IoT Techniques Implementation to Coordinate Single-phase Rooftop PVs in Three-phase LV Network

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IoT Techniques Implementation to Coordinate Single-phase Rooftop PVs in Three-phase LV Network

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Abstract. As the single-phase rooftop photovoltaics (PVs) are installed into the three-phase low voltage (LV) distribution network, the network voltage profiles become unbalanced. Although the load at the customer side has already imbalanced the network, as the single-phase rooftop PVs with random ratings of 1-5kW are installed, the power quality issues, such as voltage magnitude and angle, frequency, active and reactive powers become significantly noticeable. This is because of the grid infrastructure from plants to beyond the customer side is disrupted as several utility devices added into the network. This paper aims to implement the concept of several internets of things (IoT) techniques into the electric and communication infrastructures as they are virtuously cycling, enabling, amplifying and reinforcing the infrastructure development. This concept also applied to the voltage regulation technique (VRT), in order to improve the voltage unbalanced and other power quality issues. This communication-based VRT has been conducted by the authors in their previous studies. The results show that the concept of IoT techniques successfully implemented if both communication devices and technology properly selected and designed. Additionally, the considered classifying of the communication layers also plays an important role to coordinate sensors actuators and meters along the feeder of the LV network.

Keywords: Rooftop PVs, LV network, IoT techniques, Communication-based VRT, and Voltage profile improvement.

1. Background

As electrification supply and demand issues rise continuously, the decentralization of distributed generators (DG), especially single- and three-phases photovoltaics (PVs) within the national transmission/distribution electric network, and smart grid communication devices mark the transformation of those infrastructures to put into account [1]. As the single- and three-phases rooftop PVs are installed into the three-phase residential feeder of low voltage (LV) distribution network, the voltage profiles of the network become unbalanced. Although the load at the customer side has already imbalanced the network, as the PVs with the ratings of 1-5kW are installed along the feeder, the power quality issues, such as the voltage magnitude and angle, the frequency, the active and reactive powers become significantly noticeable [2]. This is because of the grid infrastructure from plants to beyond the customer side is disrupted as several utility devices added into the network. As the infrastructure problem raised, the power quality issues appeared.

In fact, the smart grid is no longer a new concept to develop the electric network infrastructure, however, we still have to consider the differences between ancient and smart grid systems, as can be seen in Table 1. It can be seen that the development of the grid has significantly rocketed since massive challenges top up.

Table 1. Differences between the ancient and smart grid [1].

Ancient Grid	Smart Grid
One-way directional power flow	Two-ways directional power flow
The utility pays whatever it takes to meet peak demand	Utility suppresses demand at peak
Difficult to manage high wind and solar penetration	Challenge higher wind speed and solar penetration
Unable to manage distributed generation safely	Manageable distributed generation safely
~10% power loss in T&D	Power Loss reduced by 2+%
No communication infrastructure involved	Communicate all installed DG within the network

This paper aims to implement the concept of developing the contribution of the internet of things (IoT) of electric network infrastructure as they are virtuously cycling, enabling, amplifying and reinforcing the infrastructure development. This concept in certain ways also applies the voltage regulation technique (VRT) that has been developed and mitigated in [3], in order to improve the voltage unbalanced and other power quality issues. The communication-based VRT must capable to scatter the location of PVs and customer loads and handling a numerous and massive number of sensors/meters and covers a geographical area. Therefore, the IoT technique must put into account to further improve the performance of the considered VRT.

2. Methods

To imply the IoT techniques into the communication-based VRT of coordinated single- and three-phases rooftop PVs within the LV network, there are two proposed methods, selecting and designing the proper communication of IoT techniques, and classifying the communication layer due to provide data transfer capability amongst PVs' controller and grid controller.

The considered network configuration that has successfully applied the wireless data communication techniques within the communication-based VRT is mitigated [4], therefore, these proposed IoT techniques are the enlargement of those in [4].

2.1. Selecting and designing proper communication of IoT techniques

Both wired and wireless communication technologies can be employed in the electric network infrastructure that has PVs installed within the LV network. According to [5], the popular wired technologies, used in power systems, are serial communication RS-232/422/485, bus technology (e.g., ModBus, ProfiBus, and CANBus), power line communication and broadband power line communication, and Ethernet (e.g., LAN and optical cable). On the other hand, the popular wireless technologies, used in power systems, are cellular, Wi-Fi, WiMax, ZigBee, Z-Wave, Bluetooth, Insteon, radio frequency, and Microwave. [5] also states the comparison of both communication technologies that describe the benefits and drawbacks of the network.

Due to the transfer the data to the grid controller, several parameters should be considered in selecting and designing the communication technology. There are several considerations that must put into the account.

1) The area size whereas the PVs are distributed;
2) The costs of the installation, operational and maintenance;
3) The inclusion of sensors, actuators, meters, and supporting devices;
4) The requirements of minimum data transmission rate, data precision, and maximum data packet error;
5) The future expansions flexibility; and
6) The access data of different techniques.

It is to be noticed that the electrification and decentralized control of the grid-connected PV system within the LV feeder is obviously possible since the VRT communication-based performances are within the communication layers. The PV controller, the grid controller, and the power quality parameters controller, respectively, are classified into three different communication layers. The following design in LV network communication is presented as an illustration in Figure 1.

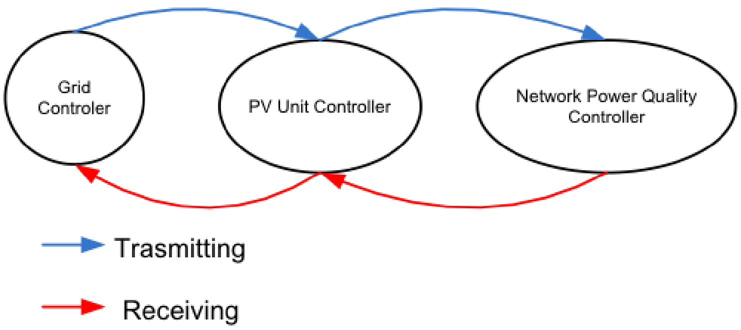

Figure 1. Design of the communication technique in LV network with PV

As the controlling and coordinating amongst PVs occurred, the monitoring has to put into account as well. Figure 2 illustrates the distributed monitoring system involving PVs within the LV network.

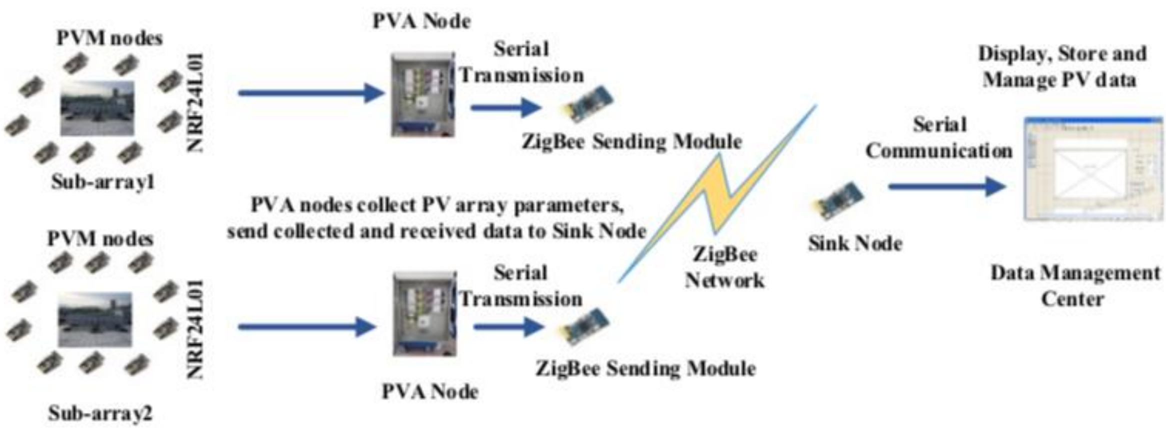

Figure 2. Distributed monitoring system involving PVs within the LV network [6]

2.2. Classifying communication layers.

Considering the location of the communication devices and also the characteristics of the data that has to be transferred, the IoT techniques in the grid-connecting PV system are classified in three layers, as shown schematically in Figure3.

The first communication layer is the control system within every PV's unit that primarily controls the operation of PV based on its local measurement. The data is fetched from the local sensors/meters using time steps of the very small sampling and eventually produces the required outputs for the PV's actuators. The PV unit operates within the constant PQ mode and generates power based on the maximum power point tracker (MPPT) technique. In the self-sufficient mode, the PV essentially operates in droop control.

The second communication layer is the grid controller that responds to control the voltage magnitude and angle and also frequency at the grid side. As the main controller, it fetched data from the installed voltage sensors. The third communication layer is the power quality of a network controller. This controller responsible for the general operation of the network power. It also defined as the operational mode of the grid, either in a grid or self-sufficient mode. The implemented concept of communication technology, either it is wired or wireless into the infrastructure network conveyed the tremendous power quality from the grid to the customer side.

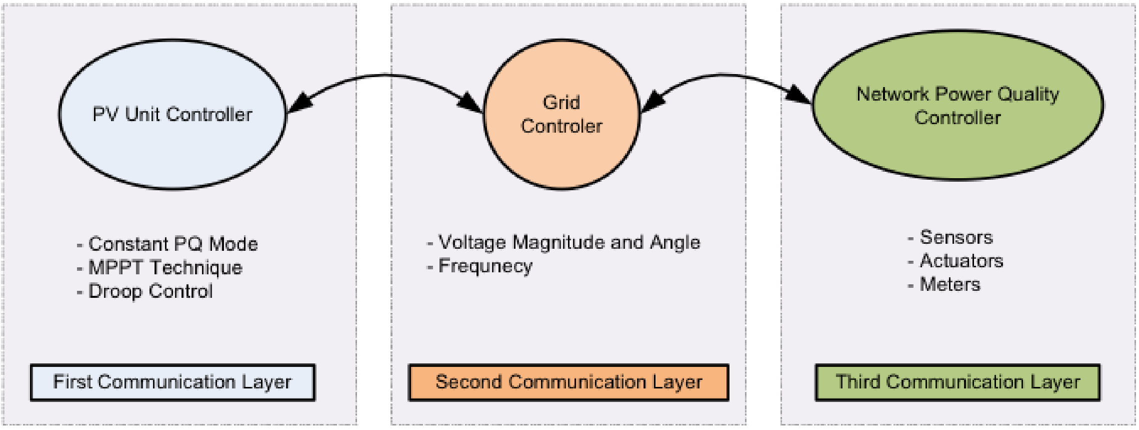

Figure 3. Hierarchal of communication layer of the considered IoT techniques in LV network

3. Conclusion

The proposed IoT techniques to implement the concept of coordinated PVs within the distribution network are built through the communication-based VRT that has been studied through several researchers that have been conducted by the authors. As the IoT techniques applied, the concept might accomplish if the selected and designed of both communication devices and technology properly. In addition, the considered classifying of communication layers also plays an important role. As the concept of electrification infrastructure, decentralization of PV system along the residential feeder and the communication among sensor, actuators, and meters are applied.

Thus, to implement the concept the development of the electric infrastructure as well as the inclusion of decentralization PVs' set and communication of devices from plant to beyond the load at the customer side must coordinate in such way that the improvement of communication-based VRT using IoT techniques to overcome the imbalanced voltage profile can be successfully conducted.

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