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Simulation of on-grid solar power system by Simulink Module in MATLAB software

Pham Van Duy[1], Nguyen Viet Huong[1], Pham Thi Hanh[1], Bui Bao Hung[1], Cu ThiThanh Huyen[1]

[1]Institute of Energy Science, Vietnam Academy of Science and TechnologyComputer
Corresponding Author:Cu ThiThanhHuyen

---***ABSTRACT***---

The study does simulate the operation of on-grid solar power system based on the Simulink integrated in the MATLAB software. The simulation results can significantly reduce design time and cost, evaluate the feasibility of ideas and designs, compared to the implementations on hardware and experimental model.

KEYWORD - *Solar power, on-grid, MATLAB, Simulink.*

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I. Introduction

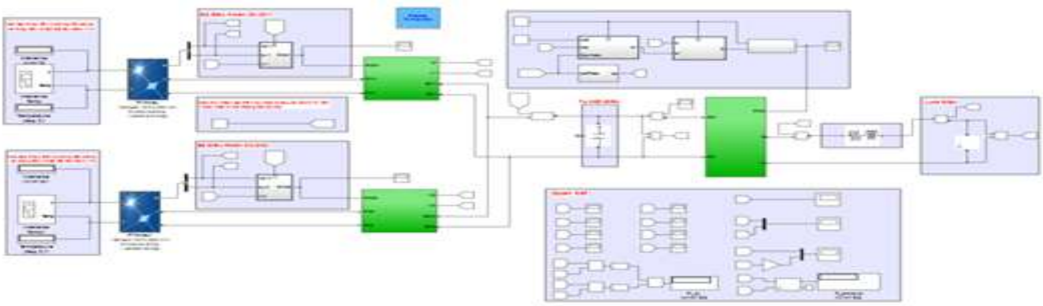
Simulation is important step in design process before actualization. Currently, with high-level simulation tools, designers can easily implement the simulation of actual system with high accuracy in the most intuitive and closest way. The simulation is useful way for proofing and verifying the mathematical models of the system, control objects as well as controller parameters set up by engineers. With the on-grid solar power system, simulation is extremely necessary for the following reasons: Survey and evaluation of the ability of the system in responding to environmental changes (radiation, temperature) are not be continuous and not exact, because of the need for environmental measuring equipment. For a large power system, to verify the performance of converter, simulation tools will be convenient and more intuitive. The simulation can easily change the control structure to optimize the system, assert the correctness of the algorithm and control parameters. Significantly reduce the time and design costs compared to the implementation on real model, actual hardware implementation while the while feasibility is uncertain.

Simulink is one of the tools packages, integrated in MATLAB, which is used very commonly in system modeling, simulation and analysis. Simulink is an easy-to-remember simulation term paired by two words: Simulation and Link. This tool allows describing linear systems, nonlinear systems, models in continuous and intermittent domain time. Moreover, it also allows running the system including subsystems with different speeds. Simulink provides an intuitive interface for building models by simple manipulations are press, drag and drop with the mouse. This is a big difference with previous simulation software because programmers, users must put in differential equations via a programming language.

II. Simulation

1. Input data

The overall diagram of the simulation program of the on-grid solar power system used two channels MPPT shown in the figure 1. The program allows changing load scenarios, conditions of radiation, ambient temperature and control algorithms to verify the dynamic properties of the control processes as well as the efficiency of the converter.



Fi**gure1**: Overall diagram of the on-grid PV system

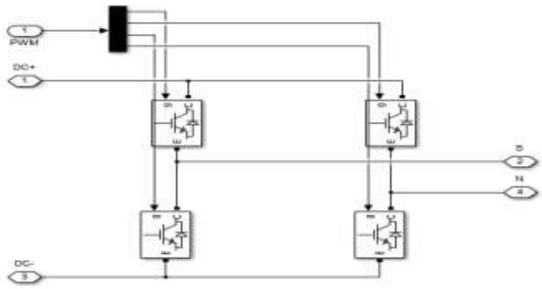


Figure 2.Force circuit DC-AC

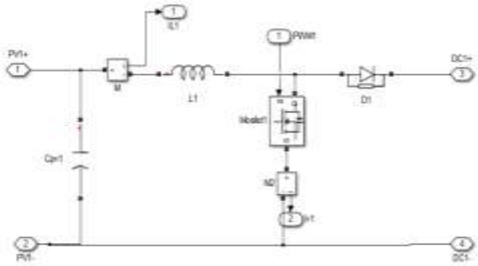


Figure 3. Force circuit DC-AC Boost Converter

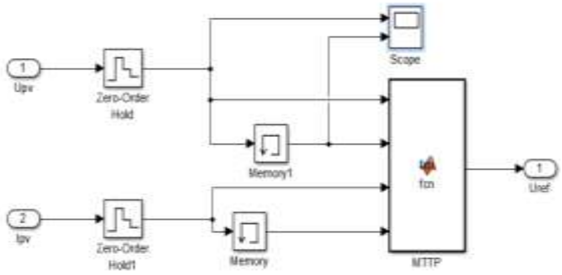


Figure 4. Algorithm structure of maximum power point tracking MPPT

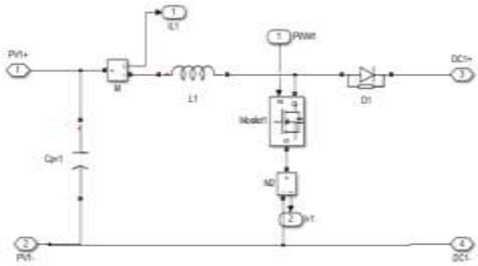


Figure 5. Control structure MPPT DC – DC Boost Converter

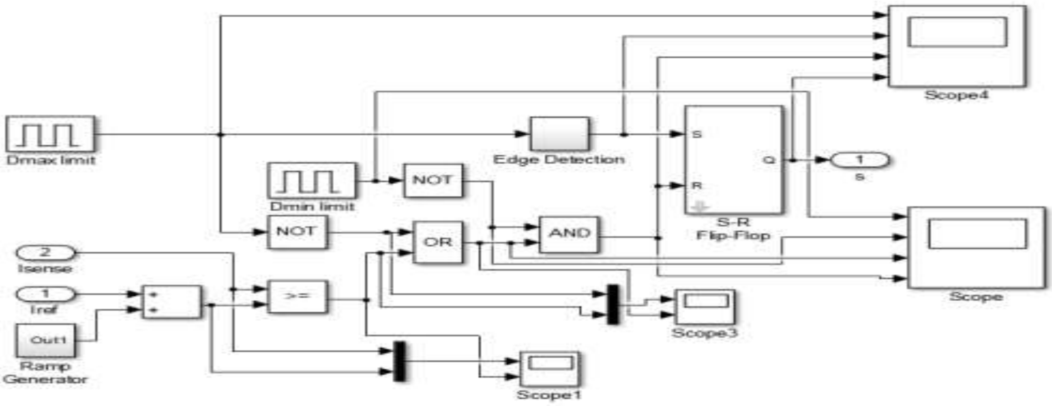


Figure 6: Structure of peak current controller for DC-DC

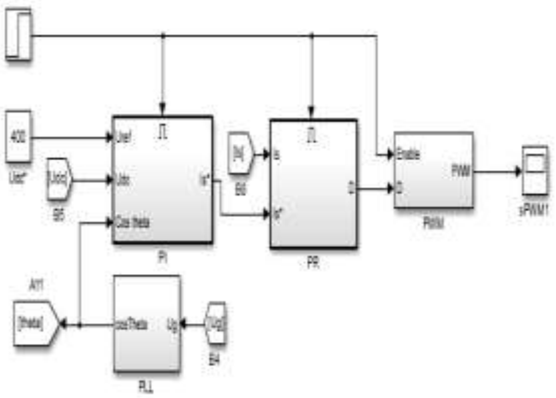


Figure 7.DC - AC controller structure

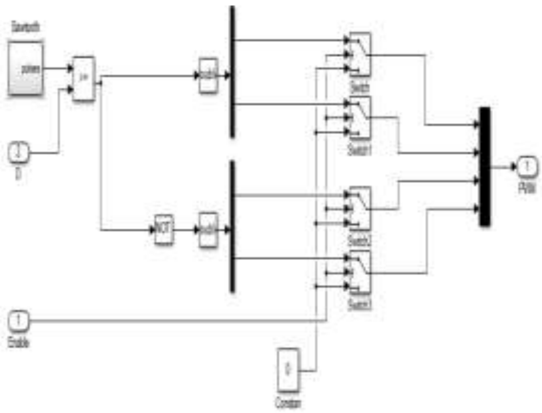


Figure 8. Diagram of structure of PWM creating phase by unipolar method

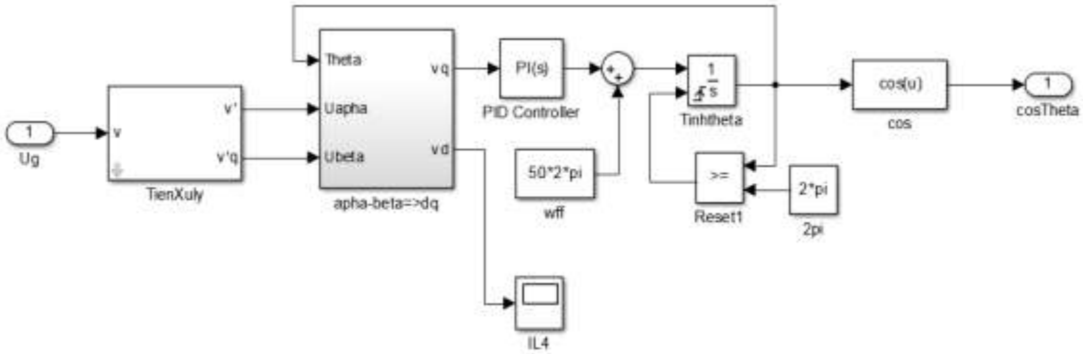
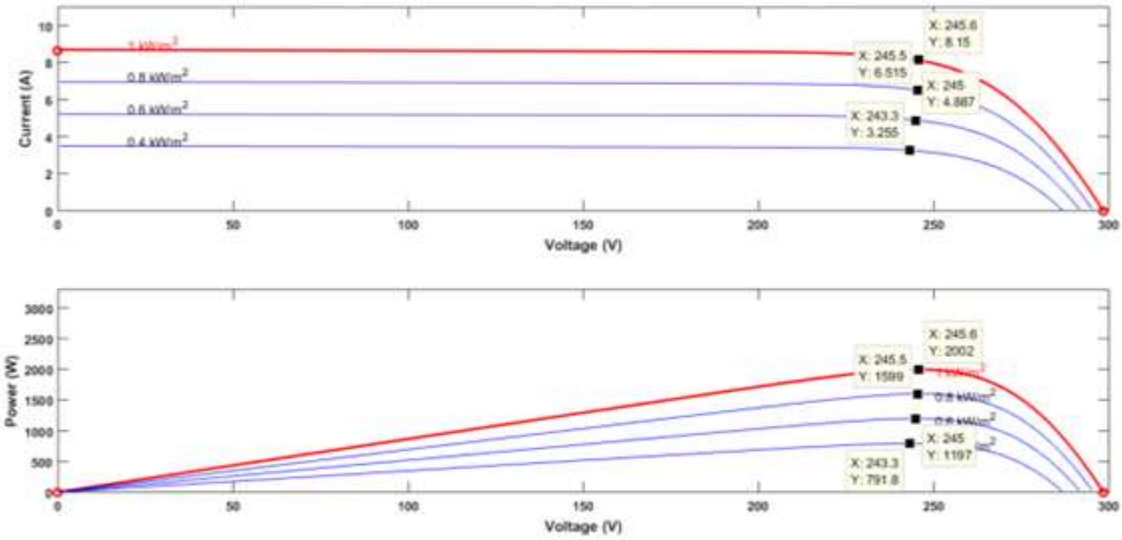


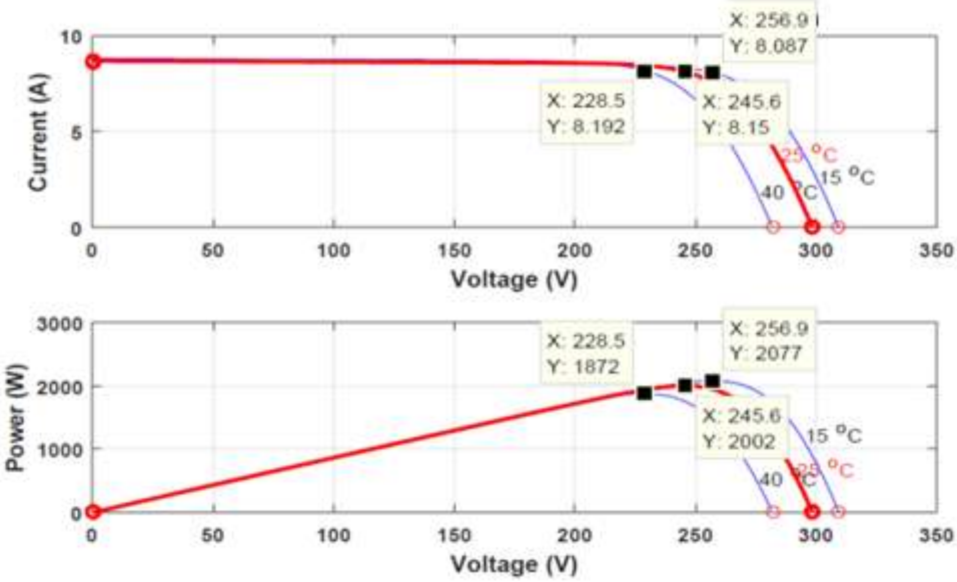
Figure 9. Diagram of phase-locked loop control

I -V and P-V characteristics of SOLTECH cells chain including 8 modules connected in series.



Fig**ure10**. I -V and P-V characteristics of SOLTECH cells chain with radiation control

I-V and P-V characteristics of SOLTECH cells chain by temperature.



Fig**ure11**. I-V and P-V characteristics of SOLTECH cells chain by temperature

<table>
<tr><th colspan="3">FORCE CIRCUIT PARAMETERS</th></tr>
<tr><td>SOLTECH 1SH-250-WH</td><td colspan="2">Total of panels: 16 panels, installed into 2 chains, each of chain includes 8 panels in series.
P_{max} = 250W, I_{mpp} = 8.15 A, U_{mpp} = 30.7 V</td></tr>
<tr><td>Set of DC-DC Boost Converter</td><td colspan="2">$C_{pv1} = C_{pv2}$ = 1280 µF, $L_1 = L_1$ =5 mH</td></tr>
<tr><td>Set of DC-AC (Active rectification)</td><td colspan="2">C_{dc}= 1500 µF, L_s = 15 mH, r_L = 0.01 Ω</td></tr>
<tr><td>Grid</td><td colspan="2">U_{rms} = 220 V, f=50 Hz</td></tr>
<tr><th colspan="3">CONTROLLER PARAMETERS</th></tr>
<tr><td>DC-DC control loop</td><td colspan="2">I controller: K_i = -39062
Pulse repetition frequency: f_s= 25 kHz</td></tr>
<tr><td rowspan="3">DC-AC control loop</td><td>Control of I_s current</td><td>Control of U_{dc} Voltage</td></tr>
<tr><td>PR controller:
K_p = 47.13, K_i = 30191</td><td>PI controller:
K_p = 0.964, K_i = 60.26</td></tr>
<tr><td colspan="2">Pulse repetition frequency: f_s= 5 kHz</td></tr>
<tr><td>PLL control loop</td><td colspan="2">PI controller K_{p_PLL} = 4.013, K_{i_PLL}= 25000</td></tr>
</table>

Table1. Simulation parameters of the on-grid solar cells system with 2 MPPT channels

2. Description of the process

Firstly, power up the capacitors: Upvl = U pv2 = 200V, Udc = 300 V. Initially, on-grid system runs in active rectifier mode, DC side of the system is not active yet. Until the active rectifier operation is stable with capacitor voltage Udc = 400 V in about 0.08s, we allow connecting solar panels and MPPT Boost converter to the system. The on-grid solar power system starts operating. From there, changing the parameters for different simulation cases to investigate.

III. RESULTS

At 0.6s, changing the radiation condition of the both cells chains from 400 W/m^2 to 1000 W/m^2, ambient temperature does not change and keep at 25^{0}C.

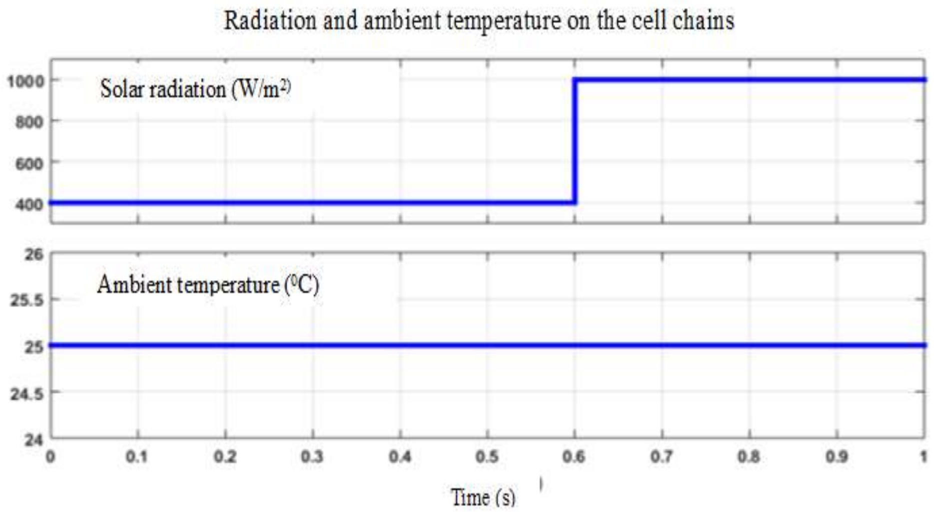


Figure 12. Simulation scenario of 2 cell chains with the same radiation and temperature conditions.

- The output voltage of each cell chain Upv increases from 243.3 V to 245.6 V, the voltage graph of 2 cell chains as below:

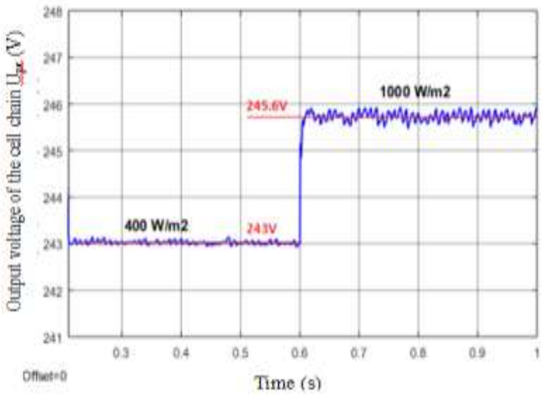


Figure 13.Output voltage graph of 2 cell chains

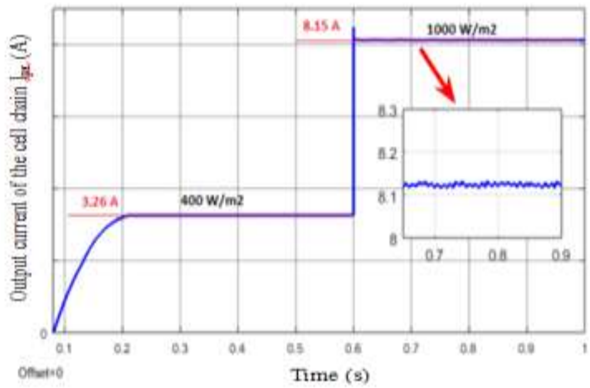


Figure 14. Output current graph of 2 cell chains

The output current of each cell chain Ipv changes when the radiation changes and tracks the maximum power working point (changing from 3.26A to 8.15A):
Current on the inductor IL of the Boost Converter and Voltage Udc on the capacitors track right according to the set value 400V.

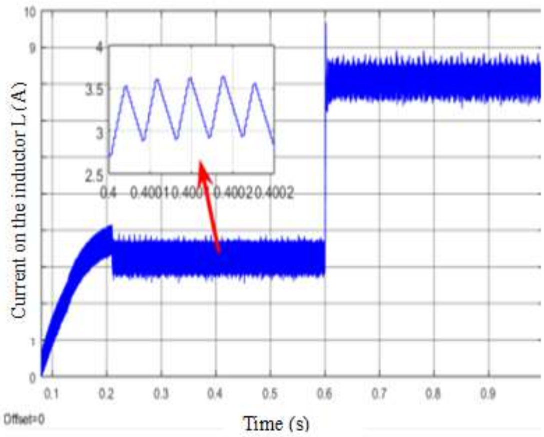


Figure 15. Current graph on the inductor of Boost converter

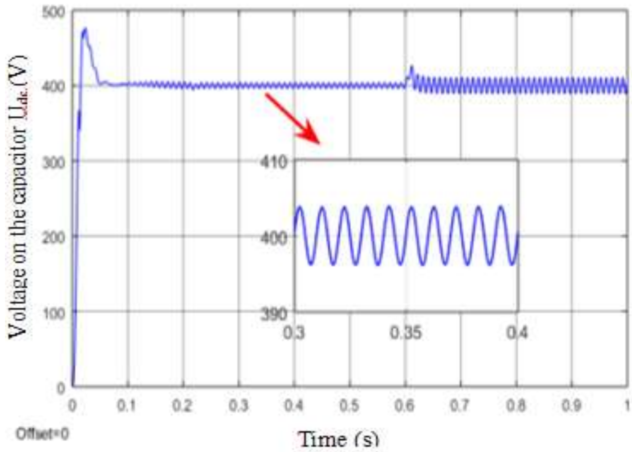


Figure 16. Balance voltage graph of the capacitor Udc

At the time of changing solar radiation impacting on 2 cell chains, the voltage Udc-Link on the capacitor increases, the active rectifier controller adjusts back the voltage on the capacitor tracking the set value of 400V. As the solar radiation intensity increases, the voltage fluctuation on the capacitor increases.
Simulation results of PLL phase lock loop algorithm and - Grid voltage and current on inductor in alternate side:

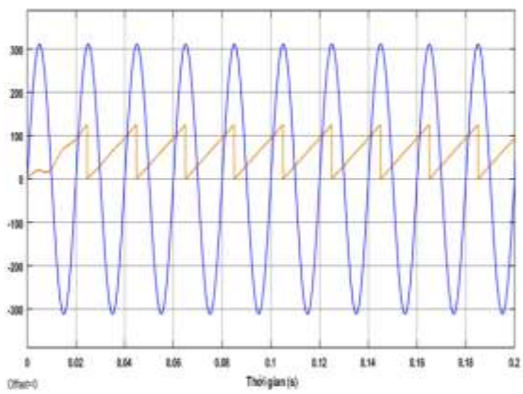


Figure 17. Grid voltage signal and PLL output phase angle amplification

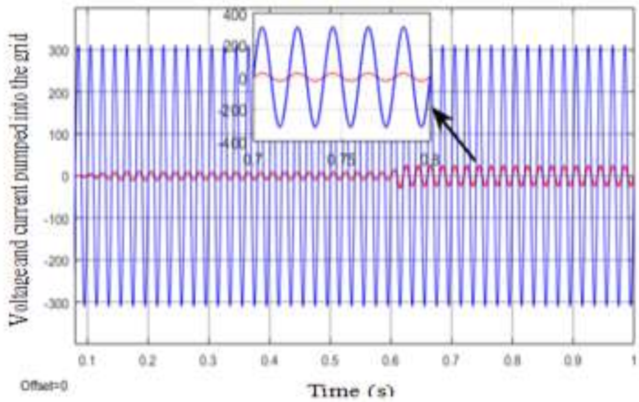


Figure 18. Balance voltage graph of the capacitor Udc

Output current pumped into the grid through the inductor that is ensured phase synchronization with the grid voltage. When the solar radiation intensity increases, the current pumped to the grid also increases. That shows the system works in accordance with the design principle, ensuring high conversion efficiency.
The current on inductor in the grid side - Analysis of the harmonic distortion indicator of the current in range of 0.25s to 0.45s:

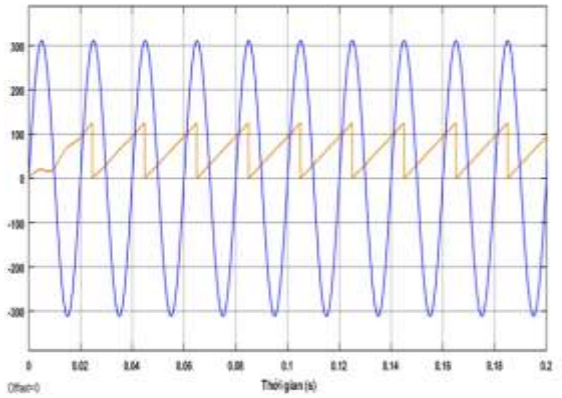


Figure 19. Graph of current on the inductor in the grid side

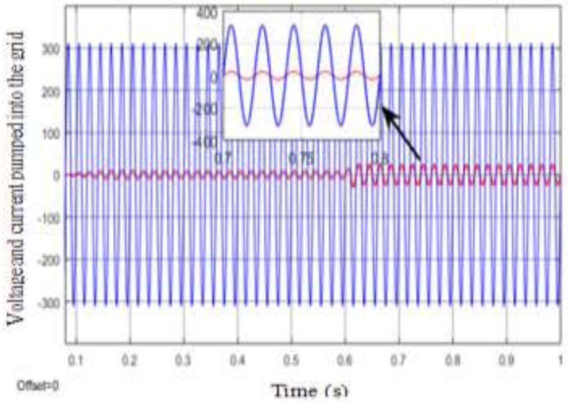


Figure 20. Distortion analysis of the harmonic current injected into the grid

IV. CONCLUSION

Through the simulation process of the on-grid solar system having 2 MPPT channels,we have some comments as follows:The simulation system of the solar power system having 2 MPPT channels has built meets the design requirements in both cases of changing solar radiation and temperature conditions impacting on 2 cell chains. In there, whether the conditions are the same or different, the system always ensures the cell chains to work in right tracking to the maximum power point and pumping the converted energy into the grid.For areas with evenly distributed solar radiation, the use of a 2-channel MPPT converter does not mean much. Therefore, the system with 2 MPPT channels is only useful and efficiency for areas with frequent fluctuations in solar radiation intensity.

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