Cairo University

CONTROL OF A GRID CONNECTED SOLAR SYSTEM USING FRACTIONAL ORDER PID BASED ON EVOLUTIONARY COMPUTATIONAL TECHNIQUES

By

Eng. Rofida Hamdy Mohamed Ghobashy

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electrical Power and Machines Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Control of a Grid Connected Solar System Using Fractional Order PID Based on Evolutionary Computational Techniques.

Key Words:
PID, FOPID, Optimization methods, Objective function methods, PV system.

Summary:

This thesis presents a new control type using "fractional order PID" (FOPID) in voltage regulation grid-connected PV system. FOPID controller is a natural extension of PID controller that used widely in industrial applications. The FOPID system is able to balance harmonic components and reactive power generated by the loads connected to the system. This thesis discusses the tuning and implementation of FOPID in industrial applications. A program has been developed to implement this controller in voltage regulation PV system The optimization algorithms has been presented to tune the parameters of FOPID to obtain the desired response with application in simulation program (MATLAB). Several comparisons between the FOPID/FOPI with the classical PID/PI controllers show that the proposed control strategy improves the efficiency of the system by decreasing the total harmonic distortion of the injected current to the grid and increases the robustness of the system against changes.
So simply, it can be said that FOPI and PI controllers have been successfully implemented and show a relative improvement in the output response.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledge all sources used and have cited them in the references section.

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List of Abbreviations

AACPSO	Adaptive Acceleration Coefficient Particle Swarm Optimization
AWPSO	Adaptive weighted Particle Swarm Optimization
FOPID	Fractional-Order PID Controller
FOPI	Fractional-Order PI Controller
IAE	Integral of Absolute Error
IC	Incremental Conductance
ISE	Integral of Square Error
ITAE	Integral of the Time Weighted Absolute Error.
ITSE	and Integral of Time Multiplied By the Squared Error.
MAACPSO	Modified Adaptive Acceleration Coefficient Particle Swarm Optimization
MATLAB	Matrix Laboratory
MPPT	Maximum Power Point Tracking
P&O	Perturb & Observe
PID	Proportional Integral Derivative controller
PI	Proportional Integral Controller
PLL	three-phase Phase Locked Loop
PSO	Particle Swarm Optimization
PV system	Photovoltaic System
VSC	Voltage Source Converter

List of Symbols

A	Accelerated Coefficient is added to improve the swarm search.
$a(Z)$	determined by Integrator method.
a and x	The integration limits for calculus equations.
$b(Z)$	determined by filter method
$c1\&c2$	Positive constants called acceleration coefficients, usually are 2.
e	Error =SP-PV
$F_m(t)$	Is the mean value of the best positions related to all particles at iteration i
g_{bestki}	The best particle position based on swarm's experience.
i	Number of iteration
I_d *and* I_q	Active and reactive currents components.
I_{mp}	current at maximum power
Isc	Short-circuit current.
k_c	Is determined based on the fitness value of G_{best} and P_{best} at iteration i
K_d	Derivative gain, a tuning parameter
K_i	Integral gain, a tuning parameter
K_p	Proportional gain, a tuning parameter.
N	Filter coefficien
n	The current generation
p_{bestki}	The best particle position based on its experience
$r_1\&r_2$	Random numbers within the range [0,1].
t	Time or instantaneous time (the present).
$U_{ref\,(abc)}$	three modulating signals
V_d *and* V_q	voltage outputs of the current controller
$Vj(i)\&X_j(i)$	The velocity and the current position of particle *i* in the search space at iteration *i*, respectively.
V_{mp}	Voltage at maximum power
V_{oc}	Open-circuit voltage.
Z	Z-domain for discrete system
w	Inertia weight Get the swarm in best area.
α	Fractional order for calculus equations.
α_w & α_c	Are determined with respect to initial and final values of ω with the same manner
Γ	Euler's Gamma function for calculus equations
τ	Variable of integration; takes on values from time 0 to the present t
λ	Order of s in integral
μ	Order of s in derivative

Abstract

This thesis presents voltage regulation of photovoltaic system tied to the grid. There are four controllers have been used; PID, PI, FOPID, and FOPI.
PV system is depending on converting the solar energy into electric energy by using semiconductors. PV system generally consists of energy conversion that take the energy source and transfer it to electricity, then it pass through energy inversion, and at the end it goes to energy distribution according to the PV systems type.
"Proportional Integral Derivative" (PID) controller is being used in large space because it is so simple in control and implementation. Simple controllers like PID controller are not suitable for all processes. PID controller is suitable for processes with almost monotone step responses on condition that requirements are not too tough. PID controllers are not fitting for process that is extremely oscillatory.
Nowadays the researchers improve this type of controllers to get the system much better in its transient response. This new controllers are called "Fractional Order Proportional Integral Derivative" (FOPID). The implementation of this controller is not easy and it needs more difficult mathematical equations description, so to make its implementation much easier a computer programs is used like MATLAB program.
The PID controller has low robust ability compared with the FOPID controller when the system has many challenges from the operating atmosphere of the system, for example temperature and weather.
Controller parameters are attuned by using four methods of optimization techniques, which are:

- "Particle Swarm Optimization" (PSO),
- "Adaptive Weighted PSO" (AWPSO),
- "Adaptive Acceleration Coefficient PSO" (AACPSO),
- "Modified Adaptive Acceleration Coefficient PSO" (MAACPSO).

Four objective function techniques are used in optimization. The good optimization is in finding the parameters of the controllers such that the objective function is minimum.
Photovoltaic (PV) system is used as an application for comparing between those controllers. By MATLAB / SIMULINK software, it has been implemented for comparing the output response of the controllers for regulating the DC voltage of PV. The output results are compared between FOPID/FOPI and the classic PID/PI controllers in simulation and illuminated that the FOPI and PI have been successfully implemented in PV system and confirmed the relative improvement in the output response.

Keywords — *PID, FOPID, Optimization methods, Objective function methods, PV system.*