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Management Platform for a VPP in an Electric System based on Python and DIgSILENT

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Abstract

Currently, the development of new technologies for the generation of renewable energies, pave the way for a new field of study for the integration and modernization of the infrastructure of current electric systems.

This document presents a theoretical framework on the concept of VPP and their importance as a management tool in a distribution electric system (based on the 37-node IEEE model), including Distributed Energy Resources (DER) as well as the proposal of a virtual platform resulting from the interaction between Python and DIgSILENT.

With this interface, the management system of the VPP is integrated as a secondary platform to the main software (DIgSILENT) which interacts and supervises the electric system in real time. Additionally, the secondary platform uses the control and calculation properties of the main platform. This strategy enables the control and management of the elements of the system from the VPP. In this case, said elements are the distributed generators, the distribution lines and the loads. This all represents a simplification in terms of the software infrastructure required for the integration of distributed generation to the electric systems in the near future.

The integration of distributed generation throughout the VPP into the studied model had no negative impact and significantly improved the levels of voltage in all nodes of the system in particular during high-demand periods. This derives in more reliability and quality in the service for the supply of electric energy, essential for the study and application of DER.

Keywords: Distributed Energy Resources (DER), Distributed Generation, Electric system, Smart Grid, VPP (Virtual Power Plant).

INTRODUCTION

Smart Grids are the future of conventional electric networks which integrate in a smart and structured manner the NCE (non-conventional energy) sources as well as consumers and producers of an electric system not only from a technical standpoint but also in the economic standpoint [1].

The standardization of conventional methods and other actions in these networks are established by the IEEE association [1]. The integration of small electric energy generators to the conventional distribution systems has become a necessary field in the expansion of the energy market and thus requires control mechanisms for new energy sources that encompass the technical and commercial aspects of these small generators [2]. As a response, the Virtual Power Plant (VPP) is proposed as a tool to tackle this issue.

VPP CONCEPTS

Nowadays, there is no unified definition of a Virtual Power Plant which means that there is no concrete conception approved by all sectors that study its development. However, the concept is condensed in a tool that allows the smart grid to interact with each component and with the electric market [1]. This tool controls the electric system of middle voltage where different distributed energy resources (DER) are added [4][5] showing an availability independent from the general system supply, which can be operated and controlled in a way that is not limited to one single generation and control point which decentralizes generation in a distribution system [6].

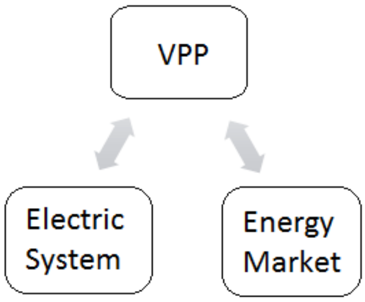

Figure 1. Interaction of a VPP.

A VPP figure 1 is mainly divided into a commercial part and a technical part depending on its approach [4]. When the VPP is mostly focused in the requirements of the electric market and has access to said market, it is called a CVPP (Commercial Virtual Power Plant) which can balance the trading book, optimize distributed generation according to costs and other functions that can offer more convenient economic benefits through control strategies that properly adapt to the electric system and to the requirements established within the market [1] [7][8]. When the VPP centers on technical aspects of the electric system it is called a TVPP (Technical Virtual Power Plant) which is governed by the technical matters concerning the use of distributed resources. Its operation is based on information presented to the system, its characteristics and conditions of operation [1] allowing the management of the system components (lines, loads and generators) through the control center. in Table 1 previous works related concepts and characteristics of VPP are presented.

Table 1. Previous work related to concepts and features of VPP.

Authors and year	Relevant Aspects
M. Technique, A. Van Der Velden, and A. Juelich, 2003	Needs and projections of the electric systems, need for tools such as VPP [2]
K. EI Bakari and M.A. Myrzik 2009	Control perspectives of an electric system through a VPP [9]
Mahesh S Narkhede and S.Chatterji 2013-2014	Energy dispatch in a VPP in an electric system [10]
M. Mohammadi, and R. Taghe, 2014	Characterization of a VPP and its features [6]
Fernando ariel inthamoussou, 2014	Control strategies for renewable energies within electric systems [7]
Alejandro Montes Ruiz, 2015	Concepts, structuration and analysis of a VPP and its features [1]
G. Messinis and N. Hatziargyriou 2016	Network flexibilities through the use of a VPP and distributed resources [8]

PROPOSAL OF VPP AS A MANAGER OF THE COMPONENTS OF THE SYSTEM

To respond to the need to integrate distributed energy resources to an efficient electric distribution system [3][4], the correct management of the components of the system is required. The implementation of a VPP is an alternative to assess [11][9], allowing the establishment of the impact of its management in the system according operation conditions that can arise. The correct integration of a VPP into an electric system must encompass each and every part that intervenes in said process. An adequate communication of each part constitutes a proper interconnection and management between the electric system and the VPP. This tool has a bidirectional connection with the agents of the electric market as well as with elements of the distribution system as shown in Figure 2.

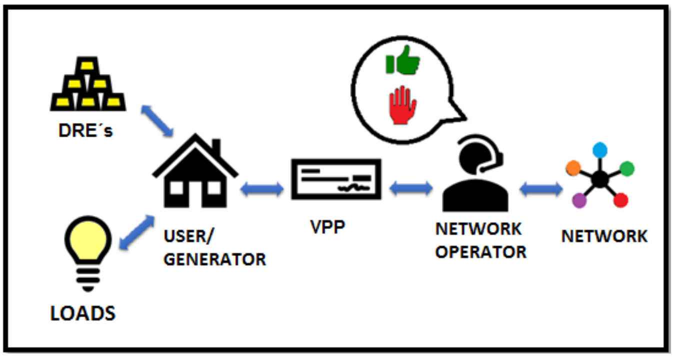

Figure 2. Communication of the VPP with agents of the electric market and elements of the electric system.

The proposed strategy of implementing a VPP involves a virtual platform built in Python that can manage the elements (lines, loads and distributed generators) using the entire hardware infrastructure that provides the necessary information for the management and monitoring software of the electric system which is DIgSILENT in this case. The modelling of the VPP with Python and DIgSILENT is presented as a platform interacting with the integrator between the VPP and the network operator (figure 3), which manages the elements of the electric distribution system according to the need and method of contingency to events present in the system. In agreement with the modifications made by the integrator and network operator and the assessed demand period, the VPP is in the capacity of enabling or disabling the connection of the distributed generation as well as the topologies of the management system for load shedding in the required nodes.

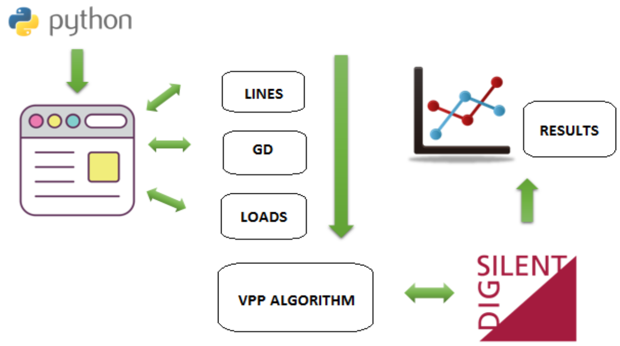

Figure 3. Operation of the interface [Authors].

To assess the implementation of the VPP, a distribution system(Figure 4) based on the 37-node IEEE model [12] was simulated. The characteristics of the loads were adjusted as well as the classification into areas as well as the integration of the distributed generation. These modifications are detailed in [13]. Distributed generation was integrated into the system according to figure 4 and the criteria in [13].

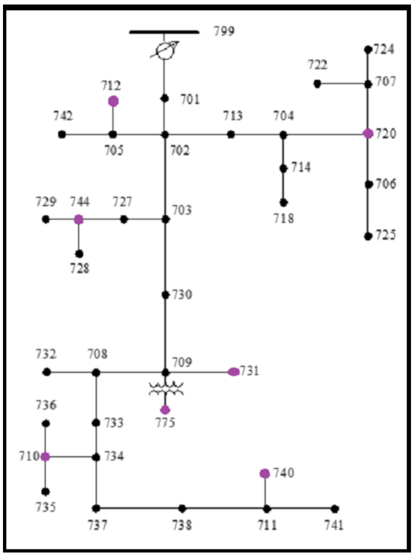

Figure 4. Distributed generation nodes in the system.

A classification based on timeslots was defined according to the demand curve of the system power given by the characteristics of its loads (industrial, commercial and residential loads). The results of the simulation scenario are presented in normal operation conditions of the system and then compared to the results of the implementation in the entire distributed generation during the high-demand period. The summary of the results is shown in [13] for low and middle demand periods.

Table 2 shows the comparison of the results of the voltage profiles in the system nodes. Basic case study and simulation scenario n ° 1 (high demand).

Table 2. Comparison of the results of voltage profiles in system nodes. Basic case study and simulation scenario n° 1 (High demand).

AREA NODE	HIGH DEMAND BASE CASE STUDY		HIGH DEMAND SIMULATION	
	Average voltage [p.u.]	Standard Deviation	Average voltage [p.u.]	Standard deviation
Nodo 705	0.994	0.0020	1.003	0.0015
Nodo 712	0.993	0.0020	1.003	0.0015
Nodo 742	0.993	0.0020	1.002	0.0016
Nodo 704	0.989	0.0024	0.999	0.0019
Nodo 707	0.979	0.0040	0.991	0.0032
Nodo 706	0.983	0.0032	0.995	0.0024
Nodo 713	0.992	0.0021	1.002	0.0016
Nodo 714	0.989	0.0024	0.999	0.0018
Nodo 718	0.988	0.0023	0.999	0.0018
Nodo 720	0.983	0.0032	0.995	0.0025
Nodo 722	0.978	0.0041	0.990	0.0033
Nodo 724	0.979	0.0039	0.991	0.0031
Nodo 725	0.983	0.0031	0.995	0.0024
Nodo 727	0.981	0.0030	0.994	0.0023
Nodo 728	0.979	0.0031	0.994	0.0023
Nodo 729	0.979	0.0031	0.993	0.0023
Nodo 744	0.979	0.0031	0.994	0.0024
Nodo 775	0.971	0.0034	0.991	0.0023
Nodo 731	0.971	0.0035	0.989	0.0025
Nodo 732	0.967	0.0037	0.987	0.0026
Nodo 710	0.955	0.0045	0.981	0.0031
Nodo 735	0.954	0.0046	0.980	0.0032
Nodo 736	0.953	0.0046	0.978	0.0033
Nodo 711	0.954	0.0045	0.981	0.0031
Nodo 737	0.957	0.0043	0.982	0.0030
Nodo 738	0.955	0.0044	0.981	0.0030
Nodo 740	0.954	0.0045	0.981	0.0031
Nodo 741	0.952	0.0047	0.979	0.0033
Nodo 701	1.008	0.0011	1.013	0.0009
Nodo 702	0.996	0.0019	1.004	0.0014
Nodo 703	0.984	0.0028	0.997	0.0020
Nodo 708	0.968	0.0036	0.987	0.0026
Nodo 709	0.971	0.0034	0.990	0.0025
Nodo 730	0.974	0.0033	0.991	0.0024
Nodo 733	0.965	0.0038	0.986	0.0027
Nodo 734	0.959	0.0042	0.983	0.0029
Nodo 799	1.025	0.00	1.025	0.00

The first analysis of the simulation scenario in comparison to the basic case study leads to concluding that the values of the voltage profiles increased with the integration of distributed generation to the system.

Figure 5 shows the comparison of the average values of voltage profiles for each node in the basic case study and simulation scenario n° 1. There is an increase in the values of the voltage profiles for all nodes. The nodes which are farthest from the main supply network have higher average values in the voltage profiles thus it can be stated that the integration of distributed generation into the system has a stronger impact in the far-off nodes in terms of their voltage profiles.

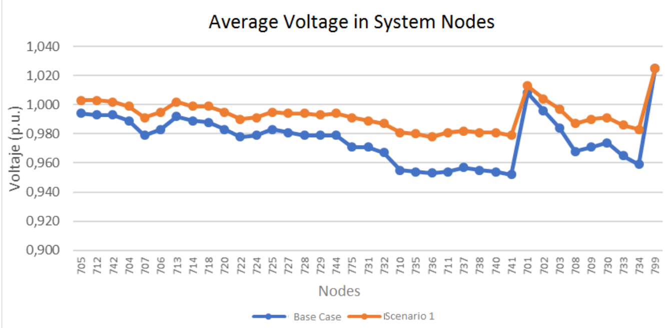

Figure 5. Comparison of average voltage profile in system nodes. Basic case study and simulation scenario n° 1 (High demand).

The values or limits encompassed in the variation of the voltage profiles for system nodes remain within a range lower than for the basic case study. Therefore, the standard deviation of said profiles reveals that the dispersion (in terms of the average value) is higher for the system without distributed generation. This indicates that during the simulated period (High Demand) the integration of DG into the system leads to more stable voltage profiles in all nodes thereby reducing their variation. Figure 6 states the relation between the standard deviation in all nodes of the system.

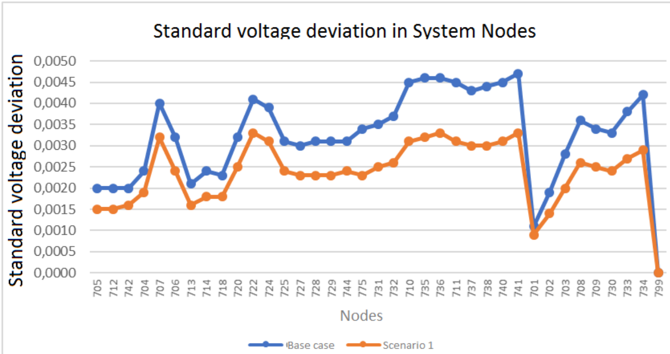

Figure 6. Comparison of the standard deviation in system nodes. Basic case study and simulation scenario n° 1 (High demand).

The reduction of the data dispersion in voltage profiles leads to conclude that the integration of DG translates into the flattening of voltage profiles which are farthest from the main supply network. In contrast, its impact in nearby nodes is lower. Figure 6 shows the comparison of the flattened voltage profiles with higher reduction in the dispersion of voltage profiles.

Comparing the results obtained for the high, middle and low demand scenarios, it can be stated that for high demand periods the integration of DG has a more favorable impact for the system in terms of the voltage profiles. Table 3 summarizes the results.

Table 3. Impact of distributed generation on the voltage profiles of the modelled system.

DEMAND PERIOD	BASIC VOLTAGE CASE (p.u.)	VOLTAGE IN SCENARIOS (p.u.)	INCREASE (%)
HIGH	0,977	0,993	1,64
MIDDLE	0,984	0,999	1,52
LOW	1,009	1,016	0,69

Considering that the voltage levels must be remain in ± 10 % of the nominal value according to Colombian regulation [14], a 1% increase is significant compared to the allowed variation range. Table 4 shows the standard deviations of the base case study and the simulation scenarios.

Table 4. Impact of distributed generation on the standard deviation of the modelled system.

DEMAND PERIOD	BASE STANDARD DEVIATION	STANDARD DEVIATION SCENARIOS	INCREASE (%)
HIGH	0.0032	0.0024	25
MIDDLE	0.0032	0.0023	28.13
LOW	0.0067	0.0049	26.87

Considering the results shown in Table 5, it can be deducted that the variations of the voltage profiles of the system show a 26.67% average reduction in a 24-hour demand period. Therefore, it is evidenced that the system is more robust against demand variations from connected loads.

The constant development of this platform as well as its characteristics would show a future integration scheme of VPP that can be replicated in different electric systems with different management and monitoring software.

CONCLUSION

This platform offers the possibility of direct interaction of the integrator with the system and the proposed case studies, which allow a better visualization of the operation of a VPP and how it manages and modifies the elements of the distribution system. The integration of the distribution system heightens voltage levels for the entire demand period.

With the analysis of dispersion in the voltage profiles, it is determined that their variations are significantly reduced. Thus, the system becomes more robust and stable in the face of variations of demand of the connected loads. As a result, there is a higher stability limit with the integration of GD into the distribution system.

The integration of DG into the system does not have a negative impact in terms of the understanding of the analysis in this project. The results were more favorable in high and middle demand periods.

The management system of the VPP establishes a platform capable of using the modelling and calculation methods of current electric system software. It represents an alternative for the implementation of the infrastructure in terms of software required in the integration of DER in electric systems. The VPP seen as an integrating manager of the components of an electric system is in the capacity of giving a fast response in the face of the contingencies that may arise.

Using programming languages such as Python, the VPP can use secondary platforms to manipulate the control operators existing in the distribution systems, thereby harnessing their calculation models and the remote interconnection with the components of the system.

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