Flexibility to DSO by VPP – Benefits, Regulatory Barriers, and Potential Solutions

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ABSTRACT

DSO, being responsible of the distribution grid, manages the network and distribution substations through its DMS (Distribution Management System) and SCADA HMI. DSO has to resolve local issues and network constraints on its own, and can benefit from the use of a VPP (Virtual Power Plant) framework to give flexibility. The paper presents a platform where IEDs (Intelligent Electronic Devices) at the distribution substation and the VPP communicate via IEC 61850 standard. The platform emerges with the increased flexibility to DSO for ancillary services. For the demonstration, the paper presents a model of VPP, with a pilot test-case. The paper then models a distribution substation, and a use-case for ancillary services which is validated for flexibility provision. Finally, the regulatory barriers are discussed for the deployment, and the possible solutions are indicated.

INTRODUCTION

The idea of VPP is seeking greater attention after the advancements in its successful implementations as new actor in market [1-2], and the DSO flexibility needs for services provision [3]. VPP can offer flexibility at all levels of DSO control: DMS and substation RTUs. Literature mostly discusses the idea of VPP market at DMS level [4], however, the paper focuses on the idea of VPP market with substation RTUs.

Detailed model of a distribution substation along with a test case for flexibility requirement is presented in Section 1. The section also describes the model of VPP. It is then proposed to utilize substation RTUs and VPP with an IEC 61850 based platform, which is modelled in Section 2. The platform comes with advantages (mainly flexibility), along with some technical and regulatory barriers.

Section 3 discusses the regulatory and technical barriers in adapting the platform, and the potential solutions. Section 4 is on validation of the proposal, while section 5 concludes the paper with potential future work.

MODEL OF DISTRIBUTION SUBSTATION & VPP

This section presents one after another the distribution substation, VPP model, and the DSO test case.

ATLANTIDE MV European Distribution Substation

The test network is a 20 kV distribution substation, extracted from the dissemination of a project ATLANTIDE as shown in Figure 1 [5-6]. Detailed representation of the grid is available in [6].

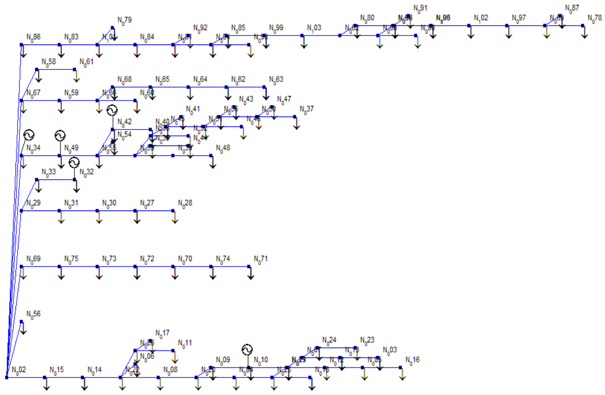


Figure 1 – Single Line Diagram - distribution grid [6]

Aggregated VPP Model for the Provision of Congestion Management Service

The model of VPP is adapted from [7], with the idea of using aggregation of different market players. The layout is represented in Figure 1. Consider that the VPP is controlling a microgrid, which is the point of main management. RTU 1 has the access to flexibility provided by storage systems, both in terms of upward and downward reserves. RTU 2 has access to customers level (within the test feeder), that serves to resolve local congestion issues. RTU 1 can further access the potential of demand-response, and has direct communication with the master control.

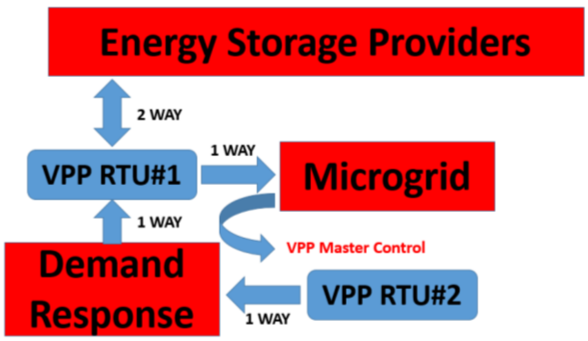


Figure 2 – Proposed aggregated VPP model

Test case: DSO Provision for Capacity & Congestion Management

DSO suffers from congestion due to the changes in distribution grid with the addition of unplanned DERs. As suggested by [8], one of the ways to solve this problem is through demand side flexibility, in addition to the available reserves. Three further cases of such flexibility are discussed in [9]. DSO based test case requirements are illustrated in Table 1, adapted from [9].

Case Number	Requirements	Solutions
1	Excess burden on one distribution substation due to high demand conditions at a particular interval	Peak Shaving
2	Excess burden on one substation due to high demand at different intervals	Time Shifting
3	Excess burden on one substation – in general	Both 1 & 2

Table 1: DSO Test Cases

PROPOSED IEC 61850 BASED MODEL FOR FLEXIBILITY TO DSO

Literature supports the idea of using IEC 61850 for flexibility as in [10]. The point of innovation here is the use of VPP as an IED. The RTU at distribution substation behaves as a mini-DMS that provides market opportunities to VPP providers. It is mandatory for VPP management system to be interoperable with IEC 61850 standard. The operational model is shown in Figure 3 and is in compliance with the framework of SGAM (Smart Grid Architecture Model) [11].

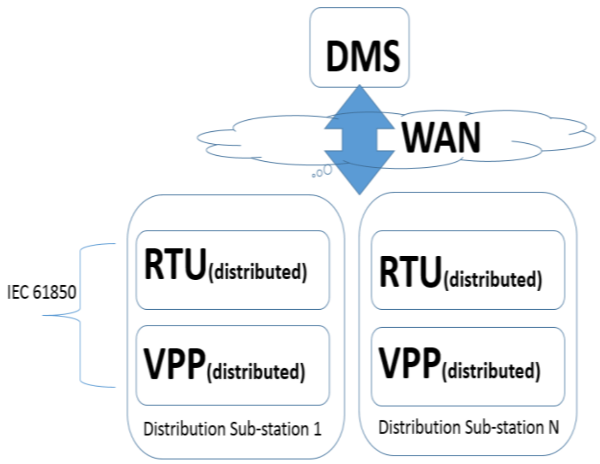


Figure 3 – Proposed architecture and communication aspects

The model includes all benefits of IEC 61850 (such as process bus sharing, easy to expand, and most importantly easy to integrate with VPP). Mainly, it allows flexibility to DSO in terms of both services and energy markets. The idea of flexibility is supported by the fact that the VPP is remotely monitored and controlled, along with the substation RTU and devices. With the inclusion of VPP as RTU, the observability of DSO RTU, and in turn the DMS is increased.

The platform, which is validated in proceeding section, has the main advantages of being modular, easily scalable, and easy to integrate with VPP-RTU, all in compliance with [12]. Technical and regulatory barriers associated with the platform are discussed in the next section.

BARRIERS AND PROPOSED POTENTIAL SOLUTIONS

Main technical barrier is the network security threats with the increase in IEC 61850 traffic, especially with sampled values. The solution is to employ a traffic controller at RTU levels. Next major technical threat is on cyber-security which becomes vulnerable due to the information sharing with VPP-RTUs, and these VPPs are not protected against cyber-attacks, specifically stealth attacks.

Literature suggests many techniques for the associated cyber risks, however, for VPP as a component IED, it is recommended to use IEC 62443-2-4 based patch management system presented in [13]. The solution may or may not include open data interoperability amongst VPP and DMS.

Country	Regulatory Barriers
United Kingdom	1-High subsidies for DERs 2-DERs cannot participate in ancillary market 3-Lack of standardization for flexibility 4-Primary reserve is a mandatory provision for main generators
Italy	1-Legal barriers in both technical and regulatory aspects 2-Lack of standards for interaction amongst the different actors 3-Data and privacy protection is not well-regulated
France	1-Primary reserve is a mandatory provision for main generators 2-Slow implementation
Portugal	1-Legal barriers in both technical and regulatory aspects 2-No reserve market for wind and PV 3-No existing demand-response.

Table 2: Regulatory barriers

Another barrier is from the regulatory authorities, which restrict VPP or distributed generators to participate directly in DSO market. Ambiguous participation policies for storage, demand response, and aggregators act as another source of barrier. Table 2 lists the barriers that major VPP providers, in major European countries, face as part of BestRES EU project [14].

The solution underlies on the refined roles of DSO, which fits the technical gaps in adapting the platform, and thus becomes evident for potential regulatory changes. Literature proposes variety of these changes, and a lot of DSOs are involved in adapting these changes with potential regulations, as suggested in [15-16]. Further details are provided in the last section.

VALIDATION AND RESULTS

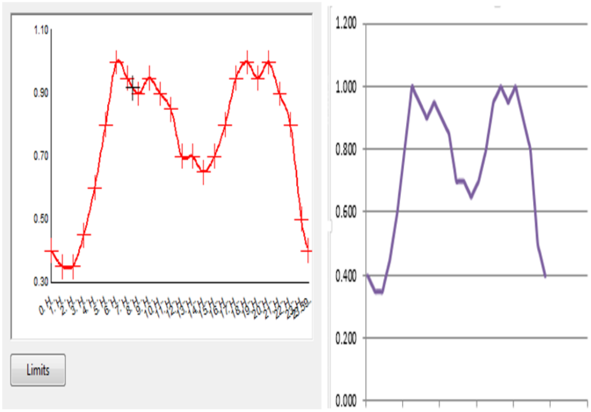
The RTU has access to the respective substation voltage, current, and power flow information. In the same manner, RTU has access to the respective VPP in order to acquire its services to resolve local issues within the substation reach, before it goes to the DMS. Feeders, laterals, and loads are not visible to both RTU and VPP. Selected ones are representatives of VPP only.

There exist different parameters for latency, encryption, and standards limitations. For the confidentiality and security of substation devices, VPP can only view the logical nodes, and cannot monitor and/or control the actual physical device. Only the respective RTU has the lookup map for the physical-logical transformation.

Validation is performed on node basis. The test-bed for the validation is as follows:

1- Distribution substation, from Figure 1, is modelled in DIgSILENT using DGS facility. Quasi-dynamic analysis is performed, and a 24 hour load profile is created w.r.t the data provided in [5-6].
2- At one of the selected nodes, i.e. 23, a residential load profile is added as shown in Figure 4 (from [5-6]).
3- RTU1, and VPP-RTU1 and VPP-RTU2 are represented by Matrikon based OPC servers.
4- WAN delay with SONET protocol.
5- Three cases are validated: congestion on node 23 with high loads in peak hours, peak shaving with and without RTU-VPP, and peak shaving with and without VPP-DMS.
6- Flexibility margins with storage, microgrid, and demand-response are indicated.

The level of maximum loading is marked and targeted, and is considered as the level of congestion w.r.t overload conditions. After this addition, the quasi-dynamic analysis is performed. Results indicate congestion at node 23, and 4 nodes with the minimum loading: 37, 43, 47, and 50. This information is reflected in the Matrikon OPC Explorer, and the idea of using OPC based communication is taken from [7]. The detailed description of microgrid, storage, and demand response participants is also available in [7].
Respective values of power, voltage, and current at these four nodes are available in the form of tags in the OPC explorer, which is shown in Figure 5.



A B

Figure 4 – Residential load profile representation in A) DIgSILENT B) MS EXCEL – Data from [5-6]

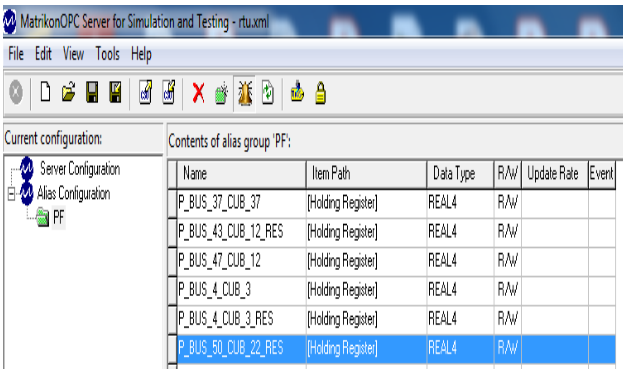


Figure 5 – Matrikon OPC Explorer with tags

These 4 tags are monitored by VPP-RTU2, which has the potential to ask for service from demand-response participant. VPP-RTU is also demonstrated by Matrikon OPC explorer in the similar fashion, with the only modification of being client, rather than server in previous RTU. Next step is the implementation of VPP-RTU1.

VPP-RTU1 acts as client for OPC under demand-response, and server for microgrid. For energy storage system, it has both capabilities for positive and negative margins. Their flexibility is associated with RTU1.

Consider that the VPP-RTU2 is used for peak shaving. Without the use of this RTU, the following delays are added: VPP internal delays, DMS delays, and SONET delays under WAN. The flexibility offered by demand response is shown in Figure 6 with the arrows.

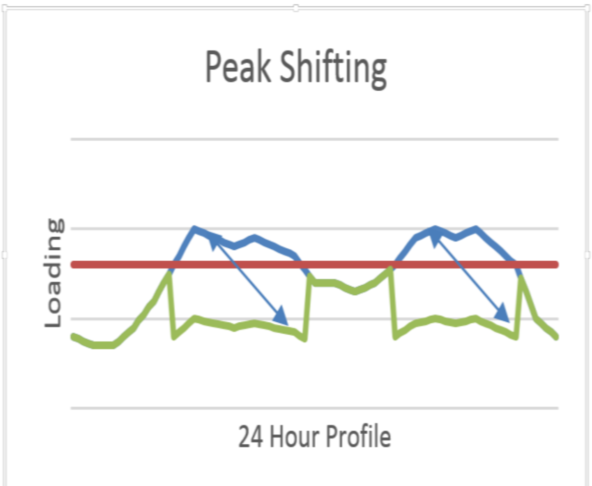


Figure 6 – Congestion management: Demand response flexibility

To validate the results, the loading is observed at node 23 in DIgSILENT. It shows 78% loading, and hence there is no congestion. Consider that the VPP-RTU1 is used for time shifting. Without the use of this RTU, the following delays are added: VPP internal delays, DMS delays, and SONET delays under WAN. The flexibility margins offered by microgrid, demand response, and storage are shown in Figure 7.

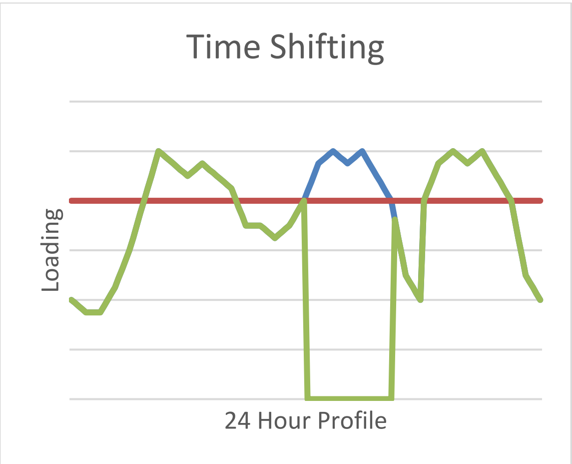


Figure 7 – Congestion management: Shifting in peak timing

To validate the results, the loading is observed at node 23 in DIgSILENT. It shows 67% loading, and hence there is no congestion. Without the use of RTU, the associated delays pose a serious risk of overloading in the initial phase when the services are procured. The idea is shown in Figure 8, which shows overloading up to 97% in the initial phase. This is the phase during which the coordination amongst IED and DMS, and then DMS and VPP, occurs for the provision of service. Therefore, to avoid such coordination delays and early overload risks, it is beneficial to use RTU level coordination platform between VPP and DMS.

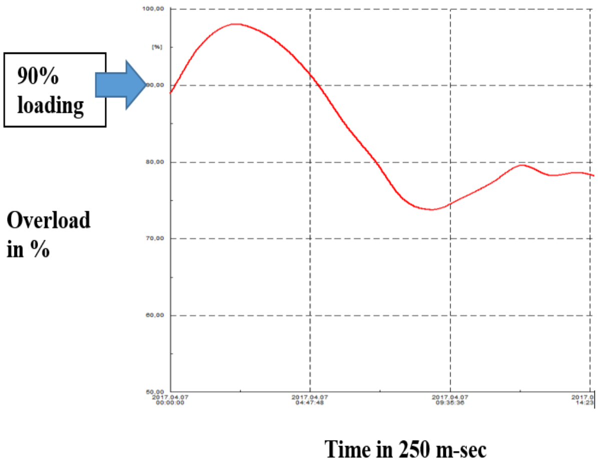


Figure 8 – Overloading Hazard

CONCLUSION

The paper focuses on the digitalization of DSO business with the proposal of a platform which uses IEC 61850 standard for the communication amongst VPP and DMS RTUs. With the inclusion of these RTU levels, the flexibility for DSO is increased. Results are verified with the modelling of real Italian distribution grid, and VPP on congestion based test-cases. Regulatory and technical aspects are discussed too.

Main motivation for the model is the involvement of different market players, and hence the trend which the later DSO should follow. The business case for this model can be developed with the utilization of four schemes presented in [17]. The four cases emphasize on different schemes of possible utilization of DERs effectively, in order to participate in ancillary market. Model presented in Figure 3 is compatible with these cases in all aspects. Therefore, all the technical benefits of operational planning, operational functions, and market functions, presented in [17], are also applicable for this model. The model gives novelty in terms of VPP participation for ancillary services with the concepts of using I) IEC 61850 standard II) VPP participation at RTU level III) Market opportunities at RTU level. To conclude, the key points in adaptation of the proposal are:

- Market opportunities and participation should be allowed to VPP at the level of substations
- The subsidies for VPP should be reduced. The better is that DSO should provide incentives for adaptation of trend.
- Regulatory barriers for VPP participation in service market should be removed.
- The concerns regarding data, privacy, and information management should be regulated. A

proper discretion of RTU, DMS, and VPP data for sharing should be done

- Demand response, storage, and in principle reserve markets should be prevalent at both MV and LV levels.
- New policies for IEC 61850 based interoperability of VPP, substation devices, and terminal units should be swift

As future work, two important tasks can be performed:

1- Validation should be performed with real time monitoring and control, rather than a steady state validation for a node congestion. For the creation of PHIL (Power Hardware in the Loop), the RTDS (Real Time Digital Simulator) can be used. A possible test-bed and experimentation is available in [18], as part of EU project Erigrid [19].

2- Cost benefit analysis by considering an extensive business case to emphasize the fact that a better flexibility margin can be achieved by creating market at RTU level.

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