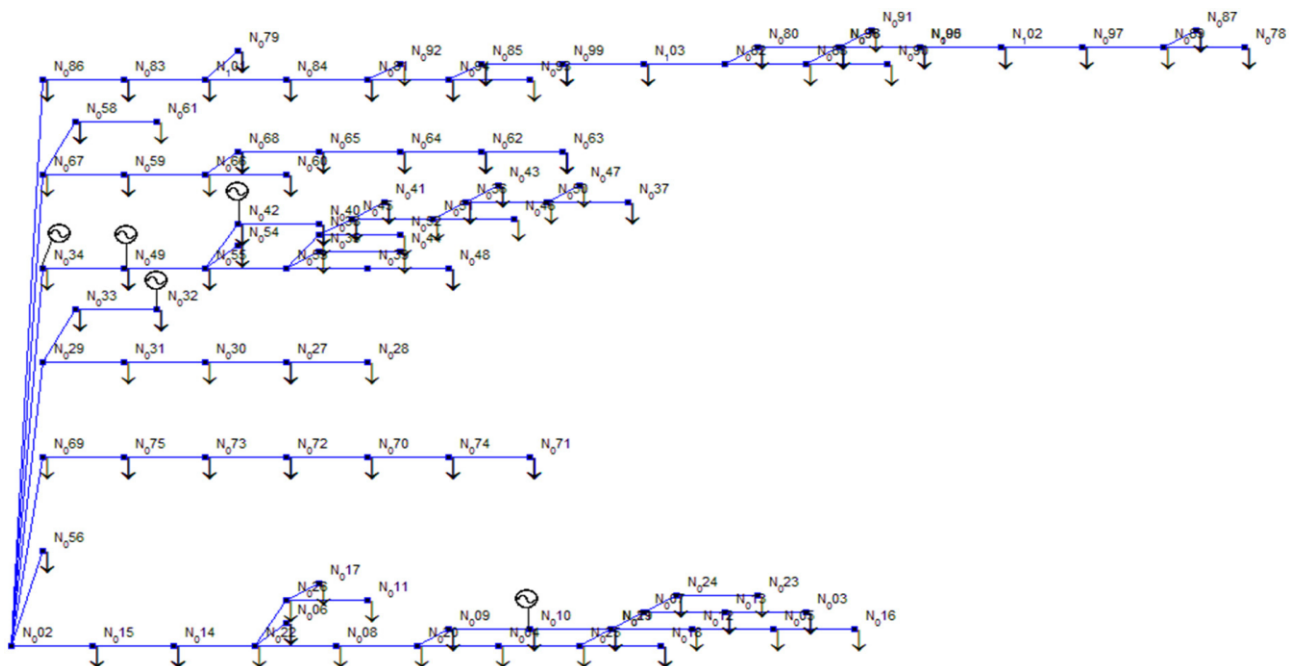
## 1.1  Objectives



Figure 1: IEEE test distribution system (EU Project ATLANTIDE [1-2])

Under MEAN4SG project, the VPP model is developed and simulated with the two possibilities:

1- A co-simulation environment is created for windfarm (DIgSILENT), customers DR (LabVIEW), and storage system (MATLAB/Simulink). These co-simulators are communicated via OPC, and VPP interface is modeled with LabVIEW-RT. Then, DSO asks for service during congestion and over-voltage issues. The possibility for reactive power provision is analyzed, and OPC tags are the source of communication amongst VPP and DMS.

2- A co-simulation environment is created for windfarm (DIgSILENT), customers DR (LabVIEW), and storage system (MATLAB/Simulink). These co-simulators are considered

part of distribution substation, and then these co-simulators communicate with other substation IEDs with IEC 61850. Service provision is then seen, and time for the service is noted.

A VPP at distribution level, named as VPP-model, with the following components:

A test distribution system [1], as shown in Figure 1, from EU ATLANTIDE Project. The 20 KV MV network consists of 103 nodes, and 7 feeders to feed the 190MV loads.

1- The distribution grid is modelled in MATLAB/Simulink under Opal-RT.
2- Storage system model is used too, along with customers (consider as VPP)
3- At DMS level, there is request for reactive power provision. Time for service is noted with OPC communication.
4- Time of service is noted when IEC 61850 communication is utilized at substation

The steps include:

1- The system in Figure 2 is modelled in MATLAB/Simulink with the operating values for distribution grid and storage system (Initiate without storage system).
2- Protection scheme and node-voltages (voltage loading) is validated.
3- DER added at node 9; protection device failure and node voltage violations at selected nodes is observed.
4- Storage system is added; and flexibility margins are noted for violated nodes (with/without storage, peak shaving, and load shifting), and protection system. For protection, DER at node 9 and storage system are communicated via IEC 61850 standard.

KPIs are compared for theoretical, simulated and the validated platform cases.

Criterion for failures:

1- 0.95 per-unit to 1.05 per-unit (node voltage; pessimistic bound)
2- Primary protection in less than 0.8 seconds
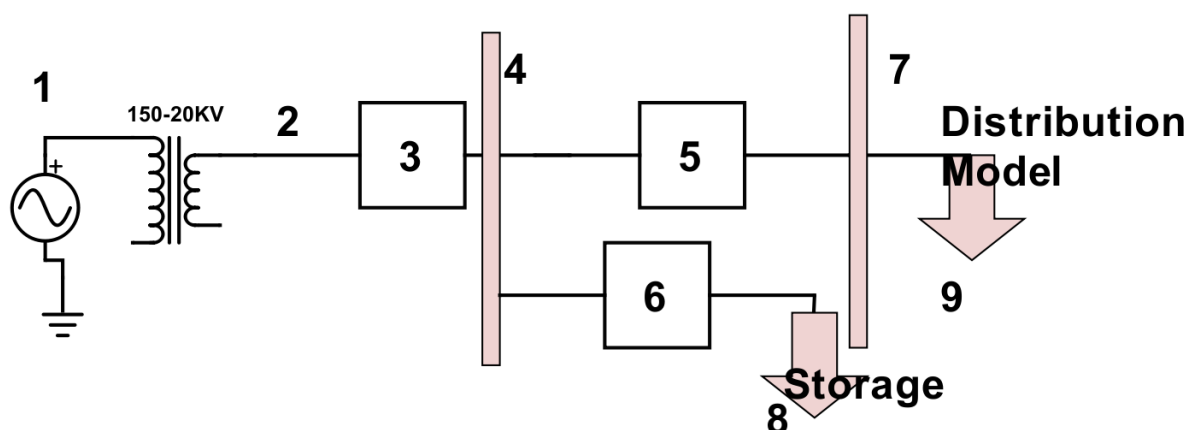3- Backup protection in less than 1.2 seconds



Figure 2: Single line diagram for test-system

## 1.2 Scope

Quantification and estimation of:

1- Flexibility by VPP in terms of reactive power VS time of service
2- Flexibility by VPP in terms of reactive power VS point of service
3- Flexibility by VPP in terms of real power VS type of reserve
4- Flexibility by VPP in terms of reduction in number of faults
5- Flexibility by VPP in terms of reduction in time of isolation after faults

Identification of:

6- Adapting changes in regulatory aspects in different European countries in terms of deployment of VPP.
7- Technical competitiveness of VPP in comparison with the existing market solutions.
8- Flexibility to operators, specifically TSO in terms of controlling the transmission grid as a whole
9- Opportunity for better TSO-DSO interaction schemes
10- Flexibility to power plants in terms of their abilities to produces reactive power and real power.
11- A better protection scheme in terms of fault identification and isolation
12- Validation for ease of adaptiveness

# REFERENCES

[1] F. Pilo et al., 2014, "Advanced active distribution simulations with the ATLANTIDE web cloud facilities", *CIRED Workshop,* Italy

[2] F. Pilo et al., 2012, "ATLANTIDE – Digital archive of the Italian electric distribution reference networks", *CIRED Workshop*, Portugal

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

Objective: Time taken by the back-up relay to operate/receive the signal to trip?

Design case:

1- Feeder 2 with an overcurrent relay (line 2-27) at beginning of all laterals.

    Voltage at 20KV
    S = 25 MVA, CT selected is 150:5
    Fault analysis leads to Ipick_up as 210 Ap, and thus TAP = 7As with TD = 2
    Fault at Node 28(consider a 3-phase fault) occus, consider a non-bolted **apply just a ground signal at node 28**.

**2-** Time of over current relay operation can be considered as **time for switch to operate in OPAL-RT (depends on the selected switch). Data sheet of switch.**

3- Differential relay at feeder 4, provides the backup. **The settings are K1 is 0.4 and k2 is 20%. However, it is to observe the time taken for IEC 61850 communication to give signal to switch at Feeder 2 from feeder 4.** Both are two different feeders within a same distribution grid.

OPAL-Scenario:

1- Time for a switch to operate at feeder 2

2- Time for communication between the two feeders (2 and 4)

## 1.3 Test Plan

The test plan aims to find the communication delay by backup protection, which demonstrates the delays the VPP will suffer during its service provision. This will confirm to the flexibility a VPP can offer to conventional coal and combined cycle power plants.

## 1.4 Standards, Procedures, and Methodology

The Function(s) under Investigation (*FuI*) is the Time for tripping. The Objects under Investigation (*OuI*) are the Relays – Overcurrent and differential. The Domain under Investigation (*DuI*) is the Electric Power system protection. The Purpose of Investigation *(PoI)* is to verify if the backup protection communicates the VPP, before the conventional backup.

## 1.5 Test Set-up(s)

The System under Test (*SuT*) is the Relays – Overcurrent and differential, Circuit Breakers, CTs, distribution grid. The Function under Test (*FuT*) is the Communication delay when the tripping signal is sent from differential relay to overcurrent relay.

## 1.6 Data Management and Processing

The target is to check the time in seconds for the communication. Delay to be less than 1 seconds, when Feeder 4 OC relay to trip, when the signal is sent by differential relay at point of interconnection.

# 2 RESULTS AND CONCLUSIONS

The host institution has OPAL-RT system with real time simulator (model based support), which was uised for the validation proposal, i.e. a PHIL platform. The VPP model was developed with the used simulation models. IEC 61850 and OPC communication support was there, and the IEC architecture at lab was perfect for DMS based test-case. The distribution grid and the storage system were tested within OFFIS simulator, and the KPIs were compared.

Result 1:

The distribution grid was validated within the OPAL-RT; and the full model (compliant with OPC) was developed in OPAL-RT. The platform was set for the GOOSE IEC 61850 substation communication.

The validation includes power flow, static and quasi-dynamic analysis(and to check the node voltages), and the OPC communication. The following were verified:
1- 0.95 per-unit to 1.05 per-unit (node voltages)
2- Primary protection in less than 80 m-seconds
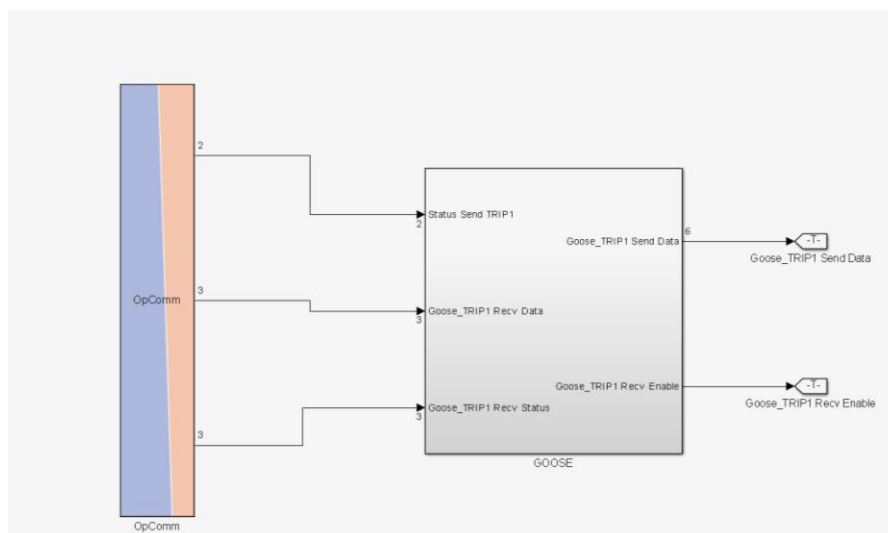3- Backup protection in less than 40 m-seconds



Figure 3: OPAL-RT distribution grid – GOOSE Command

Figure 4: OPAL-RT distribution grid – GOOSE Time Logic

Result 2:

GOOSE message was sent within a substation (between overcurrent and differential protection feeder based nodes), and the time of communication was observed (i.e. to be less than 100ms)
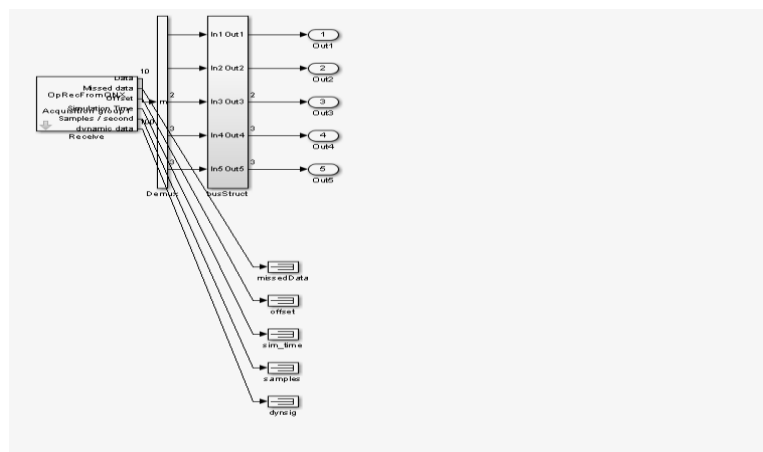


Figure 5: OPAL-RT distribution grid – GOOSE Logic

Time at which GOOSE is subscribed, and published are noted:

Time for start of subscription: 11,5600000000000s

Time for publish 11,5800000000000s

Communication delay for VPP: 20 msec(less than 100 msec for VPP)

Result 3:

Object oriented excel sheets generated within OPAL were tested in DIgSILENT. It was deduced that the DGS based DIgSILENT sheets can be transformed into the import facility for OPAL-RT. The results in #1, were compared with both ways, and were found the same.

| Bus | Base Voltage (V) | Voltage (V, pu) | Angle (deg) | Type |
|---|---|---|---|---|
| N_0002 | 20000 | 1.106379417 | -4.973655545 | PQ |
| N_0003 | 20000 | 1 | 5.666699546 | PQ |
| N_001 | 150000 | 1 | 0 | SLACK |
| N_002 | 20000 | 0.960127838 | -3.014459871 | PQ |
| N_003 | 20000 | 1.041080367 | -0.392702233 | PQ |
| N_004 | 20000 | 1.06458484 | -2.898636244 | PQ |
| N_005 | 20000 | 1.058773214 | -2.988355675 | PQ |
| N_006 | 20000 | 1.051528734 | -1.691517243 | PQ |
| N_007 | 20000 | 1.058291083 | -3.022999226 | PQ |
| N_008 | 20000 | 1.064057438 | -2.529792403 | PQ |
| N_009 | 20000 | 1.098065194 | -4.144528596 | PQ |
| N_011 | 20000 | 1.050496556 | -1.68562052 | PQ |
| N_012 | 20000 | 1.059124004 | -2.987083002 | PQ |
| N_013 | 20000 | 0.960658279 | -3.016649625 | PQ |
| N_014 | 20000 | 1.046074298 | -1.140329585 | PQ |
| N_015 | 20000 | 1.043507251 | -0.698104608 | PQ |
| N_016 | 20000 | 0.962357166 | -2.988962987 | PQ |
| N_017 | 20000 | 1.050471746 | -1.679720013 | PQ |
| N_018 | 20000 | 1.061865971 | -2.908494201 | PQ |
| N_019 | 20000 | 1.106235557 | -4.973010986 | PQ |
| N_020 | 20000 | 1.068433653 | -2.823377268 | PQ |
| N_021 | 20000 | 1.059930107 | -2.990408074 | PQ |

Figure 6: OPAL-RT distribution grid – Nodes 1-21 Details

| | | | | |
|---|---|---|---|---|
| N_083 | 20000 | 1.03520223 | -0.523240422 | PQ |
| N_084 | 20000 | 1.028979516 | -0.686061348 | PQ |
| N_085 | 20000 | 1.018427325 | -0.977709872 | PQ |
| N_086 | 20000 | 1.039972744 | -0.404492093 | PQ |
| N_087 | 20000 | 1.00073248 | -1.496686865 | PQ |
| N_088 | 20000 | 1.004444791 | -1.418722526 | PQ |
| N_089 | 20000 | 1.001218933 | -1.48669138 | PQ |
| N_090 | 20000 | 1.004200232 | -1.420274014 | PQ |
| N_091 | 20000 | 1.006598777 | -1.328635134 | PQ |
| N_092 | 20000 | 1.023986961 | -0.819238871 | PQ |
| N_093 | 20000 | 1.022027397 | -0.873983419 | PQ |
| N_094 | 20000 | 1.02207313 | -0.874175236 | PQ |
| N_095 | 20000 | 1.006539207 | -1.328241646 | PQ |
| N_096 | 20000 | 1.00664281 | -1.328752387 | PQ |
| N_097 | 20000 | 1.001460165 | -1.48821973 | PQ |
| N_098 | 20000 | 1.002539906 | -1.487897246 | PQ |
| N_099 | 20000 | 1.017308135 | -1.010298319 | PQ |
| N_100 | 20000 | 1.002011608 | -1.488874083 | PQ |
| N_101 | 20000 | 1.033715584 | -0.560892284 | PQ |
| N_102 | 20000 | 1.001679348 | -1.488742458 | PQ |
| N_103 | 20000 | 1.010057988 | -1.231037476 | PQ |
| N_3 | 20000 | 1.024041662 | -0.819457275 | PQ |

Figure 7: OPAL-RT distribution grid – Nodes 83-103 & 3 Details

Result 4:

For real power service, the time between two substations is estimated within OPAL-RT. It is greater than 20 msec, and therefore the pessimistic bound is not compliant for the VPP. Hence, the service controller needs to be modified for services from different substations.

Time at which IEC 61850 MMS is expected, and published are considered:

Time for start of subscription: 11,5600000000000s

Time for publish >11,5800000000000s

Communication delay for VPP: >20 msec(not suitable for VPP)

## 3   OPEN ISSUES AND SUGGESTIONS FOR IMPROVEMENTS

For the VPP;

1- Service for protection is verified.
2- For real power service, the model has to be improved.

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

1- PhD thesis under MEAN4SG(submitted)
2- MDPI journal (under draft)