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ign ofgridconnectedDcto Acinverter

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(ElectronicsEngineeringandElectricalCommunication)

Submitted by

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TheworkincludedinthisthesiswascarriedoutbytheauthorattheElectronicsandCommunicationsEngineeringDepartment,Faculty ofEngineering,AinShamsUniversity,Cairo,Egypt.

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ABSTRACT

SamehMostafa Mohamed Elsayed, Design of grid-connected Dc to Ac inverter, Doctor ofPhilosophyin ElectricalEngineering, Ain ShamsUniversity,2022

A comparative analysis isintroducedin this thesis among three altered controllers (PI, Fuzzy, and Fuzzy-PI)for a 9.1 kWgrid-connected scheme. This scheme is designed by using Simulink to test the recommended controllersunder the theoretical operating conditions for a household-sized PV (Photovoltaic)system. The currentstudy compares between the three controllers andgoes to select the better controller for amelioration the performance of the grid-connected system control. The studydetermines that the Fuzzy-PI controller beats the other controllers regarding the performancefactorsintermsofdynamicresponse,totalharmonicdistortion,and overshoot and settlingtime. This is recognized to the fact that the values of thegains (KIandKP) are changed by theFuzzy-PIbasedon the variations in irradiance andtemperature.

One of the main sources of renewable energy is solar energy (PV system). This means that transformingthe solar energy intoelectricity is a very essential research topic. Low efficiencyand high cost are between the imperfections of PV systems. This stimulates scientists to achieve how toincrease the quality of renewable energy resources. Thecontrol of grid-connected inverter structures is a very important part of the transformation and transmissionof energy; so,they must be amelioration to see the loads for grid interconnection. The research thesispresents a design and the hardware implementation of aFuzzy-PI which is an intelligent controller for theinverter controller to minimize the inverter total harmonic distortion and synchronize with the grid. First, the research thesis explains the Simulinkdesignof thethree-phaseFuzzy-PI controller.Next,this thesisdiscussesaMatlabGUIimplementedtodesignanygrid-connectedinverterthatisusefulinsizingPVsystems.Thethesisfinallydiscussesthe generationcodeoftheFuzzy-PIcontrollerfromtheMatlabSimulinkModel,thehardwarecomponents,andthehardwareimplementation of the system in the lab experiment. A 70 Wprototype is used in the hardware implementation, to test the study controller, trying to be as nearer as possible to reality devoid oftaking major dangers or getting into security apprehensions in case of doing experiments on the systems of high power. 70 W prototype systemsprove that the controller prototypical could be directly transformed fromSimulink to the control scheme. It also proves that the Fuzzy-PI controller is working correctly usingthe 70 Wprototypes. Once this is established, the idea can be applied to commercial systemswith proper funding. The results prove the effectiveness of the proposed Fuzzy-PI controller inachieving good performance and efficiency in hardware. The proposed methodology does notrequisite complex programming code. A Matlab coder is recommended to convert the Simulink controllerinto a C code which can be used in hardware implementation. The hardware outcomes show that therecommended methodology works and getstherequired C Code which is the essential conclusion. The Fuzzy-PI controller of the three-phase grid-connected inverter can be applied by usinglow-costconfigurablemicrocontrollers astheresults show inthelab.

THESISSUMMARY

SamehMostafaMohamedElsayed,Designofgrid-connectedDctoAc inverter,DoctorofPhilosophyin ElectricalEngineering, Ain Shams University, 2022.

1. Firstly,A block diagram of the grid-connected system and its control aims areexplained. Next, the probable current control schemes for the grid-connected inverter system areplanned.Afterthat,synchronization systemsofthegrid-connectedinverterarepresented.Finally,aexplanationofthe gridfilterstopologiesforcommunicatingthedistributedgroupwiththegeneralelectricitygridisdelivered.Acompletestudyabouttheroleofartificial intelligent Algorithms (AI) inPV research. The study shows the critical role that AI plays in the design, control, and faultdiagnosisofPV systems.

2. AverageHouseholdof the Grid-ConnectedphotovoltaicGeneratorwiththe Different

Intelligent (smart)controllers.

3. Theessential hardware implementation topologies of the renewable-energy transformation systems are offered. Completeexperimental versionsforthegrid-connectedinverter(GCI) of system areoffered.

4.Themainvariancesbetweentheexperimentalversion and thesimulationmodelare

clarified.

Thethesisisdistributedintosixchapters:

ThesisOutlines

Hereisabriefdescription oftheorganization ofthethesis:

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

Chapter 2: This chapter presents ansummary of the renewable energy sources in the world andEgypt. Presents the objectives of this thesis and proposed system and the literature reviewontheresearchfieldandproblemsassociatedwithPVsystemgridconnection.Overviewof renewableenergysystem andapplications.Areviewonthestateofthesupport of renewable energy sources(RES)like, wind energy, solar energy, and biomass energy in theEgypt policy of energy is offered. In addition, it explains the construction of distributed ofgenerationsystems.

Chapter 3: A review of the essential building blocks of the grid-connected system includingPV arrays and their industrialized technologies, DC-DC Boost converters, and three-phase inverters. The3rd chapter delivers in detail a mathematical model of PV panels. The chapter also gives astudy on DC / DC boost converter main design equations. The chapter gives also a literaturesurvey about inverter control in PV systems.

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

The study shows that AI techniques achieve higher efficiency than conventionaltechniques.The chapter gives a study on the problem of sizing PV systems. The study shows also that AItechniquesachievehigherefficiencyintheresearcharea.Thechapteralsogivesabriefliteraturesurveyabout solarirradianceforecasting.

Thefeatureofthesynchronization,forcontrolcommitments,ofthegrid-connectedsystemisoffered.Inaddition,itisdescribedthatnumeroussynchronizationalgorithmsareproficientofgettingthephaseangleforthegridvoltage,namely:filtering of grid voltages, zerocrossing-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 forthe voltage of the grid can successfullydetected by PLL .Finally, the filter of the grid that is used in the joining of the utilitygrid to an inverter isdiscussed. Threekinds ofgridfilterare listed, namely:LCL-filterLC-filter and L-filter. TheLCL-filteristhe best chosen for the grid-connected to inverter application since it is importantin the decreasing theharmonics of switching frequency for the power inverter. And, itreducestheneed ofthefilteron grid parameters.

The survey shows that AI is essential in the research area. The chapter also gives a brief studyabout output power forecasting. The study shows the role of AI in the research area. Finally,thechaptergivesaliterature surveythatplaysasolvingthis problem.

Chapter 4: The PV system control development. The control system isdistributed into two central parts: DC converter control for the maximum power point extraction andthe 3-phase of voltage source inverter control for AC current into the grid injection. Thischapter gives a comparative study between (PI, Fuzzy, and Fuzzy-PI) controllers on a 9.1 kWfor the grid-connectedinvertertoselectthebettercontrollerforincreasingtheperformance of the grid-connected system. This chapter introduces perturb and observealgorithmexplains how to implement it on Simulink.

The chapter provides a detailed Simulink model representation and explained the results. Thechapteralso gives a comprehensive study between PI, Fuzzy and Fuzzy-PI controllers. Firstly,the mainstructure of the three-phase system of inverter is presented. The model of the grid-connectedsystemisintroduced.Thecontrols of closed-loopcurrentmethodsareplanned,and thencomparing the quality performances. The comparison shows the higher quality performance of the Fuzzy-PIcontroller in terms of efficiency, overshoot, settling time, excellent steady-state response, low current ripple, totalharmonic distortion, and extremely sinusoidal waveform to the grid-connectedsystem. Output power is injected into the grid and the load with the Total Harmonic Distortion (THD) monitoring as well.Harmonicsthatoutcomeduringthepowertransformationmethodmustbestoppedfromspreading into the control system of the grid because of their destructive effects on the equivalent of power systemand quality of the power.

Chapter 5: The practical hardware implementation of the Fuzzy-PI controller system and itsexperimentalresultsispresented.Thisthesisshowsthedifferentproblemsofrealizingacontrolproce dure forthegrid-connected system.

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

C**hapter6:**Providesthemaincontributionofthethesis.Theends of the thesisbyconclusion of summariesandassertingfutureworkwhichmaybefinishedbasedonthiseffort.

Keywords:PV,Inverter,aFuzzylogic,Grid-connected,Simulation, HardwareImplementation

Publishedpapers

1- M. Sameh, A. Zekry, A. Youssef, W. R. Anis, "Average household grid-connected PV generator withdifferent intelligent controllers". 38th National Radio Science Conference (NRSC, Mansoura, Egypt;IEEE:;1, 186–198, 2021 DOI: 10.1109/NRSC52299.2021.9509783.

2- M.Sameh,A.Zekry,A.Youssef,W.R.Anis,"RaspberryPiDesignandHardwareImplementationofFuzzy-PIControllerforThree-Phase Grid-ConnectedInverter",Energies,15, 843,2022

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CONTENTS **PageNumber**

TABLEOFCONTENTS

Listoffigures