Participation of Customers to Virtual Power Plants for Reactive Power Provision

Jibran Ali
DITEN & MEAN4SG
University of Genoa
Genova, Italy
jibran.ali@edu.unige.it

Stefano Massucco
DITEN
University of Genoa
Genova, Italy
stefano.massucco@unige.it

Federico Silvestro
DITEN
University of Genoa
Genova, Italy
federico.silvestro@unige.it

Andrea Vinci
DITEN
University of Genoa
Genova, Italy
andrea.vinci@unige.it

Abstract— **Diversity in modern grid, specifically due to distributed energy resources, appeals for the developments in all the sectors of power system. Voltage changes at low and medium voltage nodes, and penetration of voltage sources due to distributed generation put in stake the power system reliability, power quality, and power system protection devices. One of the major developments is to compensate for these voltage changes through reactive power provision, and customers demand is a significant actor for these reactive power changes. The paper discusses the architecture for virtual power plant, and the interaction of customers meters through VPP controller. The paper develops the HMI to access the reactive power metering at customers end, and a recording tool for the readings at VPP controller.**

Keywords—Virtual Power Plants (VPP), LabVIEW, Reactive Power, HMI, Distributed Energy Resources, Recording Tool

I. Introduction

The modern grid is at stake due to the heavy penetration of wind, solar, and other distributed energy resources, which influence the hosting capacity as in [1], and appeals for changes in all the sectors of power system. The most common addressing issues are on power systems reliability [2], power systems protection [3] [4] [5], and power quality [6].

Effects on voltage stability and voltage loading are the points of concern in literature as in [7] [8] [9], which are the outcomes of the uncontrolled prevalence of distributed energy resources. Amongst the controlling techniques is the use of reactive power compensation for controlling the node voltages as in [10] [11] [12]. Literature suggests different reactive power compensation techniques such as AC-DC-AC converters as in [13], STATCOM as in [14], and the use of shunt filters as presented in [15]. Comparison of different reactive power compensation techniques are also analyzed in [16]. A modern technique is the use of Virtual Power Plant (VPP) concept for the provision of reactive power.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 676042.

The idea of the paper is to employ VPP concept for the provision of reactive power, which can ultimately be used for solving the issues of voltage instability. For the VPP, a centralized tool is required that can keep track of the reactive power flows, and an interactive platform is needed that is used to access the flows and to record it for future use. The paper presents such platform for the aforementioned purposes. The paper is organized in the following way: Section II talks about the architecture of VPP used for reactive power compensation and the specific subset of the architecture to be utilized for the purpose of reactive power compensation. Section III is on the development of the architecture in LabVIEW, while section IV is dedicated to the Human Machine Interface (HMI) and the Microsoft Excel based recording tool. Section V concludes the paper.

II. Architecture of Virtual Power Plant for Reactive Power Provision

Virtual Power Plant is a latest trend towards grid stability, by utilizing the usual storage, customers, distributed generation etc., but with proper management. The concept is explored as in [17] [18], and further matured as in [19] [20]. The architecture for the VPP is taken from [16], and the relevant portion is shown in figure 1.

The VPP controller can access the reactive power profile for all these components that take part in the architecture. However, only the residential and industrial customers, as a subset, are considered in the scope of this paper. The reactive power consumption for these customers is accessible through the meters of the customers.

III. Interface to Customers Meters for Reactive Power Visibility

For the participation of customers to the reactive power provision for VPP, the meters have the capability to support implemented with LabVIEW also supports the communication of signals via Modbus [21]. The address to point towards a specific parameter is according to the structure in Figure 2.

978-1-5386-2910-9/18/$31.00 ©2018 IEEE

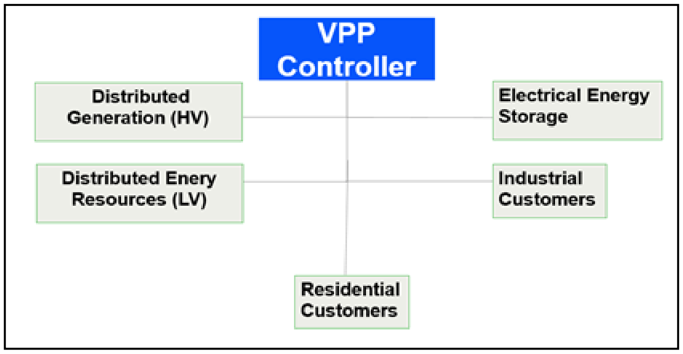

Fig. 1. Architecture of Virtual Power Plant

The same structure is implemented inside LabVIEW using Create TCP Master block for defining the IP address, Set Unit ID block for setting the modbus id, and Read Holding Registers for defining the specific parameter of the meter, i.e. the reactive power in the context of this paper.

Ip address → Modbus id → register

Fig. 2. Structure of Address

The structure is shown in Figure 3; however, the values are not indicated for the confidentiality purposes. Pink box indicates the IP address, and the box in the middle indicates the Modbus id. The two boxes on the right define the Modbus register and the number of bytes required to acquire the data for the parameter.

Eight customers, four at MV and four at LV nodes, are the sources of investigation in the paper. The next step is to the acquisition of the reactive power metering data for each of the customers. After that, the step is to store the data in a buffer. LabVIEW offers the functionality of creating an output array via ”Build Array” block, and this array is utilized for the development of buffer for the reactive power readings. The approach is to create a shift register via While loop. In other words, the array receives two inputs which are the reactive power reading on rum-time, and the input of while loop, which in turn depends on the output of while loop which is generated through the output of the array.

The buffer can store the reactive power measurements for a single meter. In order to record measurements for all the eight customers, the buffer is extended, and eight shift registers are developed within a single while loop [22]. These shift registers run in parallel, and store the readings for each customer in their respective arrays. For the sake of explanation in a better way, the buffer system for the two customers is explained in Figure 4.

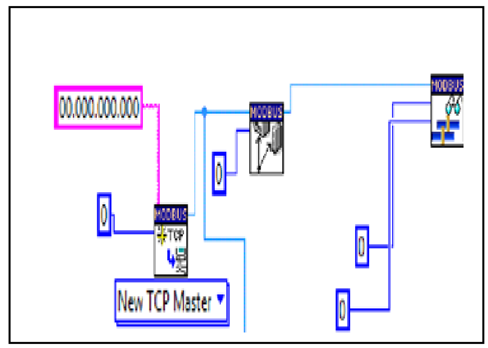

Fig. 3. Representation of Meter Data Addressing

IV. Human Machine Interface and Recording at VPP Controller for Reactive Power Visibility

The meters are polled at a rate of 100 milli-seconds and the buffers store and display the reactive power consumption for all the customers. The HMI is shown in Figure 5. However, the HMI displays, and then over-writes the measurements. Therefore, a recording tool is required at the control center for the access and use of these measurements at a later stage. One option is use the option of “Export Data to Excel”, but it creates a file for a measurement at each polling instant. Therefore, the problem is the wastage of memory to save abundance of files. Another problem is that the measurements only, and not the time-stamps are recorded.

The technique is to use the block ”Write To Measurement File”, and set the output of each measurement as a signal to the block [23]. Within the block, the location for the storage of file can be provided. It also supports the option for file append, and thus the measurements are appended with each polling instant, and as a result a single generated file can record all the polling measurements for a single meter end. With the utilization of TDMS functionality, both the data and time can be synchronized, and recorded as signals.

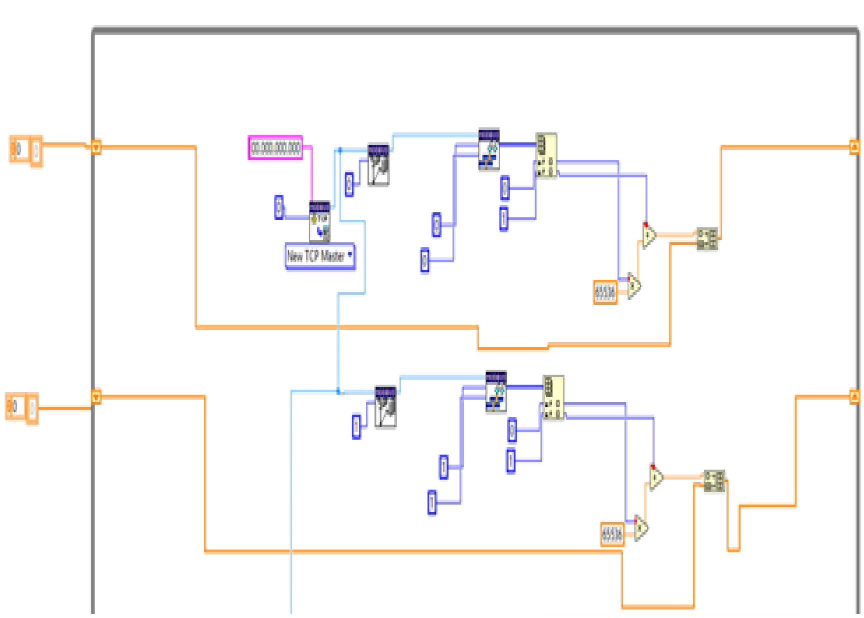

Fig. 4. Buffer for Reactive Power Readings

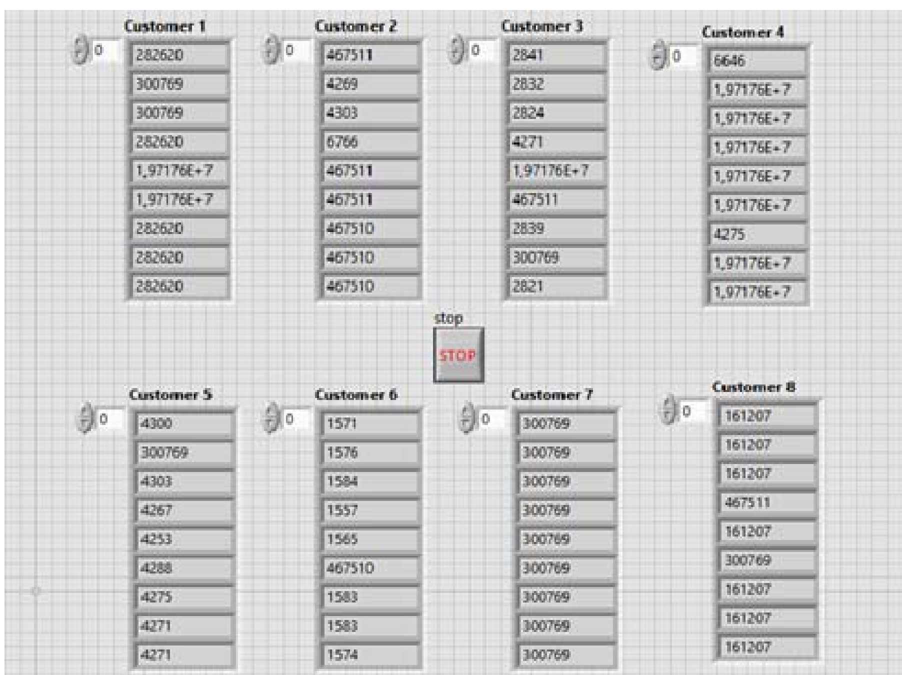

Fig. 5. Human Machine Interface for Reactive Power Readings

The recording format is shown in Figure 6. It displays the time, date, the reading number, and the measurement value for each measurement. In this particular case, these will be eight files for the eight customers that can record the reactive power measurements for the customers independently.

1	Time	Time*	Untitled
2	06/12/2017 04:40:32,325 PM	0	6465
3	06/12/2017 04:40:37,199 PM	1	2E+07
4	06/12/2017 04:40:42,032 PM	2	2E+07
5	06/12/2017 04:40:45,324 PM	3	4275
6	06/12/2017 04:40:45,617 PM	4	2E+07
7	06/12/2017 04:40:50,511 PM	5	2E+07
8	06/12/2017 04:40:53,085 PM	6	2E+07
9	06/12/2017 04:40:55,943 PM	7	2E+07
10	06/12/2017 04:40:59,273 PM	8	2E+07
11	06/12/2017 04:40:59,607 PM	9	6646

Fig. 6. Pattern for Reactive Power Recordings

The next step is to validate the performance of the interface, HMI, and recording unit at different test cases. These test cases represent the demands by TSO, and the effective mismatch proportion at both transmission and load levels. These demands may vary as per the time, amount, and the location for the mismatches in reactive power. The test cases are presented in Table 1. The table indicates the three major extremes for the services, and the possibility of support by the presented system. The requirements for adaptability within the tool, and the actions to be taken by the infrastructure are also elaborated.

For case 1, the idea is to poll the system at a more frequent rate. As a result, Modbus communication needs to be fast. It can result in two possible issues: the Modbus master is unable to handle many requests during the high polling period, and the missed data reading propagates the error from one Modbus client to the others (based on other customers). The requirement is to include an error handler, which accepts avoiding a few readings as per the requirements.

The error handler is implemented in LabVIEW, and one unit of each of them is added to each of the Modbus platform for customers. HMI does not support this change due to the limitations of buffered arrays. The recording tool has the tendency to record this large quantity of values in a timely fashion.

For case 2, the concept is to check the feasibility of the system at high amount of reactive power requirements. It is

TABLE I. TEST-CASES FOR REACTIVE POWER REQUIREMENTS

Serial Number	Validation Look-Up		
	Needs* and *Actions	***HMI Supported***	***Recording Supported***
1	**Faster services are required for high system reliability, specifically to deal with faults and contingency issues.** **The tool should support reduced polling intervals.**	NO	YES
2	**High proportion of reactive power is required. It may be during the case the microgrids, unexpected and large addition of distributed energy resources, tripping of any major line and/or generator etc.** **The tool should support large readings, via mechanism to erase the previously supported largest value for datalogging.**	YES	YES
3	**The requirement is at geographically scattered locations. The scenario may result in case of multi-area systems, and islanding.** **The tool should handle a large network range.**	YES	NO

the scenario when there are is a huge requirement of reactive power due to unexpected tripping, and addition of variable renewable generation resources. The tool requires addition of an increasing counter in order to avoid overwrite and overload issues with buffers.

For case 3, the requirement is the extended network range, and it may require the Ethernet address variations. The error handler in case 1 can resolve the issue; however, the recording tool does not allow these variations. The architecture in Figure 7 describes the full model of tool, with indications of the customers, HMI, recording tool, and the two additions of increasing counter and error handler. Other than reactive power, the tool has the capability to record and manage voltages at nodes, active power flow, and the details of the effective loading. It only requires the access of the required port of Modbus, and ultimately the addition of separate buffers to create multiple channels.

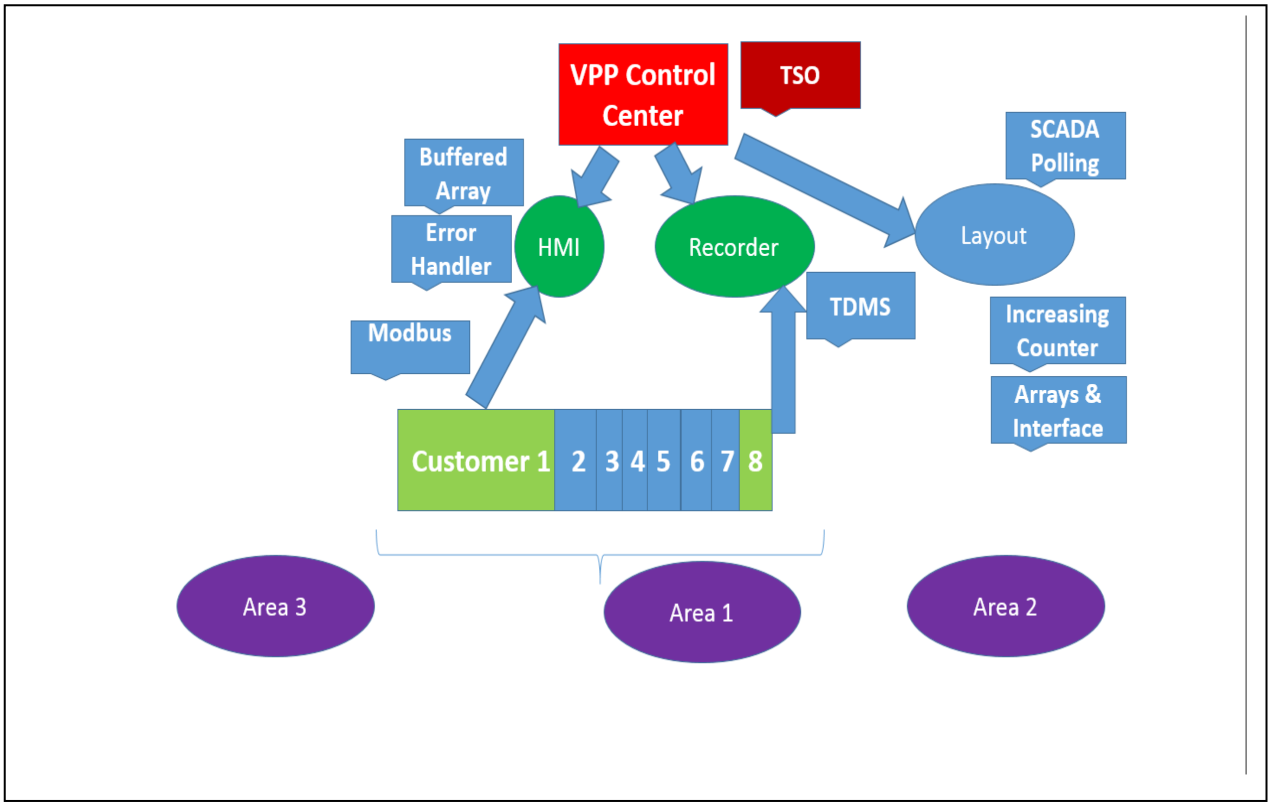

Fig. 7. Architecture of the Overall Tool

V. Conclusion and Future Work

The paper presents the architecture, HMI, and the recording tool for the VPP controller. The controller can take care of the reactive power flows to the customers, and thus it can follow a proactive approach for dealing with voltage instability based on reactive power control. As a future work, a decision system algorithm can be developed, and it can be validated through a real time simulator.

In order to create a more realistic picture of VPP, and as an extended case, the other actors of VPP (as in figure 1) should be aggregated together with the customers. This will include the energy storage elements, and other distributed generation resources, which will not only give the flexibility to VPP controller, but will also provide the involvement of different actors of power system in the provision of voltage instability, and thus it will create a better market opportunity.

As indicated before, other parameters including voltages and load-ratings can be future extensions too. Other VPP providers and their tools can also be analyzed in order to create the grounds for the comparison. Parameter of cost is another potential addition.

Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 676042.

References

[1] J. Smith, M. Rylander, L. Rogers, and R. Dugan, "It's all in the plans: maximizing the benefits and minimizing the impacts of ders in an integrated grid", IEEE Power and Energy Magazine, pp. 20-29, February 2015.

[2] O. A. Ansari, N. Safari, and C. Y. Chung, "Reliability assessment of microgrid with renewable generation and prioritized loads", IEEE Green Energy and Systems Conference (IGSEC), Long Beach, CA USA, December 2016

[3] J. M. Gers and C. Viggiano, "Protective relay setting criteria considering ders and distributed automation", International Conference on Development in Power System Protection (DPSP), UK, March 2016

[4] J. Yang and Y. Wang, “Review on protection issues of low-voltage distribution network with multiple power electronic converter interfaced distribution energy resources”, International Conference on Renewable Power Generation (RPG), China, October 2015

[5] V. Telukunta, J. Pradhan, A. Agrawal, M. Singh, and S. G. Srivani, “Protection challenges under bulk penetration of renewable energy resources in power systems – a review”, CSEE Journal of Power and Energy Systems, vol. 3, pp. 365-379, December 2017.

[6] E. Hossain, M. R. Tur, S. Padmanaban, S. Ay, and I. Khan, “Analysis and mitigation of power quality issues in distributed generation systems using custom power devices”, IEEE Access, vol. 6, pp. 16816-16833, March 2018.

[7] Euramet,“SmartGrid-II”,project. (*http://gridmeas.eu/2017/05/15/news-smart-grids-ii-workshop-slides-now-available-online/*)

[8] Euramet,“FutureGrid”, project. (*http://futuregrid.emrp.eu/*)

[9] Euramet,“GridSens”, project. (*http://gridsens.eu/*)

[10] B. H. Chowdhury and C. W. Taylor, “Voltage stability analysis: VQ power flow simulation versus dynamic simulation”, IEEE Transactions on Power Systems, vol. 15, pp. 1354-1369, November 2000.

[11] A. M. Abed, “Wscc voltage stability criteria, undervoltage load shedding strategy, and reactive power reserve monitoring methodology”, IEEE Power Engineering Society Summer Meeting, Canada, July 1999

[12] B. H. Chowdhury and C. W. Taylor, “Closure to discussion of Voltage stability analysis: VQ power flow simulation versus dynamic simulation”, IEEE Transactions on Power Systems, vol. 16, pp. 931-932, November 2001.

[13] C. N. Jibhakate, M. A. Chaudhari, and M. M. Renge, “Reactive power compensation using induction motor driven by nine switch ac-dc-ac converter,” IEEE Access, vol. 6, pp. 1312-1320, December 2017.

[14] G. Kumar and P. Nijhawan, “Simulation-based performance analysis of three-level 48-pulse statcom with constant dc link voltage for reactive power compensation,” India International Conference on Power Electronics (IICPE) , India, November 2016.

[15] L. B. G. Campanhol, S. A. O. da Silva, and A. Goedtel, “Application of shunt active power filter for harmonic reduction and reactive power compensation in three-phase four-wire systems,” IET Power Electronics, vol. 7, pp. 2825 – 2836, November 2014.

[16] J. Ali, S. Massucco, and G. Petretto, “Reactive power provision to tso/dso by aggregators and conventional generators,” IEEE International Conference on Smart Grid Communications, Dresden, Germany, October 2017

[17] “The new green grid: utilities deploy virtual power plants.”. (https://www.theguardian.com/environment/2016/aug/02/the-new-green-grid-utilities-deploy-virtual-power-plants)

[18] Horizon 2020 work programme 2018-2020.
(*http://*ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-energy en.pdf /)

[19] Virtual power plants. (*http://* www.kisters.eu/energy/applications/energy-market-roles/ipp-aggregator/virtual-power-plants.html /)

[20] Virtual power plant operator power trader: Our path is digital, flexible, and sustainable. (*http://* www.next-kraftwerke.com/company /)

[21] Introduction to modbus using labview.
(*http://* www.ni.com/whitepaper *7675/en/*)

[22] Transferring values between loop iterations. (*http://* zone.ni.com/reference/en-XX/help/371361G-01/lvconcepts/ shift registers feedback node//)

[23] Using the write to measurement file express vi
(*http:// digital.ni.com/public.nsf/allkb/CB46BC11A488621E86256D19005A386E*)