PV FACILITATING CAPACITY DEPENDENCE ON HARMONIC VOLTAGE DISTORTION IN LOW-VOLTAGE GRIDS

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ABSTRACT:
This paper introduces a brief analysis on facilitating capacity and related concepts as applied to distribution network systems. Furthermore, it addresses the applicability of hosting capacity study methodologies to harmonic voltage distortion caused by photovoltaic panels (PV) connected at a low-voltage (LV) side of a university campus grid. The analysis of the penetration of new distributed generation technologies, such as PV panels, in the distribution grid of the campus was carried out via measurement processes, and later by computer simulations analyzing a new concept of the hosting capacity approach in relation to voltage harmonics distortion. The voltage rise due to harmonic injection is analyzed and discussed with the aim of validating the discussed model and also putting forward recommendations for connecting PV generation across other network systems.

Key words: *Renewable energy; distributed generation; power quality; harmonic background; voltage rise; distribution system*

1. INTRODUCTION

The use of power electronics in residential appliances has been significantly increasing owing to their importance and numerous advantages. Whether for control, protection or filtering, electronic components are not to be waived in the electronic-based modern devices, which are extensively used in a broad variety of industrial, commercial and domestic applications. Owing to their nonlinear characteristics, power electronic-based loads generate harmonic currents in the supply system, which in turn cause high voltage distortion as they interact with the distribution grid [1]. It has been established in the literature that the harmonics injected from individual residential loads can collectively increase feeder harmonic current distortion levels compared to commercial and industrial loads [2]. The typical nonlinear household loads usually consist of two types of power electronic front ends −diode-based rectifier like electronic ballasts for compact fluorescent lamp (CFL) [3] or thyristor/triac (SCR) -based rectifier like dimmers [4]. Despite the new generation of home appliances with PWM (pulsewidth modulation) -switching rectifier are being increasingly introduced in the market, diode/thyristor-based loads are still commonly used in the LV residential distribution systems. Furthermore, due to the raising concerns on environmental pollution and the decreasing costs of the PV modules which was strongly supported by the government policies around the world, additional grid-connected PV systems are being progressively connected to the distribution network [5]. In fact, the substantial percentage of installed PV systems is dominated by residential areas with low rated power. Consequently, the high penetration levels of PV systems, which are connected to the distribution grid through PV inverters, inject additional harmonic currents to the LV grid level [6]. Since PV inverters use self-commutating technologies, the harmonic current is basically dependent on the switching frequency of the PWM as well as the bandwidth of the measurement filters.

2. HARMONIC DISTORTIONS ON LV GRIDS

power electronic-based residential loads and distributed generation systems (DGs), higher harmonic current magnitudes have been extensively introduced, in particular odd harmonics with low-order such as 3rd, 5th, 7th, 9th and 11th [7], [8]. Moreover, the increased penetration of single-phase rooftop mounted PVs resulted in a significant increase in the voltage unbalance factor as well as the magnitude of the 3rd harmonic current and its multiples, which may cause an excessive loading of the neutral conductor [9]. The injection of harmonic current in distribution networks was found to reduce the power quality and also cause major economic and technical setbacks. Such distortions may result in an overheating of the connected loads, generators and conductors and hasten the thermal aging process [10]. Additionally, the capacitors used for power factor correction and harmonic filtering of the nonlinear loads may generate parallel resonance with the harmonic source at certain frequencies. This in turn may lead to excessive capacitor currents and voltage distortions [11]. When different converters are parallelly connected to the distribution grid, harmonic interaction effects may occur between individual converters which result in resonance, control interaction or protection interference [13]. The harmonic content does not only depend on the amplitudes of the harmonic, but also on the phase angles. As a result, the harmonics from individual appliances and PVs can add together producing unexpected current distortion levels at the point of common coupling (PCC). In order to keep the harmonic propagation within prescribed limits, the PV integration must comply with the currently relevant standards and guidelines for the interconnection of DGs [14]–[17]. Within this framework, various studies have been published to analyze and address this issue. [2] Presented the harmonic current characteristics of residential distribution systems. [6]– [12] investigated the harmonic impact of residential loads and DGs on LV networks.

3. PROPOSED SYSTEM CONFIGURATION

An overview illustration of the LV grid with typical line lengths, distribution of loads and PVs and their connections are shown in Fig. 1.

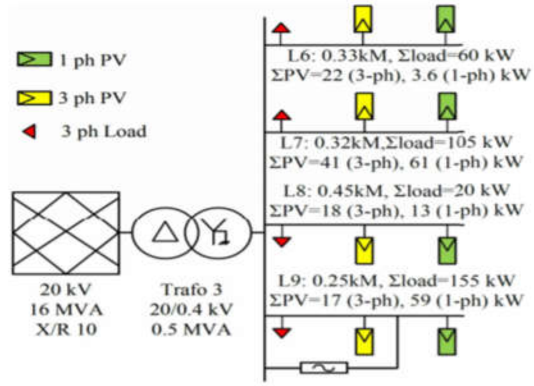

Fig. 1. Schematic diagram of LV grid from Germany

The PV plants as well as the loads are fed with PV and load profiles based on realistic measurements of the PV power and consumption behaviors in southern Germany. Each day is represented by 144 measuring points, where a measuring point is recorded every 10 minutes. Fig. 2 shows a sample of the PV and load profiles of one day during summer normalized on their maximum peaks. It should be emphasized that the profiles shown in Fig. 2 are for demonstration and not assigned for all the PVs and loads. The maximum generation existed for 3-phase and single-phase PV are 43 kW and 5 kW respectively while the maximum single-phase load demand is 1 kW. This model was successfully tested in [21] as this was adopted in this work. However, it should be noted that only the feeder cables L6, L7, L8 and L9 were examined, due to the huge computational requirements. This drawback by harmonics transient simulations can be alleviated using improved harmonic domain models based on alternative modeling techniques [22].

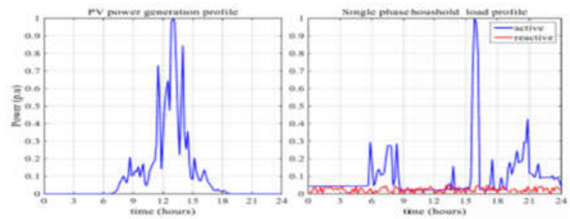

Fig. 2. Sample of PV and load profiles

4. PV MODELING

The circuit diagram of a 3-phase and single-phase grid-connected PV inverter, excluding the filters, is presented in Fig. 3. The objective of the line side converter (LSC) is to ensure that the DC link voltage is always close to its predefined nominal value in order to allow the power flow to the grid. Additionally, LSC provides voltage support capability through reactive power provision.

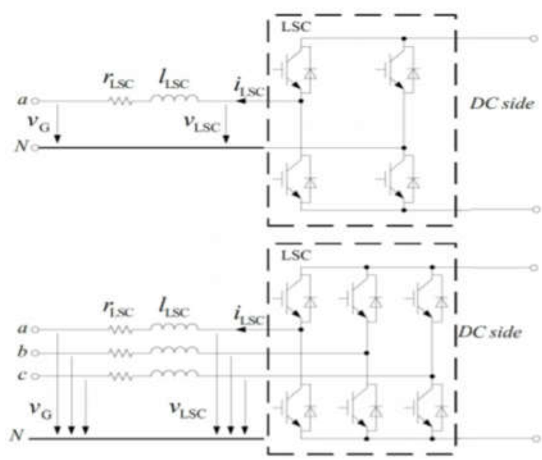

Fig. 3. 3-phase and 1-phase grid-connected PV inverter circuit diagram

The high active power injection from the PV results with high voltages at the feed in point due to the ohmic nature of the LV cables. Additionally, in case of long feeders, the voltage at the transformers should be increased in order to ensure the minimum voltage threshold at the consumer. The new grid codes regarding small and medium sized PV plants require the capability of the grid-connected PV to feed in reactive power with PF up to 0.95 lagging/leading from PV power up to 3.68 kVA and PF up to 0.9 lagging/leading from PV power higher than 13.8 kVA [17]. Accordingly, a proportional controller is implemented to produce the required reactive power for grid voltage support. The required reactive power is limited according to the maximum power factor and the maximum allowed value with the priority set to the positive sequence active current as shown in Fig. 4.

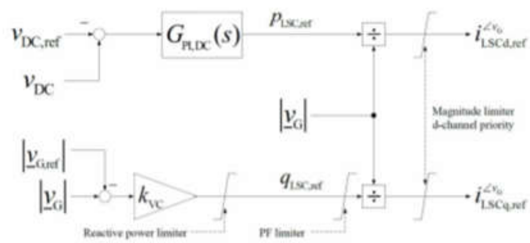

Fig. 4. Outer control loop of PV positive sequence controller

The harmonic frequencies, produced by the pulse width modulated (PWM) inverter, are related to the carrier frequency as follow

$$f_h = m.f_c \pm n.f_{fund}$$

Where m and n are positive integers and f_C and f_{fund} are the carrier and the fundamental frequency, respectively. To ensure an efficient modulation, the switching frequency was set at 16 kHz. In addition, the inverter was equipped with filters in order to attenuate the injected harmonics and keep the THD in the predefined limits in accordance to [20].

5. SIMULATION RESULTS

When the PVs are connected, the active power reverses and reaches its maximum value during mid-day time, as shown in Fig. 6. As already mentioned, the transformer terminal voltage increases in response to the high active power feed-in from the PVs, as depicted in Fig. 7. The behavior of each individual load remained stochastic which resulted in unbalanced harmonic currents with small magnitudes, as displayed in Fig. 8. The imbalance in the harmonic voltages was found to be minimal without PVs. However, when the PVs are connected, the magnitude of the unbalanced harmonic voltages increased, in particular the 2nd and the 5th harmonic, as shown in Fig. 9. As an end effect, the THD of the voltage was found to be low without PVs, which was attributed to the low load demand and the low magnitudes of the harmonic currents. On the other hand, the THD of the voltage increased when the PVs were considered, particularly at mid-day when the voltage and current magnitudes reach their maximum values. Additionally, the THD value can be different from one phase to the other, as illustrated in Fig 10

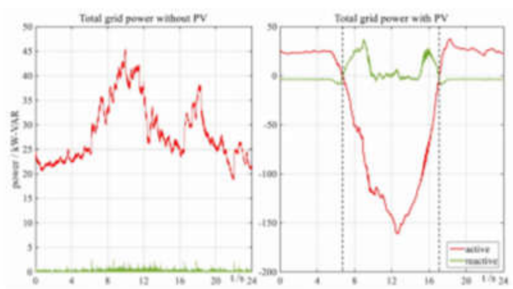

Fig. 5. Total power in the grid

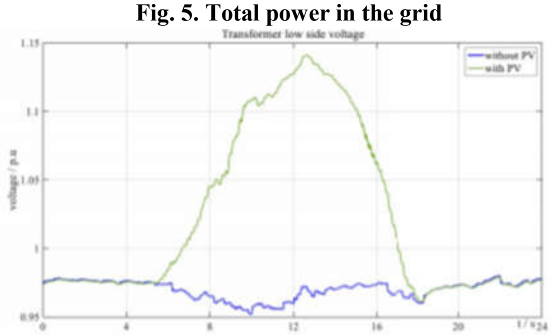

Fig. 6. Transformer low side terminal voltage profile

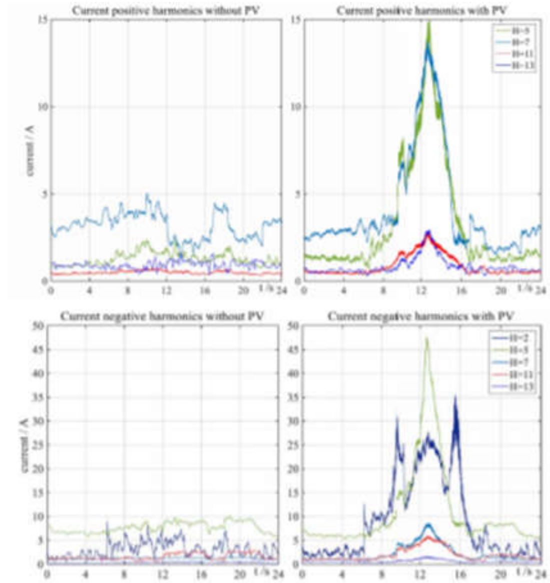

Fig. 7. Harmonic contents of the current flowing through the transformer

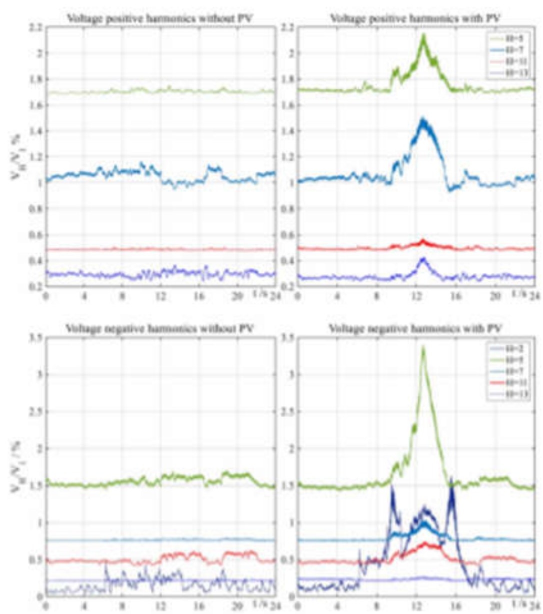

Fig. 8. Harmonic contents of the transformer low terminal voltage

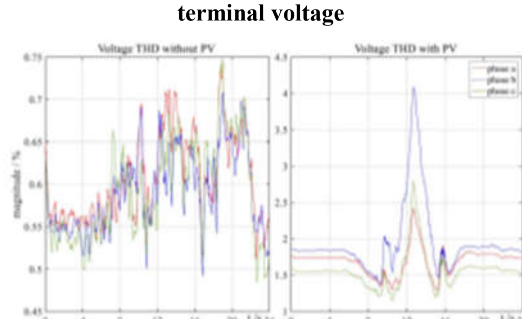

Fig. 9. THD of the voltage at the transformer low side terminals

CONCLUSION

In this paper, we examined the impact of high infiltration of 3-stage and single-stage rooftop mounted PVs in appropriation arrange and in addition the expansion of intensity electronic-constructed loads with respect to the consonant contortion. Point by point models of various sorts of burdens and in addition for the PVs were produced considering the exchanging examples of the control electronic circuits. The heaps and in addition the PVs were furnished with consonant channels intended to restrict the THD of the current in agreement as far as possible determined in the measures.

A while later, an EMT recreation was completed for a run of the mill genuine LV network arrangement from southern Germany utilizing the created definite models, where each load and PV was fed by a typical load and generation profile individually in light of reasonable estimations. The simulation results demonstrated that the stochastic nature of the loads results in unequal consonant flows, which thus deliver lopsided consonant voltages furthermore, unique THD of each stage voltages.

REFERENCES

1. Pesaram, M.; Huy, P.D.; Ramachandaramurthy, V.K. A review of the optimal allocation of distributed generation: Objectives, constraints, methods and algorithms. Renew. Sustain. Energy Rev. 2017, 75, 293–312.

2. Tan, W.S.; Hassan, M.Y.; Majid, M.S.; Rahman, H.A. Optimal distributed renewable generation planning: A review of different approaches. Renew. Sustain. Energy Rev. 2013, 18, 626–645.

3. Carvalho, M.S.; Correia, P.F.; Ferreira, L.A.F.M. Distributed Reactive Power Generation Control for Voltage Rise Mitigation in Distribution Networks. IEEE Trans. Power Syst. 2008, 23, 766–772.

4. Bollen, M.H.J.; Hassan, F. Integration of Distributed Generation in the Power System; Wiley-Blackwell: New York, NY, USA, 2011.

5. Oliveira, T.E.C. Estudo da Capacidade de Hospedagem de Fontes de Geração Distribuída no Sistema Elétrico de um Campus Universitário. Master's Thesis, Universidade Federal de Itajubá, Itajubá, Brazil, 2015

6. Bollen, M.H.J.; Ronnberg, S.K. Hosting Capacity of the Power Grid for renewable Electricity Production and New Large Consumption Equipment. Energies 2017, 10, 1325.

7. Oliveira, T.E.C.; Ribeiro, P.F.; Santos, I.N. Determining the harmonic hosting capacity of PV sources for a university campus. In Proceedings of the 17th International Conference on Harmonics and Quality of Power (ICHQP), Belo Horizonte, Brazil, 16–19 October 2016; pp. 836–841.

8. Standard. Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional—PRODIST Módulo 8—Qualidade da Energia Elétrica. 2015. Available online: http://www.aneel.com.br (accessed on 11 November 2017).

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