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ign of grid connected Dc to Ac inverter

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(Electronics Engineering and Electrical Communication)

Submitted by

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This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Engineering (Electronics and Communications Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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ABSTRACT

Sameh Mostafa Mohamed Elsayed, Design of grid-connected Dc to Ac inverter, Doctor of Philosophy in Electrical Engineering, Ain Shams University, 2022

A comparative analysis is introduced in this thesis among three altered controllers (PI, Fuzzy, and Fuzzy-PI) for a 9.1 kW grid-connected scheme. This scheme is designed by using Simulink to test the recommended controllers under the theoretical operating conditions for a household-sized PV (Photovoltaic) system. The current study compares between the three controllers and goes to select the better controller for amelioration the performance of the grid-connected system control. The study determines that the Fuzzy-PI controller beats the other controllers regarding the performance factors in terms of dynamic response, total harmonic distortion, and overshoot and settling time. This is recognized to the fact that the values of the gains (K_I and K_P) are changed by the Fuzzy-PI based on the variations in irradiance and temperature.

One of the main sources of renewable energy is solar energy (PV system). This means that transforming the solar energy into electricity is a very essential research topic. Low efficiency and high cost are between the imperfections of PV systems. This stimulates scientists to achieve how to increase the quality of renewable energy resources. The control of grid-connected inverter structures is a very important part of the transformation and transmission of energy; so, they must be ameliorated to see the loads for grid interconnection. The research thesis presents a design and the hardware implementation of a Fuzzy-PI which is an intelligent controller for the inverter controller to minimize the inverter total harmonic distortion and synchronize with the grid. First, the research thesis explains the Simulink design of the three-phase Fuzzy-PI controller. Next, this thesis discusses a Matlab GUI implemented to design any grid-connected inverter that is useful in sizing PV systems. The thesis finally discusses the generation code of the Fuzzy-

PI controller from the Matlab Simulink Model, the hardware components, and the hardware implementation of the system in the lab experiment. A 70 W prototype is used in the hardware implementation, to test the study controller, trying to be as nearer as possible to reality devoid of taking major dangers or getting into security apprehensions in case of doing experiments on the systems of high power. 70 W prototype systems prove that the controller prototypical could be directly transformed from Simulink to the control scheme. It also proves that the Fuzzy-PI controller is working correctly using the 70 W prototypes. Once this is established, the idea can be applied to commercial systems with proper funding. The results prove the effectiveness of the proposed Fuzzy-PI controller in achieving good performance and efficiency in hardware. The proposed methodology does not require complex programming code. A Matlab coder is recommended to convert the Simulink controller into a C code which can be used in hardware implementation. The hardware outcomes show that the recommended methodology works and gets the required C Code which is the essential conclusion. The Fuzzy-PI controller of the three-phase grid-connected inverter can be applied by using low-cost configurable microcontrollers as the results show in the lab.

THESSSUMMARY

Sameh Mostafa Mohamed Elsayed, Design of grid-connected Dc to Ac inverter, Doctor of Philosophy in Electrical Engineering, Ain Shams University, 2022.

1. Firstly, A block diagram of the grid-connected system and its control aims are explained. Next, the probable current control schemes for the grid-connected inverter system are planned. After that, synchronization systems of the grid-connected inverter are represented. Finally, an explanation of the grid filter topologies for communicating the distributed group with the general electricity grid is delivered. A complete study about the role of artificial intelligent Algorithms (AI) in PV research. The study shows the critical role that AI plays in the design, control, and fault diagnosis of PV systems.

2. Average Household of the Grid-Connected photovoltaic Generator with the Different Intelligent (smart) controllers.

3. The essential hardware implementation topologies of the renewable-energy transformation systems are offered. Complete experimental versions for the grid-connected inverter (GCI) of system are offered.

4. The main variances between the experimental version and the simulation model are clarified.

The thesis is distributed into six chapters:

Thesis Outlines

Here is a brief description of the organization of the thesis:

Chapter 1: The first chapter gives a brief introduction to the thesis then the thesis motivations, Objectives and it describes in detail the thesis contribution.

Chapter 2: This chapter presents a summary of the renewable energy sources in the world and Egypt. Presents the objectives of this thesis and proposed system and the literature review on the research field and problems associated with PV system grid connection. Overview of renewable energy system and applications. A review on the state of the support of renewable energy sources (RES) like, wind energy, solar energy, and biomass energy in the Egypt policy of energy is offered. In addition, it explains the construction of distributed of generation systems.

Chapter 3: A review of the essential building blocks of the grid-connected system including PV arrays and their industrialized technologies, DC-DC Boost converters, and three-phase inverters. The 3rd chapter delivers in detail a mathematical model of PV panels. The chapter also gives a study on DC / DC boost converter main design equations. The chapter gives also a literature survey about inverter control in PV systems.

The survey shows the critical role that AI plays in inverter control. The study shows the critical role of (Artificial Intelligence) AI algorithms in this problem, control and mistake analysis for PV systems and the design, this chapter provides a study on the parameter identification problem.

The study shows that AI techniques achieve higher efficiency than conventional techniques. The chapter gives a study on the problem of sizing PV systems. The study shows also that AI techniques achieve higher efficiency in the research area. The chapter also gives a brief literature survey about solar irradiance forecasting.

The feature of the synchronization, for control commitments, of the grid-connected system is offered. In addition, it is described that numerous synchronizationalgorithms are proficient of getting the phase angle for the grid voltage, namely: filtering of grid voltages, zero crossing detection, and technique of PLL. It is finished that the PLL is the greatest select for the grid-connected application of inverter. Since the phase angle for the voltage of the grid can successfully be detected by PLL. Finally, the filter of the grid that is used in the joining of the utility grid to an inverter is discussed. Three kinds of grid filter are listed, namely: LCL-filter, LC-filter and L-filter. The LCL-filter is the best chosen for the grid-connected to inverter application since it is important in the decreasing the harmonics of switching frequency for the power inverter. And, it reduces the need of the filter on grid parameters.

The survey shows that AI is essential in the research area. The chapter also gives a brief study about output power forecasting. The study shows the role of AI in the research area. Finally, the chapter gives a literature survey that plays a role in solving this problem.

Chapter 4: The PV system control development. The control system is distributed into two central parts: DC converter control for the maximum power point extraction and the 3-phase of voltage source inverter control for AC current into the grid injection. This chapter gives a comparative study between (PI, Fuzzy, and Fuzzy-PI) controllers on a 9.1 kW for the grid-connected inverter to select the better controller for increasing the performance of the grid-connected system. This chapter introduces perturb and observe algorithm and explains how to implement it on Simulink.

The chapter provides a detailed Simulink model representation and explained the results. The chapter also gives a comprehensive study between PI, Fuzzy and Fuzzy-PI controllers. Firstly, the main structure of the three-phase system of inverter is presented. The model of the grid-connected system is introduced. The controls of closed-loop current methods are planned, and then comparing the quality performances. The comparison shows the higher quality performance of the Fuzzy-PI controller in terms of efficiency, overshoot, settling time, excellent steady-state response, low current ripple, total harmonic distortion, and extremely sinusoidal waveform to the grid-connected system. Output power is injected into the grid and the load with the Total Harmonic Distortion (THD) monitoring as well. Harmonics that occur during the power transformation method must be stopped from spreading into the control system of the grid because of their destructive effects on the equivalent of power system and quality of the power.

Chapter 5: The practical hardware implementation of the Fuzzy-PI controller system and its experimental results is presented. This thesis shows the different problems of realizing a control procedure for the grid-connected system.

The comparison among the R.M.S output voltage for the three-phase of simulation result and the experimental result.

Chapter 6: Provides the main contribution of the thesis. The ends of the thesis by conclusion of summaries and asserting future work which may be finished based on this effort.

Keywords: PV, Inverter, a Fuzzy logic, Grid-connected, Simulation, Hardware Implementation

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