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C-HIL SIMULATION OF HOME PV SYSTEM

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Abstract: The widespread deployment of photovoltaic (PV) systems in urban areas poses new challenges for integration into the low-voltage grid, operation under variable meteorological conditions, and the impact of local disturbances. Research using Hardware-in-the-Loop (HIL) simulations, especially techniques with physically present controllers (Controller Hardware-in-the Loop - C-HIL), represents a powerful environment for testing and validating power electronics-based converter control strategies in real-world conditions without the risks and costs associated with field experiments. This paper presents the application of C-HIL simulation to analyze and optimize the operation of a home PV system integrated into an urban distribution grid. The conducted case studies address operational scenarios such as rapid changes in solar radiation, load fluctuations, and voltage disturbances, demonstrating the effectiveness of the C-HIL platform for assessing dynamic performance, voltage quality, and stability. The results confirm that C-HIL simulation can provide useful insights for the design of PV systems aimed at the safe and widespread deployment of distributed renewable energy sources in urban networks.

Keywords: real-time simulation, home PV system, urban distribution grid, grid inverters, C-HIL.

1. INTRODUCTION

The integration of residential photovoltaic (PV) systems in urban environments is rapidly increasing, driven by the need for decarbonization and distributed energy generation [1]. However, operating PV systems in cities poses challenges due to fluctuating irradiance, shading effects, local air pollution, and complex interactions with the urban distribution grid [2]. Practically, installed PV systems work during short period of time under nominal power conditions, i.e. nominal operating conditions for PV panels [3]. All this leads to potential problems with unwanted harmonic distortions of currents and voltages generated by these systems, regardless of how they are used [4]. Also, the potential wider use of PV systems can initiate unstable operation with large voltage and frequency fluctuations due to the low inertia of this inverter-based resources (IBRs) [5].

In an urban environment, the mix of consumption becomes quite complex and in addition to classic thermal consumers, it increasingly includes various electronic consumers with highly non-linear and time-varying characteristics. The significant participation of light sources powered by switching sources, followed by air conditioners that incorporate appropriate motor drives, lead to a combination of non-linear consumers that inject significant higher harmonic currents into the network [6]. All this makes the application of the usual methodology for testing the behaviour of IBRs in the context of such consumers and distribution networks quite questionable. Moreover, the usual aggregate consumption models used so far are quite imprecise and require not only a change in time distribution, but also the introduction of additional quantitative and qualitative factors such as harmonics and harmonic distortion values.

Urban PV integration has been extensively studied through numerical simulations and pilot projects [7]. Existing works emphasize the impacts of variability in production and consumption conditions, as well as power quality issues in urban distribution networks. Laboratory tests and field measurements provide valuable data, but they lack flexibility and are resource-intensive [8]. Therefore, research usually relies heavily on computer simulations, most recently by using specialized software to reduce the time required to form complex models of these urban distribution networks. Depending on the simulation methodology used, certain inaccuracies may occur in the results, especially when it is necessary to verify the functionality of innovative solutions for solving high-dynamic problems caused by regular operation or in fault modes.

Namely, traditional offline simulations cannot fully capture these dynamics, as they usually rely on simplified system models and do not accurately reproduce the time conditions, element nonlinearities and hardware-dependent behaviours that occur in real-world converter operation (grid inverters and DC/DC converters). Due to the need for simplified models, measurement noise, switching sequence effects, and control loop delays are often neglected, which can lead to inaccurate predictions of system responses during fast transients or fault conditions. As a result, interactions between the controller and the physical system, especially in critical situations such as faults, rapid changes in operating conditions and load sequences, may remain untested and unverified [9].

In contrast, conducting these tests directly on physical hardware is often very demanding, requiring expensive and complex laboratory infrastructure, specific high-power installations, and demanding safety protocols [8]. Similar problems exist with field testing, with the added problem of reproducing and repeating experiments under identical test conditions, which sometimes makes this approach time-consuming and quite expensive.

In recent years, several advances have been made that allow overcoming the above-mentioned shortcomings of field or laboratory testing [10]. Hardware-in-the-Loop (HIL) approaches bridge this gap by combining real controllers with simulated grid conditions, enabling cost-effective and repeatable experiments [11]. In this way, this approach simplifies, increases the reliability and repeatability of tests and at the same time shortens testing and validation time, while the reliability of these tests is improved in combination with real physical devices – control systems and/or adjustable power supplies.

Controller Hardware-in-the-Loop (C-HIL) simulation offers a flexible and realistic environment where actual control hardware is tested against a detailed real-time model of the PV system and grid [12]. Power Hardware-in-the-Loop (P-HIL) simulation involves connecting a real device to a real-time model via a power interface, so that the device works as if it were connected to a real power system, thus performing tests under real energy conditions with full control and safety of the laboratory environment [13]. While P-HIL is often used for inverter testing, C-HIL is particularly suitable for evaluating control algorithms and operational strategies in real time without the need for high-power interfaces.

This paper presents the application of C-HIL simulation to analyse and critically evaluate the performance of a home PV system in an urban context. The main contributions include: (i) design of a C-HIL testbench for residential PV, (ii) evaluation of system response under representative urban operating scenarios, and (iii) discussion of benefits for grid operators and prosumers.

2. METHODOLOGY

The performance of grid-connected home inverters was tested using a controller-hardware-in-the-loop (C-HIL) test environment. This methodology integrates a real inverter controller with a simulated real-time model of a PV system, residential loads, and the local city distribution network. By connecting the real controller to a realistic and detailed model of the power system, it becomes possible to evaluate performance, stability, and control behaviour in realistic, but fully controlled and repeatable laboratory conditions.

Unlike conventional simulations that run entirely in software, the C-HIL setup allows the control hardware to interact with a high-quality real-time model of the system. This allows the study of control algorithms under various dynamic and transient operating conditions before building a physical prototype. Consequently, this approach significantly improves the efficiency, safety and reliability of the development process of modern PV inverters and their integration into urban power grids.

The developed experimental setup consists of two main components:

– A real-time simulator (Typhoon HIL404, [14]) that runs detailed models of the photovoltaic array, DC/DC converter, grid-connected inverter and household loads; and

– A real-time controller (dSpace DS1103. [15]) that implements the inverter control algorithms, including maximum power point tracking (MPPT), current and voltage control loops and grid synchronization logic.

The simulator and controller are interconnected via digital Pulse Width Modulation (PWM) and analog interfaces. The PWM signals generated by the dSpace controller act as switching commands for the inverter model within the simulator, while key feedback signals, such as DC voltage, inverter currents, and grid voltage, are transmitted back as analog signals to the controller. This closed-loop configuration reproduces real-world inverter behaviour with microsecond-level synchronization and fidelity. The basic scheme of the C-HIL experimental setup is shown in Fig. 1.

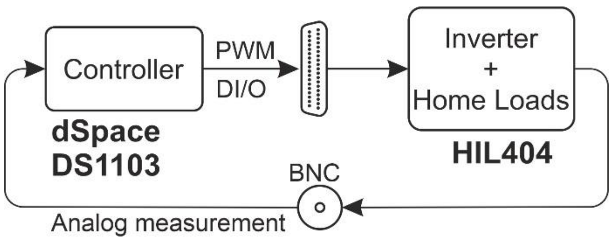

Figure 1. *Scheme of C-HIL setup*

The modelled PV source consists of an array of 20 monocrystalline panels with a total installed capacity of 10 kWp. The model incorporates the nonlinear current and voltage characteristics of the PV modules and dynamically responds to variations in irradiance and temperature. To represent real-world conditions, the irradiance input is shaped as a time-varying function, allowing the simulation of fast transients such as partial shading or cloud movement. The inverter itself is modelled as a two-stage, three-phase 7.5 kW converter, with IGBT switches and an LCL output filter. The inverter is connected to a simplified representation of the city's low-voltage grid and typical residential loads, allowing for realistic interaction between distributed generation and consumption.

The C-HIL methodology provides several key benefits:

– Safe testing of grid conditions. Faults such as short circuits, voltage dips, overvoltage events, load variations, and frequency fluctuations can be accurately emulated. This allows testing of the inverter's response without the risk of equipment damage or safety hazards, which is especially important when evaluating grid support functionality.

– Accelerated development. Control algorithms can be validated and optimized in real time on the C-HIL platform long before a physical prototype is available. This "upfront" testing approach shortens design cycles, facilitates rapid prototyping, and reduces overall development costs.

– Repeatability and transparency. Identical test scenarios can be reproduced at any time, enabling consistent benchmarking, debugging, and iterative refinement of control strategies.

– High-precision insights. The direct interaction between the digital model and the physical controller captures fast transients and nonlinear effects that are often overlooked in offline simulations. This enables early detection of potential instabilities or control saturation issues.

– Cost-effectiveness. By minimizing the need for numerous physical prototypes and reducing reliance on field testing, the C-HIL method provides significant financial and time savings.

– Compliance and reliability testing. The platform enables a systematic assessment of grid compliance, including week grid behaviour, voltage imbalance, and harmonics.

In this study, the developed setup was used to evaluate MPPT performance, grid synchronization, and voltage control capabilities under typical and disturbed urban operating conditions. The real-time response of the controller to grid irradiance and voltage variations was analysed, providing a robust framework for validating advanced control strategies that improve both energy efficiency and grid stability.

This C-HIL-based approach thus bridges the gap between theoretical design and field implementation, establishing a reliable platform for the future development of smart inverters and adaptive control schemes in urban PV systems.

3. HIL SETUP AND CASE STUDIES

Within the real-time simulator (Typhoon HIL404), a detailed simulation of the grid-tied inverter and residential load was implemented to represent a typical household prosumer. The modelling of residential loads was performed using individual components from the core library of Typhoon HIL Control Center software, complemented with the Residential Energy Toolbox [16], which provides pre-configured blocks for typical domestic loads, including nonlinear appliances.

In this article, residential loads are represented using the standard ZIP model [17], which describes energy consumption as a combination of three components: constant impedance (*Z*), constant current (*I*), and constant power (*P*). This more comprehensive approach models the voltage-dependent behaviour of typical household appliances, allowing for a more realistic simulation of load dynamics in low-voltage networks. The simulation model expresses active and reactive power as nonlinear functions of the terminal voltage, which enables valid modelling of the load response to voltage fluctuations in the household power system. The active (*P*) and reactive (*Q*) power are expressed as functions of the root-mean-square (RMS) voltage V_{load} at the point of device connection:

$$P_L(V) = P_{nom}\left[Z_p\left(\frac{V_{load}}{V_{nom}}\right)^2 + I_p\left(\frac{V_{load}}{V_{nom}}\right) + P_p\right] \tag{1}$$

$$Q_L(V) = Q_{nom}\left[Z_q\left(\frac{V_{load}}{V_{nom}}\right)^2 + I_q\left(\frac{V_{load}}{V_{nom}}\right) + P_q\right], \tag{2}$$

where P_{nom} and Q_{nom} are nominal active and reactive power values, V_{nom} is nominal voltage, Z_p, I_p and P_p are the weighting factors for active power, and Z_q, I_q and P_q are the weighting factors for reactive power. These coefficients should satisfy the normalization conditions:

$$Z_p + I_p + P_p = 1, \tag{3}$$

$$Z_q + I_q + P_q = 1 \tag{4}$$

In modern residential power systems, an increasing share of household energy consumption is driven by electronic loads based on switch-mode power supply (SMPS) technology. Devices such as televisions, computers, LED lighting, chargers, and various kitchen appliances draw nonlinear current waveforms that differ significantly from traditional resistive or inductive loads. Nonlinear power electronic loads that generate significant current harmonics during operation are therefore modelled using a different approach to better capture their impact on voltage quality and grid behaviour.

The "Power Electronic Loads" component from the Residential Toolbox models typical household appliances using a generic approach based on a switch-mode power supply (SMPS) circuit [18]. This model can reproduce the instantaneous power waveform with good accuracy, while preserving key behaviours observed in real devices, such as harmonic injection and nonlinear distortion. As a result, it is well suited for studying power quality in residential, commercial, and industrial environments. The circuit is essentially composed of a diode bridge rectifier, where the load-side impedance varies depending on the appliance category. The impedance on the load side of the diode bridge consists of four components: R_{in}, which models the inrush-current protection using a Negative Temperature Coefficient (NTC) resistor; L_{in}, a series inductance representing the Power Factor Correction (PFC) stage of the SMPS circuit; and the parallel combination of R_{dc} and C_{dc}, which models the DC-side load and the corresponding DC-link capacitor. This structure captures the key nonlinear characteristics of SMPS-based appliances, particularly the pulsed current draw and harmonic distortion introduced by the diode bridge and DC-link dynamics.

Three types of consumers are represented in this model:

– PEL1 - Compact and Linear Fluorescent Lamps (CFL/LFL): "Fluorescent Lamp"

– PEL2 - Switch-Mode Power Supply without Power Factor Correction (SMPS_noPFC): "Low-Power Consumer Electronics"

– PEL3 - Switch-Mode Power Supply with Passive Power Factor Correction (SMPS_pPFC): "High-Power Consumer Electronics", "Microwave Oven"

The photovoltaic system model consists of a PV module array and a two-stage conversion system composed of a DC-DC converter and a three-phase grid inverter. The DC-DC converter and the grid-connected inverter were implemented using generic switching components (ideal switches), while their control functions were executed externally through digital PWM inputs, enabling real-time interaction with the physical controller. The electrical parameters of the converter system, together with the numerical values of the classical current PI controller

***Table I** Details of hardware components of grid inverter and current controller parameters*

Inverter rated power S_n	7.5 kVA	Rated DC voltage V_{dc}	450 V
Inverter-side inductance L_1	4.0 mH	Supply grid line voltage (rms) V_g	400 V
Inverter-side resistance R_1	0.078 Ω	Supply grid frequency	50 Hz
Grid-side inductance L_2	1.84 mH	Discretization time	100 µs
Grid-side resistance R_2	0.017 Ω	PWM switching frequency	10 kHz
Filter capacitance C_f	4.7 µF	DT PI current controller proportional gain	15.41
Damping resistance R_d	9.4 Ω	DT PI current controller integral gain	474

developed in Matlab/Simulink and deployed to the dSPACE controller via the real controller interface, are listed in Table I. Additional details on parameter selection and the discrete-time (DT) implementation of the controller can be found in [15].

The grid-tied inverter operates in Grid-Following (GFL) mode, meaning that both active and reactive power injected into the grid are explicitly controlled. The active power delivered by the PV inverter is proportional to the maximum available PV array power; therefore, the primary control objective on the active power side is Maximum Power Point Tracking (MPPT). In this two-stage inverter topology, MPPT is implemented within the control loop of the DC-side boost converter. The reactive power reference is maintained at zero under normal operating conditions, although the controller is capable of adjusting reactive power when required.

The complete simulation model of the household PV system, including the selected groups of residential loads, is shown in Figure 2. Residential loads are commonly categorized into ten subgroups, as presented in [17]. However, several of these subcategories are not typical for households in Serbia, while some specific local appliances are not included in this international classification.

In the model shown in Fig. 2, household loads are grouped into four main categories, representing the following consumer types:

Load 1: Thermal loads with predominantly symmetric behaviour toward the grid, represented as an equivalent three-phase load. This group includes typical appliances in Serbian households such as electric heaters, three-phase furnaces, electric boilers, or the aggregated representation of water heaters and electric stoves.

Load 2: Lighting loads, placed on phase L1, comprising two subcategories: incandescent lighting and LED lighting.

Load 3: Single-phase dynamic loads, connected on phase L2, which introduce time-varying and often unbalanced consumption due to motor-driven appliances such as washing machines, refrigerators, and air-conditioning units.

Load 4: Nonlinear electronic loads, supplied by phase L3, and modelled using the PEL3 category, representing devices with pronounced harmonic content and power-electronic front ends (e.g., consumer electronics, chargers, microwave ovens).

The complete list of loads, together with the corresponding ZIP model parameters, is provided in Table II.

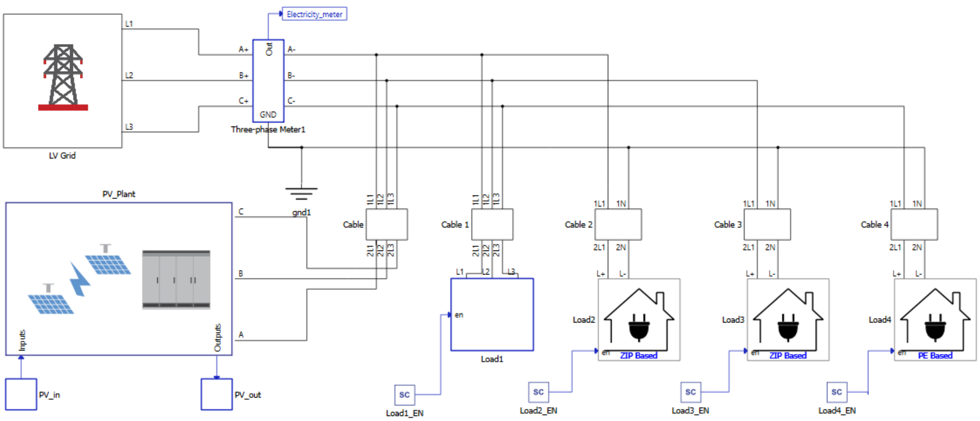

***Figure 2.** HIL simulation scheme of home PV system*

***Table II** Residential Load Groups and Assigned Model Parameters*

Load category	S_{nom} [kVA]	P_{nom} [kW]	Q_{nom} [kVAr]	Z_p	I_p	P_p	Z_q	I_q	P_q
Load 1: 3-phase load	6.0	6	0	1	0	0	0	0	0
Load 2: Incandescent Lamp	0.5	0.5	0	0.43	0.69	-0.12	0	0	0
Load 2: LED Light Sources	0.2	0.027	-0.198	0.23	0.85	-0.08	-1.05	0.04	0.01
Load 3: Washing machine drum rotation	1.0	0.9	0.436	0.5	-0.62	1.11	1.54	-1.43	0.89
Load 3: Washing machine heating	1.0	1	0	1	0	0	0	0	0
Load 4: PEL3	1.5	$R_{in} = 0.2998\,\Omega, L_{in} = 4.15\,mH, C_{dc} = 2.51\,mF, R_{dc} = 70.53\,\Omega$							

The inverter control was carried out using a dSpace DS1103 real-time controller, programmed in a full Rapid Prototyping environment via MATLAB/Simulink. The interface between the DS1103 controller and the HIL404 device was established through PWM gating signals, while the corresponding analog feedback signals from measurement points were connected to the DS1103 analog inputs. The laboratory setup used for executing the experiments is shown in Fig. 3. It is important to note that the parameters of the HIL and Rapid Control Prototyping (RCP) setup (Table I) are fully identical to those used in experiments with the actual hardware [15]. This includes the same scaling of analog signals as well as the digital controller parameters, ensuring a one-to-one correspondence between the virtual and physical implementations.

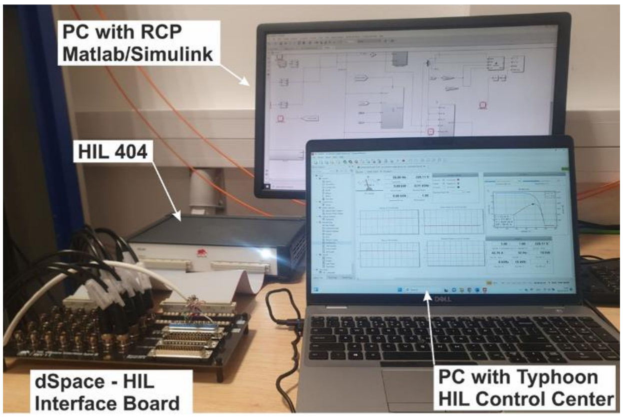

***Figure 3.** Laboratory setup for experiments with C-HIL simulation of a residential PV system*

To demonstrate the applicability of the developed platform, several test scenarios were defined for the operating mode in which the system is connected to the low-voltage (LV) distribution network (on-grid mode):

a) initial synchronization and grid connection in order to evaluate the inverter's ability to synchronize with the LV grid and smoothly transition to steady-state operation;

b) Load fluctuations caused by the simultaneous operation of household appliances, used to assess the inverter's capability to maintain voltage regulation and active/reactive power balance under dynamically changing demand;

c) Voltage disturbances in the urban feeder, including harmonic distortion, applied to evaluate the robustness and stability of the inverter control under non-ideal grid conditions.

d) Clouding, shading or soiling effects, implemented as a reduction in PV array effective irradiance, representing typical urban atmospheric conditions.

Each scenario is executed in real time with full interaction between the controller hardware and the simulated system.

4. RESULTS AND DISCUSSIONS

In the first scenario of the initial connection of the photovoltaic inverter to the LV distribution network, a three-phase symmetrical load (Load 1) is connected first. After that, the synchronization procedure and the active-power reference ramping were initiated. The obtained results are presented in Fig. 4.

The figure shows the initial current surges that occur at the moment of connecting the inverter to the grid, followed by a gradual increase in the injected active power. At approximately 0.16 s from the start

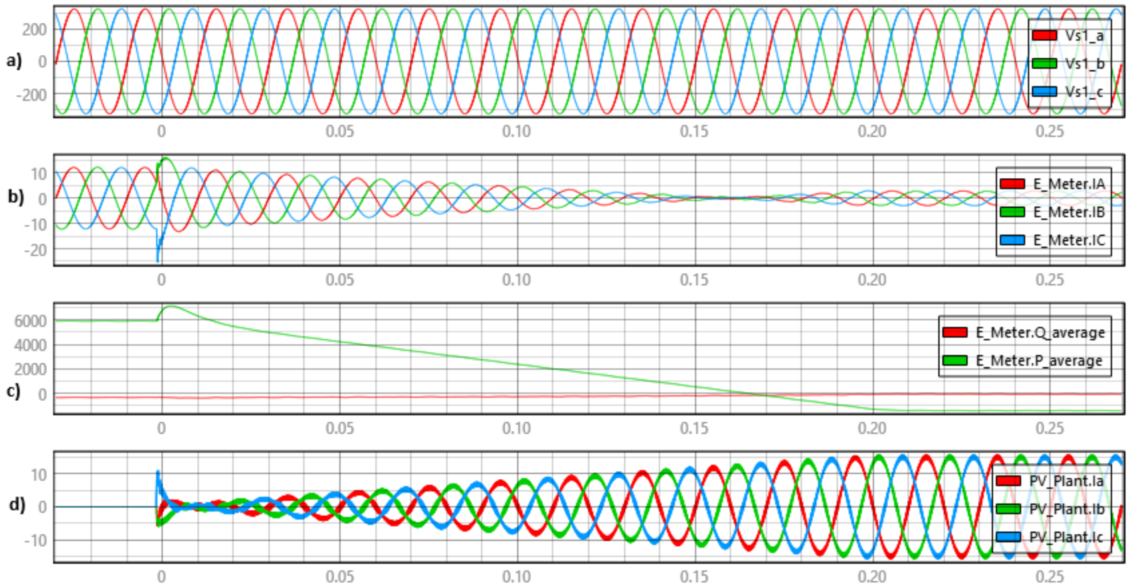

Figure 4. *Initial start-up of the residential PV system showing: a) grid phase voltages; b) grid phase currents; c) active and reactive power at the smart meter; and d) inverter phase currents.*

of the inverter operation, the active power changes sign from positive to negative, which means that the residential photovoltaic system starts to export active energy back to the grid. The inverter currents show a satisfactory quality, very similar to the ideal currents injected into the grid.

The next scenario considers the operation of the PV inverter under unbalanced loading conditions, where single-phase household loads are connected to phases L1 and L2, resulting in sinusoidal but asymmetric load currents. As shown in Fig. 5, in this case the PV inverter—while injecting balanced three-phase currents—effectively increases the current unbalance seen by the distribution network. Although the total power of the residential PV system remains on the generation side (net active-power export), this comes at the cost of significantly increased current asymmetry at the grid connection point.

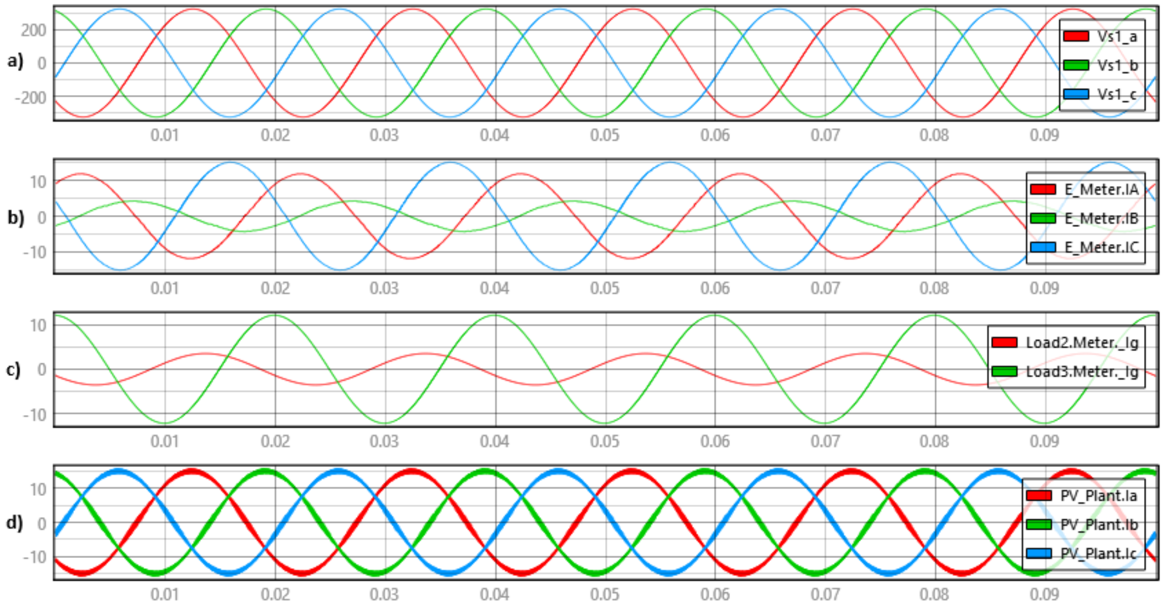

Figure 5. *Operation under single-phase load conditions (Load 1 and Load 2): a) grid phase voltages; b) grid phase currents; c) load phase currents; and d) inverter phase currents.*

The next critical situation is when a nonlinear load (*Load 3*) with significant harmonic content is connected to phase L3. From the following Fig. 6, it is observed that the harmonic distortion of the grid current of phase L3 is caused by the superposition of the consumer current. This can be confirmed by comparing the harmonic spectra of the household input currents of these two characteristic cases, which are shown in Fig. 7, where the values of the characteristic harmonics are observed. In practice, the higher harmonics of the consumers are superimposed on the input network currents with the same amplitudes and harmonic order.

In addition to the impact of nonlinear household loads on the low-voltage distribution network, the influence of the grid itself on the behaviour of devices within the residential installation must also be considered. Grid-connected inverters are known to be particularly sensitive to voltage harmonic distortion. For this reason, the next simulation scenario includes the presence of a 5th order voltage harmonic with an amplitude of 3% relative to the fundamental component.

The results are presented in Fig. 8, starting with the case where the PV system is not in operation and the three-phase household load is supplied solely from the LV distribution network. As expected, due to the linear nature of the load, the distorted voltage waveform is directly reflected in the corresponding current waveform drawn from the grid.

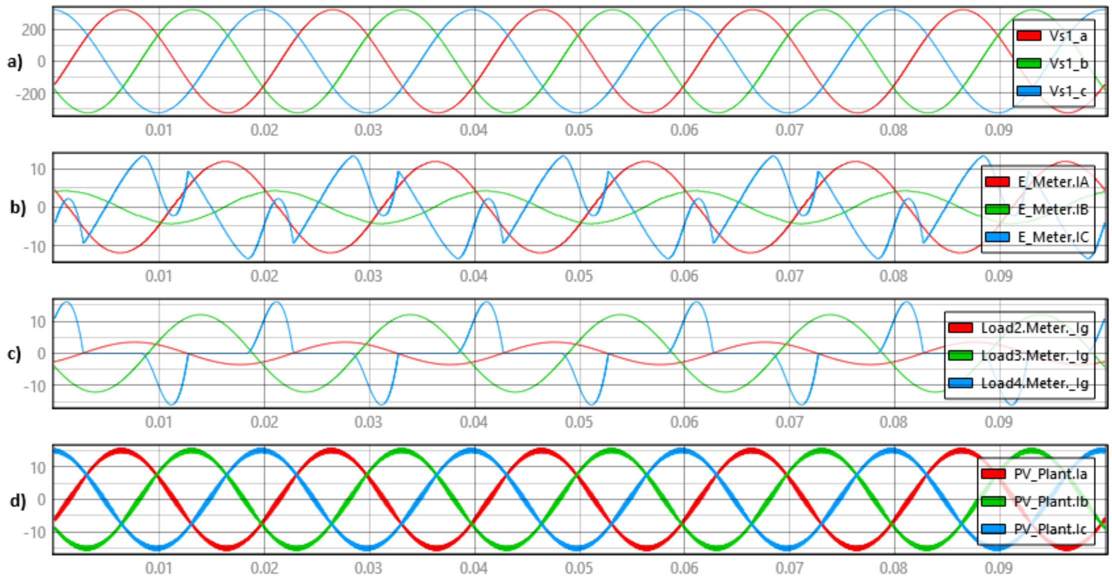

Figure 6. *System operation with a nonlinear, harmonic-rich load (Load 3) connected to phase L3: a) grid phase voltages; b) grid phase currents; c) load currents; and d) inverter phase currents.*

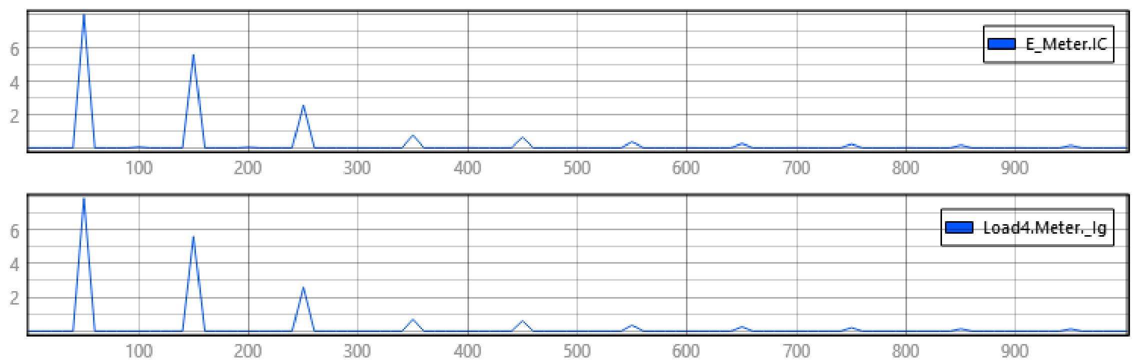

Figure 7. *Harmonic spectra of the grid current in phase L3 (a) and the current of Load 3 (b)*

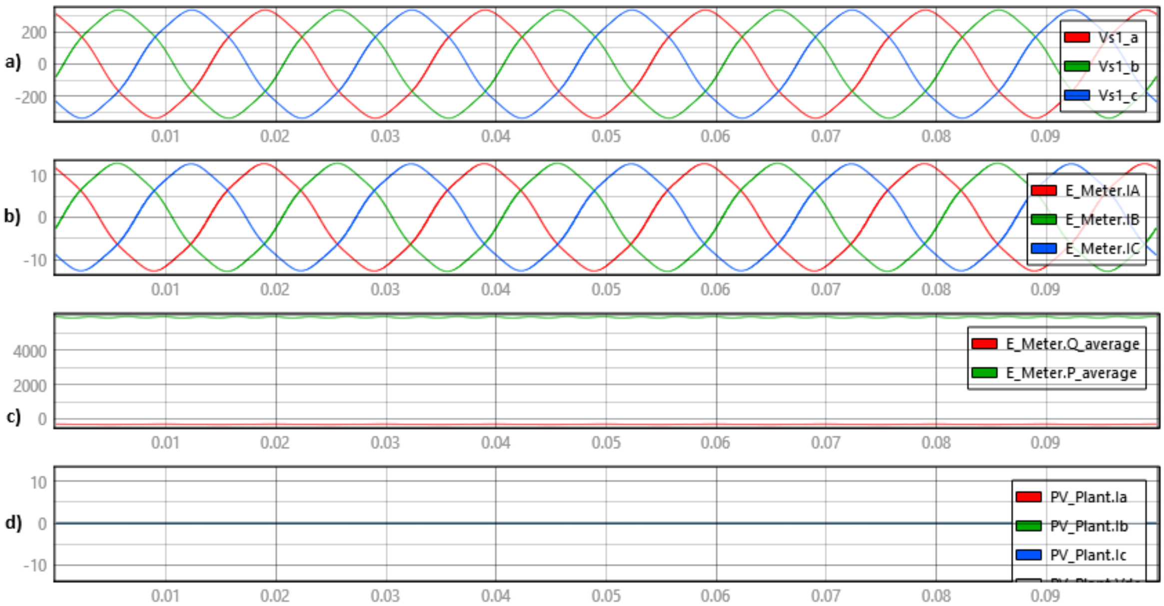

Figure 8. *System operation with a 5th-order harmonic presence in grid voltages: a) grid phase voltages; b) grid phase currents; c) load currents; and d) inverter phase currents*

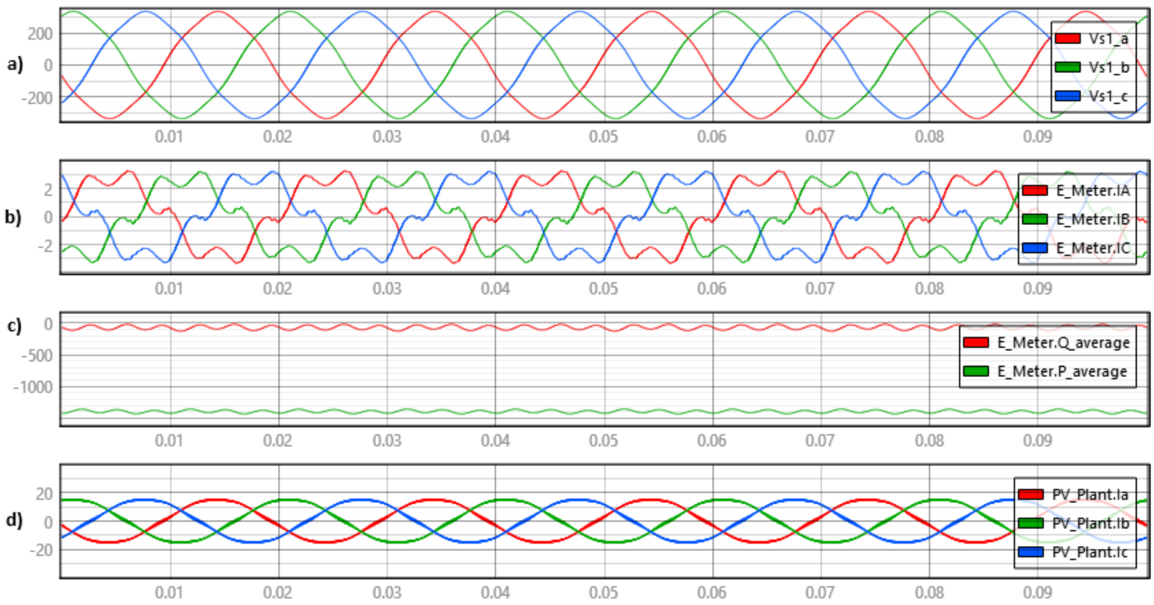

Figure 9. *System operation under distorted grid conditions with a 5th-order voltage harmonic and the PV inverter connected: a) grid phase voltages; b) grid phase currents; c) load currents; and d) inverter phase currents*

However, the operating conditions change significantly once the grid-connected inverter is activated. This situation is illustrated in Fig. 9, where several characteristic system variables are presented. It can be observed that the inverter currents themselves are not significantly distorted; however, the currents associated with the total household consumption exhibit pronounced distortion. This behaviour indicates that, under such realistic grid conditions, conventional inverter control strategies may not be sufficient, and alternative control approaches are required to preserve the desired level of power quality.

Finally, a scenario involving a reduction in solar irradiance from the standard value of 1000 W/

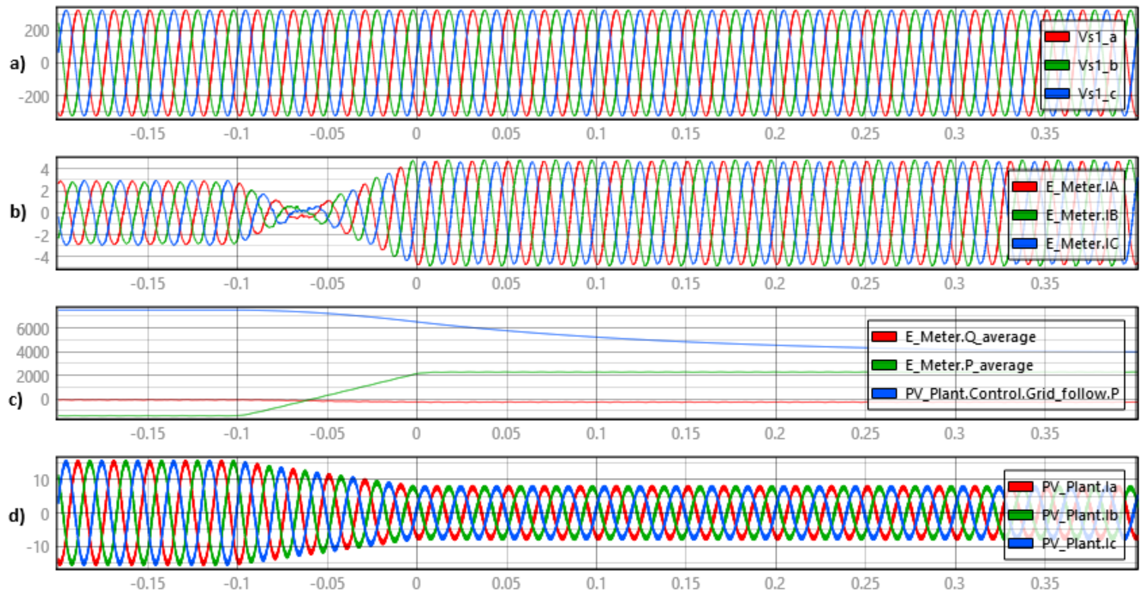

Figure 10. *System operation under reduced solar irradiance: a) grid phase voltages; b) grid phase currents; c) active and reactive power at the smart meter and PV plant active power; and d) inverter phase currents*

m² to 500 W/m² was simulated, emulating a sudden increase in cloud coverage. As a result, the power output of the residential PV system decreases proportionally, causing the household to shift from net energy production to net energy consumption. As shown in Fig. 10, this transition occurs smoothly, without any disturbances to the operation or stability of the household power system.

All previously simulated situations were intended to illustrate the possibilities of the proposed C-HIL approach in modelling and analysing the functionality of a home PV system. From the above, it can be seen that there may be problems in the operation of the system, especially in cases where voltage or current harmonics occur in the network, which is a practically relevant situation for real operating conditions. Also, the proposed approach provides exceptional flexibility for testing the functionality of the control hardware in almost real exploitation conditions, which ultimately leads to faster development of fully functional devices.

5. CONCLUSIONS

The presented study demonstrates the advantages and practical relevance of controller-hardware-in-the-loop (C-HIL) simulation for testing and validating small grid-connected photovoltaic systems in an urban residential context. The developed C-HIL setup enabled realistic emulation of photovoltaic system dynamics under varying irradiance and load conditions, providing valuable insights into inverter behaviour and control performance.

The results confirmed that the integration of a residential PV system significantly reduces the amount of electrical energy drawn from the distribution network. The classical GFL control structure of a three-phase grid-tied inverter performs adequately under balanced load conditions; however, it becomes suboptimal in the presence of pronounced single-phase loads. This limitation is particularly evident with high PE loads that introduce substantial current harmonic distortion. In such cases, the operation of a three-phase PV inverter within a household installation can noticeably degrade the overall current spectrum, which may have long-term negative effects on power quality. These findings highlight the need for innovative inverter control strategies capable of mitigating load unbalance and actively compensating undesirable harmonics injected into the grid. Such advancements are essential to enable wider and more sustainable integration of renewable energy sources in urban distribution networks.

In addition to its technical validity, the C-HIL approach significantly reduces development time and costs by bridging the gap between offline simulation and real-world hardware testing. It provides a safe and repeatable environment for evaluating control robustness before field implementation, which is particularly useful for densely populated urban areas where large-scale experimental setups are not feasible.

Overall, this research highlights the potential of C-HIL simulation as a powerful tool for designing and validating intelligent inverter control strategies that contribute to the flexibility, resilience, and sustainability of future urban power grids. Future work will focus on expanding the framework to include more inverters, integrating energy storage, and testing advanced grid support functionalities.

6. ACKNOWLEDGE

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C-HIL СИМУЛАЦИЈА КУЋНОГ ФОТОНАПОНСКОГ СИСТЕМА

Апстракт: Широка примјена фотонапонских (PV) система у урбаним подручјима поставља нове изазове у погледу интеграције у нисконапонску дистрибутивну мрежу, рада у условима промјенљивих метеоролошких утицаја, као и утицаја локалних поремећаја. Истраживања заснована на симулацијама типа Hardware-in-the-Loop (HIL), а нарочито технике са физички присутним регулаторима (Controller Hardware-in-the-Loop – C-HIL), представљају моћно окружење за испитивање и валидацију стратегија управљања претварачима заснованим на енергетској електроници у условима блиским реалним, без ризика и трошкова повезаних са теренским експериментима. У овом раду приказана је примјена C-HIL симулације ради анализе и оптимизације рада кућног фотонапонског система интегрисаног у урбану дистрибутивну мрежу. Спроведене студије случаја обухватају радне сценарије као што су нагле промјене сунчевог зрачења, варијације оптерећења и напонски поремећаји, при чему је демонстрирана ефикасност C-HIL платформе у оцјени динамичких перформанси, квалитета напона и стабилности система. Добијени резултати потврђују да C-HIL симулација може пружити значајне увиде за пројектовање фотонапонских система усмјерених ка безбједној и широкој примјени дистрибуираних обновљивих извора енергије у урбаним мрежама.

Кључне ријечи: симулација у реалном времену, кућни фотонапонски систем, урбана дистрибутивна мрежа, мрежни инвертори, C-HIL.

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