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Impact of On-grids Solar PV Rooftop on Low Voltage Grid Systems: A Case Study of PEA Udonthani, Thailand

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Abstract. This paper presents the impact of on-grid solar PV rooftop on local power systems of 10 kW - typical low voltage power rating for households campaigned by Thai Government. The overvoltage, frequency variation and harmonic contamination were investigated and analyzed. The condition of peak power generated from PV was also considered. The experimental data used for the analysis were collected by turning on and off the solar PV system of PEA power system on Udonthani province, Thailand for every hour with duration time between 6.00 AM and 6.00 PM. The voltage at the connecting point of solar PV rooftop to the grid increases from 3-8 V (1.4-3.6%.). The frequency slightly increases from 49.97-50.06 Hz. In addition, the total harmonic distortion is not significantly different - varying in narrow range of 0.1-0.2 VTHD.

1. Introduction

The renewable energy policy has been raised and the Ministry of Energy of Thailand plans to increase the capacity of renewable energy to 25% of the country's overall capacity by 2021of which solar power has the highest proportion [1]. During the early stage, large solar farm plants were encouraged and first feeding started in 2008. In 2013, the government imposed policy to encourage solar PV rooftop with target capacity of 200 MWp [2]. However, impact of on grid solar PV rooftop on local power systems has not been properly investigated in Thailand.

At present, many households have jointed Solar PV Rooftop campaign and will soon start distributing power to the low-voltage grid of PEA. However, the on grid solar PV rooftop on the low-voltage grid is new to Thailand, the country only has experience in high-voltage grid that supports solar farm plant. Thus, the impact investigation on the on grid solar PV rooftop on low grid voltage systems such as local power system is highly importance and compulsory for entrepreneurs and PEA to realize the impact of solar PV rooftop to the power system of the houses located close by.

In [3], the simulation results proposed the effect of high solar rooftop PV penetration on grid voltage system in Chiang Mai using PVWATTs online calculation technique that the maximum difference in voltage up to 15 V could be in the day time.

This article emphasizes on the impact of solar PV rooftop to the low-voltage power system by measuring the difference in voltage, frequency, and harmonic at the switching point before and after the installation. The low voltage grid power systems in Udonthani, Thailand have been studied in article. This case study can be help to plan for installation and PEA.

2. PV Array Characteristics

A simple equivalent circuit of the PV array can be represented by an electrical circuit, as shown in Figure 1, as well as described by mathematical in Eq. (1) [4].

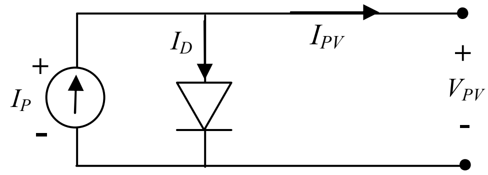

Figure 1 PV cell equivalent circuit.

$$V_{PV} = \frac{N_S nkT}{q} \ln\left[\frac{N_P I_{SC}\left(\frac{I_r}{100}\right) - I_{PV}}{N_P I_0} + 1\right] \quad (1)$$

where I_p is the photocurrent (A), I_sc is the short circuit current (A), I_r is the solar irradiance level (%), V_pv is the terminal voltage of the cell (V), I_D is the diode current (A), I_o is the saturation current (A), n is the ideality factor, q is the charge of the electron (C), k is the Boltzmann's constant, T is the junction temperature (K), N_p is number of cells connected in parallel and N_s is number of cells connected in series.

Eq. (1) demonstrates that V_pv is relative to I_r (Irradiance) whereas I_r varies according to solar concentration. Therefore, the higher I_r will result in higher V_pv. When V_pv is not properly controlled, overvoltage may incur. This provides the basic electrical characteristics used for design and analysis related to the solar PV rooftop systems.

3. Configuration of Experimental System and Area

The on-grid solar PV rooftop system used in this experiment is 10 kW power system using 40 individual PE multi-crystalline solar panel of 240 W connected together. The DC power generated from the PV system is then converted to 220 V AC using 2 sets of standard of 5 kW inverter [2]. The experimental system is then connected to a local low grid voltage of PEA system as shown in Fig. 2. This PEA power system is located at Amphur Muang, Udonthani province that is under the coverage of PEA1, Northeastern, Udonthani, Thailand. The area is a middle-size town with a 160 kVA transformer, there are 312 households with total of 37,198 kWh that the most of the loads are residential.

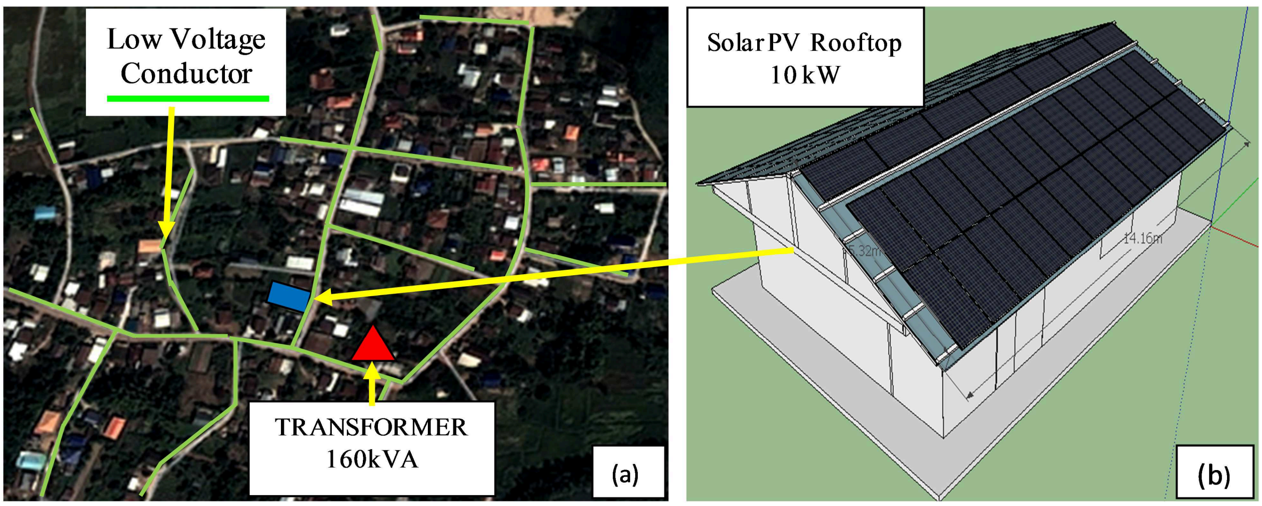

Figure 2 (a) Experimental area and (b) drawing solar PV rooftop 10 kW.

4. Experimental Results and Discussions

By placing power quality measurement equipment to the solar PV rooftop and pushing the ON-OFF switch every hour to imitate the environment of before and after the installation then measure the voltage gap at switching point. The results are shown in following chart.

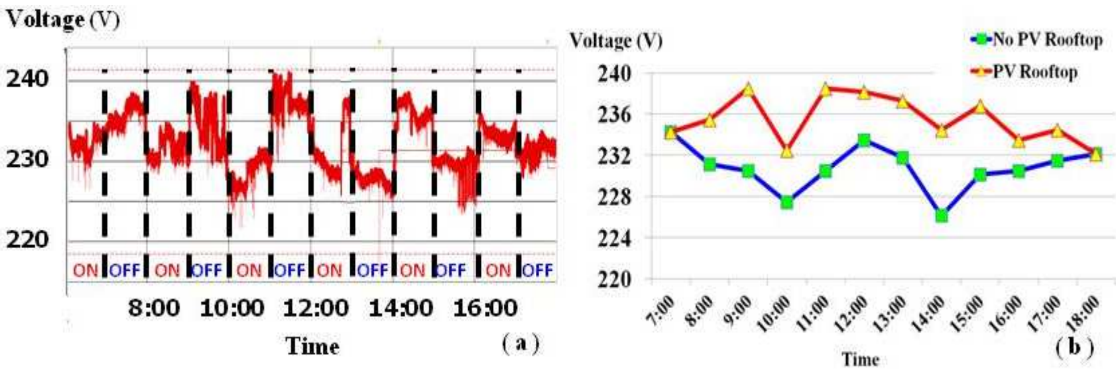

Figure 3 (a) Measurement data of voltage and
(b) the voltage before and after the installation of solar PV rooftop.

When the solar concentration is low (at 7.00 AM and 6.00 PM), the voltage gaps are low, as shown in Fig.3. However, it is in higher solar concentration, the voltage gaps are higher. Since, the inverter will trip over to protect the circuit from overvoltage when the voltage reaches 240 V (the inverter limit setting does not over PEA standard) thus the voltage gaps during 12.00 PM are similar to the gaps of during 9.00 AM to 2.00 PM.

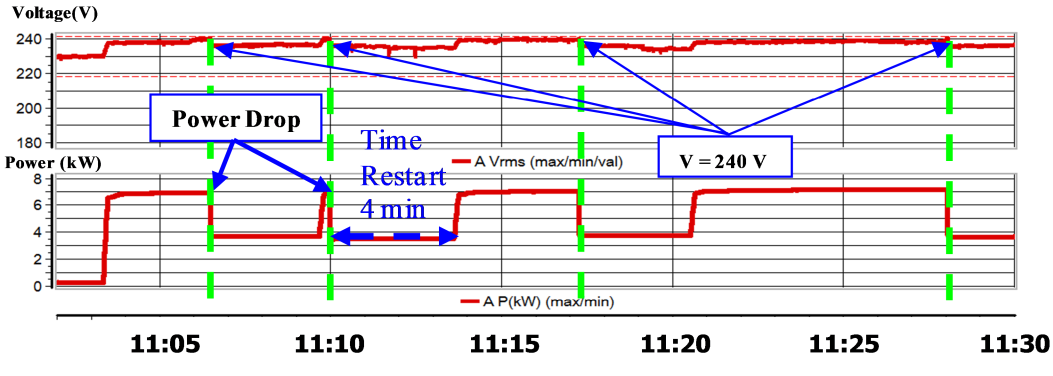

Figure 4 The voltage and power values of voltage reaches 240 V.

The inverter will trip over when the voltage reaches 240 V and the generated power will drop simultaneously, as shown in Fig. 4. It takes approximately 4 minutes for the power production to resume because inverters used for Solar PV Rooftop will set up to trip over at 240 V to avoid overvoltage in the system that results in loss of power production during the restart period.

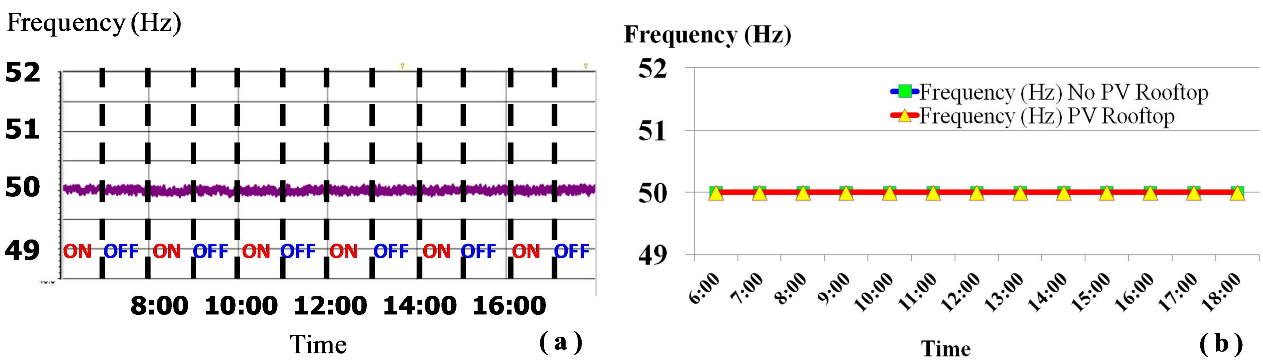

Figure 5 (a) Measurement data of frequency and
(b) the frequency before and after the installation of solar PV rooftop.

There is no difference in frequency before and after the installation of solar PV rooftop, as shown in Fig. 5, because the on-grid inverter employs the frequency of PEA for referent sine wave that causes in different frequency on the system.

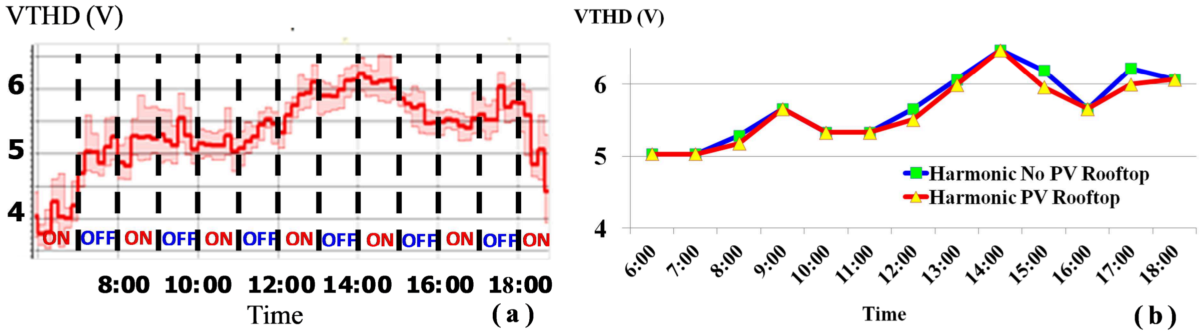

Figure 6 (a) Measurement data of voltage harmonics and
(b) the voltage harmonics before and after the installation of solar PV rooftop.

There is no difference in voltage harmonics (VTHD) before and after the installation of solar PV rooftop, as shown in Fig. 6, because the on-grid inverter employs good for harmonics filter.

4. Conclusions

This paper presents the impact of on-grid solar PV rooftop of 10 kW on low voltage systems of PEA Udonthani, Thailand. The installation of on-grid solar PV rooftop of 10 kW to the power line of PEA results in higher voltage of the system of approximately 3-8 V during the period of 8.00 AM to 4.00 PM. The maximum voltage is 240 V. However, frequency and VTHD will not be affected. This experimental can be used for development on-grid solar PV rooftop of Thailand in the future.

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