IoT-based Communication Techniques of PVs Random Settlement in Residential Feeder

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Abstract – Whenever the additional random 1-5 kW rating and location photovoltaics (PVs) are connected into the residential feeder, the voltage profiles of the feeder become unbalanced. Besides the various load at the customer side has already imbalanced the feeder, the installed single-phase rooftop PVs do the same thing. They caused the power quality issues, namely voltage magnitude and angle, frequency, active and reactive powers become expressively recognized. Since the ancient electric utility infrastructure from power plants to customer side is now disrupting by the added settlement of several utility devices, the power quality issues have raisin significantly. This paper aims to implement the concept of several internets of things (IoT) technologies into the electric and communication infrastructures as they are able to virtuously cycle, enable, amplify and reinforce the utility development. To improve the imbalanced voltage and other power quality issues, this concept applied to the existed voltage regulation technique (VRT). The results show that the concept of IoT-based communication is successfully implemented if both the devices and technologies properly selected and designed. Additionally, the classification of communication layers, then the coordination of sensors, actuators, and meters along the residential feeder need to be considered as well.

Keywords: PVs, residential feeder, IoT technologies, Communication-based VRT, and Voltage profile improvement.

I. INTRODUCTION

The electrification issues regarding supply and demand have been continuously growing as the decentralization of distributed generators (DG) especially single- and three-phases photovoltaics (PVs) installed within the network line. Moreover, smart grid communication devices that are settled along the ancient infrastructure feeder influenced the utility parameters since the imbalance three-phase might occur along the feeder [1]. As the PVs are installed randomly into the residential feeder, the voltage profiles of the network become unbalanced. Even though the load at the customer side has already imbalanced the network, as the PVs with the ratings of 1-5kW are settled randomly along with the network power quality issues, such as the voltage magnitude and angle, the frequency, the active and reactive powers become significantly noticeable [2]. This is because the grid infrastructure from plants to beyond the customer side is disrupted as several utility devices added into the network. As the power quality issues raised, the modification development of utility infrastructure needs to be considered as well.

Smart grid is no longer a new concept to develop the electric network infrastructure, however, the transformations from ancient to smart grid systems still show differences. Table 1 described the differences along with the significant increased challenges.

This paper objects to deploy the developing concept of modified ancient utility infrastructure into smart grid by including the contribution of the internet of things (IoT) that communicate the settlement of electric devices along the network as they are virtuously cycling, enabling, amplifying and reinforcing the infrastructure development. By applying the voltage regulation technique (VRT) that has been developed and mitigated in [3], the improvement of unbalanced voltage profile and other power quality issues might occur. The communication-based VRT must capable to i) locate the random location of PVs; ii) locate the various loads at customer side; iii) handling a numerous number of sensors and meters; and iv) covers a geographical area. Furthermore, we need to consider the IoT technique to further improve the performance of the VRT.

Few studies have been conducted regarding the coordination and communication amongst PVs in residential feeder. As mentioned in reference [2], [3] and [4], the aim of using IoT can overcome the unbalance voltage profiles along the feeder while PVs are located randomly. While in [4] and [5], the authors have implemented several wireless communication devices into the PV system interconnected to the LV feeder and their action in certain layers.

IoT technology for power conditioning unit monitoring in solar power plants is proposed in reference [6]. This proposed method shows the satisfactory results in monitoring the solar power conditioning unit parameters, visualization and report generation of energy outputs, storage of monitored parameters in cloud for historic analysis. While in reference [7], Smart solar PV system using IoT had shown great monitored performance and less maintenance possibilities. Here an intelligent hybrid system with primary energy sources, unified power supply unit, and the battery storage facility is adopted. For this intelligent system, IoT technique enables to operate and charge the battery during the energy source

presence and also helps in shifting to the storage option as the supply unit during the absence of energy source.

For that reasons, this paper is then proposed a concept of interconnecting PVs as distributed generators (DGs) into the electricity utility system and including the communication devices within the IoT technique. The structure of the paper is as follow, section one describes the background of the settlement of single-phase PVs in the residential feeder and the way to modified grid infrastructure. Section two explains the methods of including IoT technology into the grid infrastructure while communicating the installed PVs along the feeder. Section three discusses the results as the selected and designed of the proper communication technique of the IoT technology are implied. Finally, section four concludes the improvement of voltage profile and other power quality issues of implying the communication technique of random settlement of PVs in residential networks based on IoT technology.
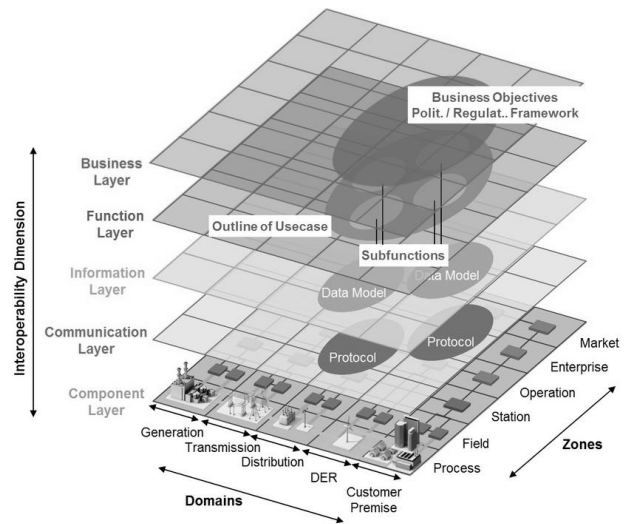
Table I
Differences between The Ancient and Smart Grid [1]

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

II. METHODS

To deploy the IoT techniques into the communication-based VRT of coordinated PVs along the residential feeder, two methods need to be considered, namely i) selecting and designing the proper communication techniques of IoT technologies, and ii) classifying the communication layer of data transfer amongst PVs' and grid controllers.

Basically, As defined in [8], there is a method that helps in designing an architectural approach of coordinating and communicating PVs in the feeder. This method allows a neutral representation of the involved technologies highlighting their interoperability supported by standards and, consequently, enabling standards gap analysis. This method defines a three-dimensional model consisting of five interoperable layers: (i) Component Layer, (ii) Communication Layer, (iii) Information Layer, (iv) Function Layer and (v) Business Layer (Figure 1).

Fig. 1 Architecture Model with Interoperability Layers

However, since the discussion of this paper is on the communication layer, thus from here on, the details provided are within the mentioned layer.

The authors then have considered the feeder configuration that has successfully applied the wireless data communication techniques within the communication-based VRT that is mitigated in [4], therefore, these considered IoT technologies are the development of those in [4].

A. Selecting and Designing Proper IoT Communication Techniques

The communication technique of the considered IoT technology that can be employed in this paper by developing the one that mitigated in [4] is illustrated in Figure 2. The settlement of random 1-5kW PV along the residential feeder essentially coordinated using wireless communication techniques namely, Wi-Fi, Wi-Max, ZigBee, Z-Wave, radio frequency, and Microwave [5]. Beyond those communication techniques then the IoT technology of grid infrastructure controller can be employed.
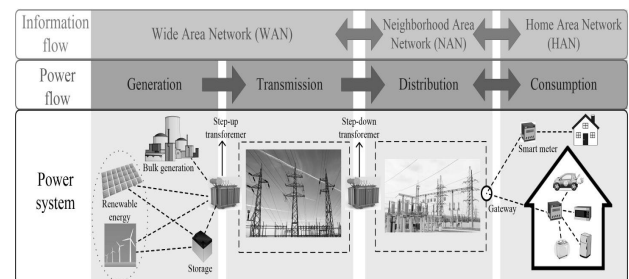

Fig. 2 Design of The IoT Technique

To allocate the data to the grid controller, several parameters that should be considered in selecting and designing the communication technology are illustrated in diagram of Figure 3.
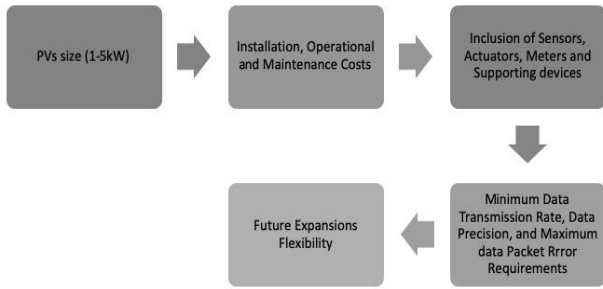
Fig. 3 Selected and Design of Data Transfer from Grid to
Customer Side

As the controlling and coordinating amongst random settled single-phase rooftop PVs occurred, the monitoring has fundamentally considered [9]. Figure 4 illustrates the monitoring system of PVs from the residential point of view.
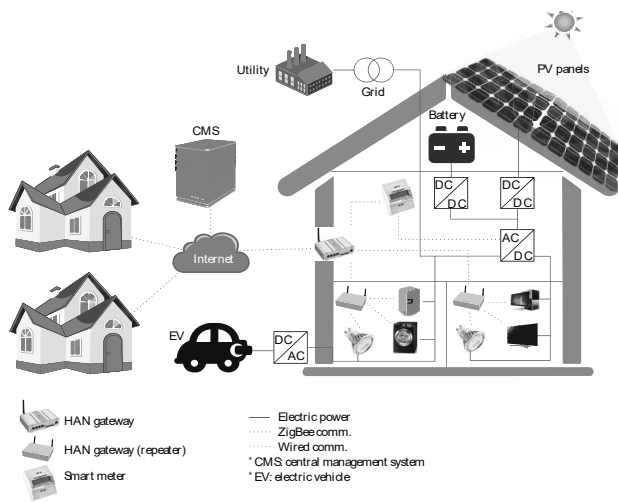

Fig. 4 Monitoring System of PVs along The Feeder [10]

The implementation of IoT paradigm to home energy monitoring system (HEMS) solve the limitation of the devices in service domain embed an adaptive rule-based engine. it generates the control signal directly according to rules, so that the system reduces the service creation and execution time [10].

B.   Classifying Communication Layers

The location of the communication devices and also the characteristics of the data that have to be transferred, are compulsory to consider. The three communication layers that have to be classified is shown schematically in Figure 5. The first layer is the PV unit controller that principally controls the operation based on the local measurement. The data then is fetched from sensors and meters using the very small sampling of time steps and then produces the required outputs for the actuators. PV unit controller operates within the constant PQ mode and generates power based on the maximum power point tracker (MPPT). In the stand-alone mode, the PV basically operates in droop control.

The second layer is the grid controller that responds to arrange the voltage magnitude and angle and also the frequency at the grid side. It fetched data from the sensors. The third layer is the feeder power quality controller. This controller is responsible for the general operation of the feeder power. It also defined as the operational mode of the grid, either in grid or stand-alone mode. The implemented concept of communication technique of IoT technology, into the infrastructure network, conveyed the tremendous power quality from the grid to customer sides.

Communication Layer contains all the protocols and the software components to allow a fast-bidirectional communication over the Internet. This layer also exploits two main protocols for the communication over the Internet.
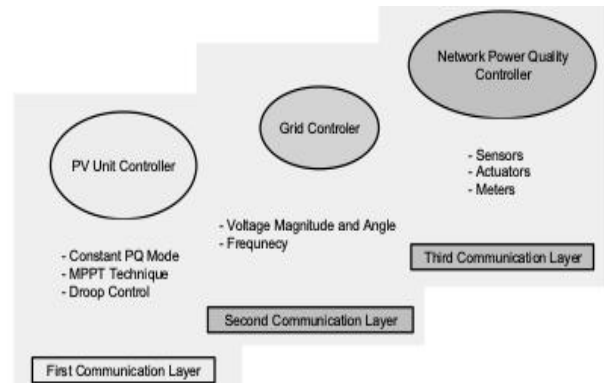

Fig. 5 Three Communication Layers of Developed IoT Technique
in Residential Feeder

III.   RESULTS AND DISCUSSION

It is noted that the IoT-based communication techniques of the grid-connected PV system within the residential feeder might occur if the VRT communication-based performances are within the communication layers. The PV unit controller, the grid controller, and the feeder power quality parameters controller, respectively, are within the supply and demand system and classified into three different communication layers. It is illustrated in Figure 6.
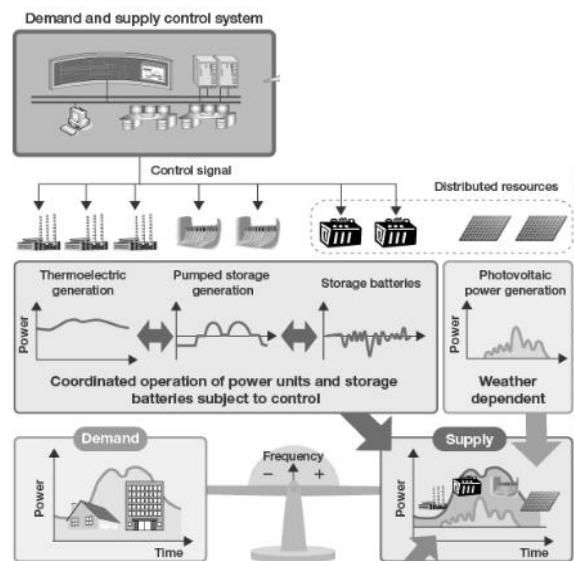

Fig. 6 Controllers performances

The main input of the PV is temperature and irradiance over the time in real-sky conditions. PV detects encumbrances on roofs (e.g., chimneys and dormers) that prevent the deployment of PV panels, and shadows on roofs over one year. This phase identifies the suitable area, which is the real area of a roof that can be used to deploy PV panels. To estimate the incident global radiation, solar radiation is decomposed by considering the attenuation due to air pollution. Solar radiation decomposition needs as inputs both the direct normal incident radiation and the diffuse horizontal incident radiation, and the characteristics and parameters indicate as default values. However, such parameters can be changed according to the characteristics of PV systems.

The monitor of demand and supply control system read the measured utility parameter namely voltage profile and active and reactive power. We maintain the frequency of the system to be synchronized to frequency of the utility, 50Hz. As the results, voltage profile of the system is stabilized (within its permitted limit, ±5%).

The similar behaviour is also applied to active and reactive power. The ideal condition of PVs as interconnected DGs in the LV feeder, in this case the residential feeder, must address the injection and absorption of active power P, and reactive power Q, respectively, into and from the grid. Therefore, the coordinated operation of power units and batteries as storage must meet the supply and demand conditions.

IV.　CONCLUSION

The developed concept of IoT technology communication technique that implied into the settled single-phase rooftop PVs along the residential feeder is built through the communication-based VRT that has been mitigated in authors' previous studies. Since the IoT applied, the properly selected and designed of both communication devices and techniques were successfully deployed as well as the classifying of communication layers plays important roles. Then the development of the infrastructure, the settlement of PVs along the residential feeder and the communication among sensors, actuators, and meters were also successfully developed. The implemented concept of communication technique of IoT technologies is objected to improve the performance of communication-based VRT, conveyed the tremendous power quality from the grid to customer sides to prevent imbalance voltage profiles along the residential feeder.

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