Review on Harmonic Domain Modeling of PV System for the Assessment of Grid Integration Impact

Amandeep S Potdar[1]*, Anil A Tekale[1], Pratik Ghutke[1], and Disha A Potdar[2]

[1] Tulsiramji Gaikwad Patil College of Engineering and Technology, Mohgaon, Nagpur, India

[2] Cusrow Wadia Institute of Technology, Pune, India

Review Article

ABSTRACT

In the document, we study the fundamentals of design to model the photoelectric system to evaluate the impact of network integration using the harmonic domain. The model is useful to evaluate the harmonic correlation between the photovoltaic system and the network. Several components of the photovoltaic system, such as the inverter, the LCL filter, and the connected transformer are integrated into the model. Using this model, consistent flows of photovoltaic systems connected to deformed and undamaged networks were measured.

INTRODUCTION

Operational and technical issues such as power quality issues, reverse power flow, increased power loss, and harmonic pollution are very important and require technological innovation. Harmonic contamination often challenges the operation of the system due to device failure, device overheating, resonance, and the like. In this study, public surveys related to harmonic pollution were the most common survey.

Accurate models are essential when designing photovoltaic (PV) systems. Since the PV model relies on a set of transcendental nonlinear equations, the complexity of the model increases. The letter proposes an easy and simple model method for simulation of the solar power generation system. This improves accuracy by utilizing the simplicity of the ideal model, deriving a mathematical representation and extracting accurate estimates of model parameters directly related to the manufacturer's data sheet. Experimental measurements demonstrate the effectiveness of this method. The PV system is modeled as a current source in parallel with the impedance. This impedance is modeled as a single capacitor.

Recent trends have shown great growth in the number of Renewable Distributed Generators (RDG) related to power grids, and this trend will continue. The reason was that it was to try to reduce carbon emissions, national independence of energy and energy sources, especially from cheaper renewable energy sources such as solar and wind energy. Other benefits derived from integration include RDG power assistance services such as frequency, voltage, and reactive power support systems, nutrition conversion and nutrient pressure loading, and reduce the loss to the minimum etc. Among the various RDG, wind and PV RDG are extremely frequent and rapid development [1-3].

Despite the benefits of the integration of RDG into the distribution system, it is known that the technical and operational challenges, such as problems of energy quality, reverse energy flow, increased energy loss, pollution harmonica etc. they are very important and require technological innovations [4-6]. Harmonious pollution often challenges the operations of the system by manipulating devices, warming equipment, humming, etc. Resonance research was one of the most common studies of harmonic contamination in the literature [7,8]. This analysis is usually done using a

frequency or impedance study to determine the resonance frequency. In [8], a resonance problem was reported due to the integration of the photoelectric system. The photovoltaic system is designed as an existing source in parallel with the impedance. This impedance is designed as a single capacitor. The authors argued that although a particular photovoltaic installation can meet the regulatory requirements for network integration as stipulated in IEEE 1547 and IEC 61727, the collective harmonic contributions of many of these systems may pose some problems of pollution of harmonics in the network. On the contrary, [9,10] suggests that such a resonance capacitor evoked by the candidate system related to the secondary photoelectric side of the distribution system are often discouraged from negative resistance loads and the buffer filter. This document also reported that the PV-DG-related side of the low-voltage network poses no problems to the resonance or side of the HV MV distribution system. However, the real modeling and simulation of the MT and AT networks were not presented to study the resonance. In addition, both documents focused mainly on PV surfaces on surfaces connected to the low voltage distribution network to the network.

In [11] and [12], impedance models for photovoltaic measurement systems were developed. While [11] replication (using the Raphsons method) achieves the values of conventional circuit impedances that satisfy the theories in the PCC with the data measured as the primary frequency, [12] making appropriate data measurements. In fact, the iterative method can represent numerical instability and thus pose convergence problems. These are four unknown variables that will be determined from a single non-linear equation in [11] and many measured data (possibly with some measurement noise) have been used repeatedly. In addition, the above methods can lead to multiple impedance solutions for the same photovoltaic inverter. Again, the use of separated Fourier Transforms (DFT) or Fourier Transforms (FFT) in the result can separate the errors in both directions.

As a result, the document seeks to achieve two objectives in the primary sense of developing an improved PV model (one and three phases) and then repeat the research on the occurrence of mvdn using the proposed model. The suggested harmonic range (HD) technology has been implemented in [13] and [14]. The proposed model can be referred to as the HD Norton equivalent circuit model for the VSC-PV system. The HD method is useful to describe the interaction between the photovoltaic system and the network that works under distorted and undistorted conditions. In addition, this model is suitable for proposed studies of harmonic energy flow (HPF) using a technique developed in HD (taking into account the harmonics and between both harmonics).

To carry out a MVDN resonance study, network components such as transformers, loads and capacitors have been extruded as in HD. The standard IEEE 13 bus distribution system was modified and used for simulation. The technical and insightful results are presented and discussed.

PV SYSTEM MODELLING

The photovoltaic system includes a range of photovoltaic modules, power conditioning unit, filter, control circuits, protection devices (for example, isolation keys), connected transformer, etc. VSC is a type of PV in this work although the method is also applicable. The reflector of current source photovoltaic systems. **Figures 1** and **2** are used to develop circuit equations for single and triple phase photovoltaic systems, respectively. The DC voltage is estimated from PV modules/matrices that act as inputs to the inverter using different formulations. The inverter is designed using the conversion function technique. This method treats the inverter unit as a black packet and, therefore, depends on its operation instead of a circuit-based model. The input (DC voltage) and the output are equated by (1).
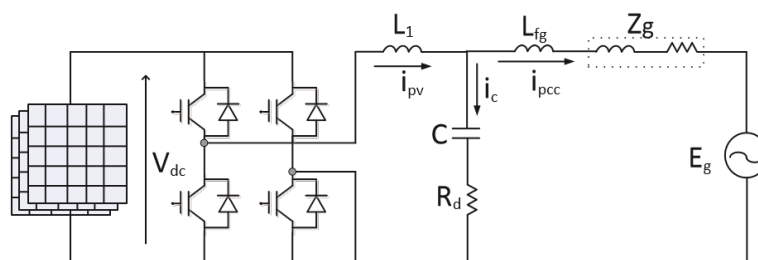

Figure 1. Schematic diagram of a single-phase PV system.

In fact, the expressions of the conversion function are not unique [15,16] where multiple expressions can be derived for the same conversion process. This modeling approach was published in [16] although no explicit expressions of the conversion functions used were given. The document also assumed a bipolar substitution process that was inferior to the unipolar strategy deployed here. This is because the former generates more harmonics than the latter [17]. The double Fourier series is also used in [18], but this requires many computer requirements and is difficult to integrate with other models of the photovoltaic system, for example. LCL filter. Therefore, in this document, the method adopted in [19] was used to derive the HD coefficients of the following conversion function of the photovoltaic system in 3 stages.

PROPOSED MODEL VALIDATION

Some of the previous works have achieved the effect of network distortion on the output performance (in terms of harmonic generation) of photovoltaic systems. In SPICE simulations were used for simulations and experiments were performed to verify the results by the author [1]. Both the ideal grid and the real (deformed) effects of the voltage were examined. The researchers concluded that the nature of the harmonic currents of interconnected photovoltaic systems depends on the state of the voltage. Similarly, measurements were made and then some models and simulations were published (using a phase-scale approach) to verify their results. The idea of "phase angle variations" and "attribution of combinations" was also proposed to evaluate the compatibility interactions between the network and the photovoltaic system in its model.

By comparing the generation of photovoltaic currents in three stages of the simulation results of an undistorted and distorted state as shown in **Figures 1** and **2**, respectively, the last waveform is considered distorted for the first, which is smooth. This shows an agreement between the results of our simulations and those of other researchers mentioned above.

In addition to the agreements in the results between our proposed model and those already in the literature, our model shows some strength in some aspects. First, the model suggested in this document can accurately capture all unusual and unusual harmonics and thus eliminate the assumption of distinctive harmonics by themselves.
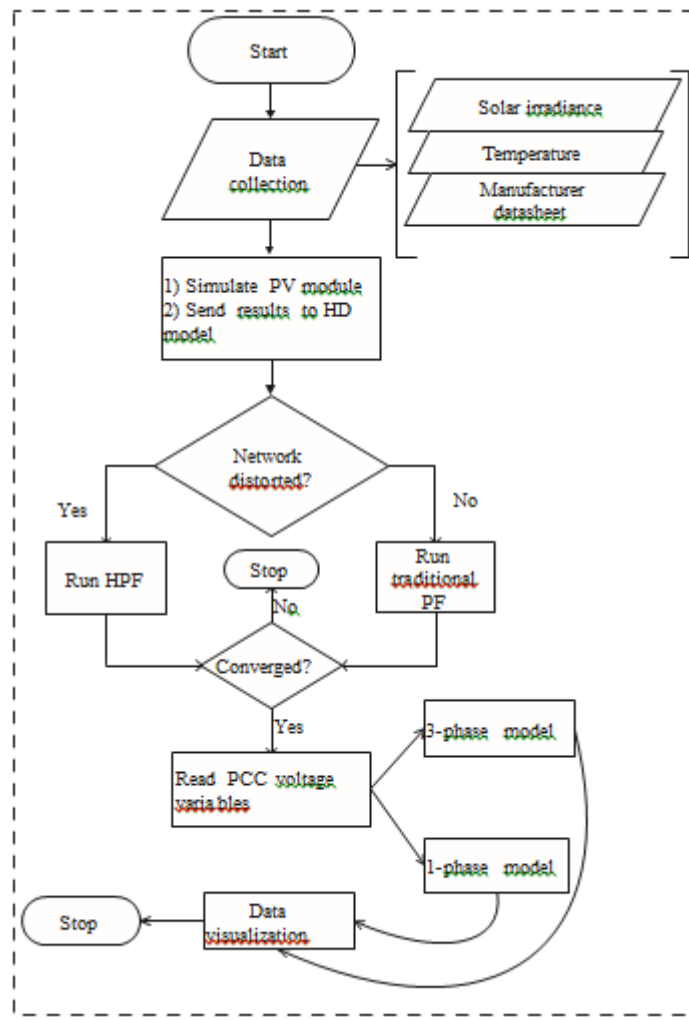

Figure 2. Harmonic prediction algorithm using the proposed model.

Secondly, the harmonic interpretation between the photovoltaic system and the non-linear component (such as the transducer in the saturated state) or the load (like the asynchronous speed motor) can be fully calculated in our proposed analytical model, unlike the interval approach of phases that separates the interaction. From this point of view, the possible cancellations between the PV harmonics and the network can also be easily captured using our model. Therefore, the assumption about the variation of the phase angle of the harmonic components becomes unnecessary.

The resonance test carried out with the proposed model also confirms the effect of the resistance to inhibition and the negative charge on the inhibition of the resonance affected by the interaction between the LCL inverter filter and the network. This is also consistent with [9].

After validating our model, it is important to clarify that the model proposed in this document is the first HDRF model for the VSC-PV system (for better knowledge of the authors) and has useful applications beyond the resonance probe where it can also be published in HPF studies developed in HDRF.

CONCLUSION

In this work, we propose a complete HDRF system model for the PV VSC system for interactive single-phase and triple interactive systems. These HD models were used to evaluate and measure the interaction between the performance of the harmonics in the photovoltaic system and the network. The results of the simulation show a consensual interaction between the harmonic currents of the photoelectric system and the background distortions of the network. In addition, an MVDN resonance was investigated in a three-phase photovoltaic system using the previous model. The results confirm that the resonance excitation (both sequences and parallelism) is possible due to the interaction of the systemic impedance with a PV filter capacitor. Although the well-known buffer solution of the chain resistance was able to discourage phase A and C resonances, the parallel resonance of phase B cannot be completely avoided. This is not out of line with a different level of negative charges related to different stages. With equal loads, all three phases were wet, indicating that the negative charges on the PCC significantly helped to dampen the resonance.

Therefore, we recommend a detailed evaluation and possibly measure the harmonic performance of the network before and after the PV installation to differentiate between the real harmonic effects caused by the PV integration.

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