A FLC BASED FO-NOTCH FILER TO IMPROVE POWER QUALITY IN SOLAR SYSTEM

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ABSTRACT: This work proposed a fractional order notch filter (FONF) based on fuzzy logic controllers for a grid-connected solar photovoltaic (PV) system. The PV system uses the suggested FONF control method to identify basic signals from nonlinear loads for gating pulses that power voltage source converters (VSC). The FLC control mechanism of the suggested system compensates for low power quality at the common connecting point while simultaneously meeting the load's active power requirement. Harmonic distortion, unbalanced connected loads, and the system's reactive power demand are the power quality concerns that are taken into account. The integer order notch filter's structure should be changed, according to the FONF-based control. Fixed integrator and differentiator terms limit integer order filters. To get the system to react appropriately to the application, the power of the integrator employed in the FONF notch filter can be adjusted. To illustrate the operation of the FONF-based control, a proposed grid-connected solar PV system is constructed using MATLAB/SIMULINK. Results from simulations with changing solar irradiation are achieved for both steady state and imbalanced loads. In accordance with IEEE-519, harmonic distortions have been identified in the system.

KEYWORDS: FLC, Fractional Order, Harmonics, Power Quality.

I.INTRODUCTION

Growing concern about global climate change and increasing electricity demand have provided an impetus to renewable energy sources (RESs). Among several RESs viz. wind power, biomass, biogas, fuel cell, small/micro-hydro, the solar photovoltaic (PV) energy conversion system is the preferred choice because of its availability, easy installation, environment friendly nature and reduced cost [1]. An installation of large-scale grid connected solar PV generating stations, is becoming more prevalent in developed as well as developing countries. Government of India has also set a goal to install solar PV generation of 100 GW by 2022 [2]-[3]. The grid-connected PV system provides a link of the PV array and the grid via a voltage source converter (VSC). These systems are often equipped with maximum power point tracking (MPPT) control to extract as much power as possible from the

PV panel. This can be achieved by controlling the duty cycle to determine the on and off states of semiconductor device used within the DC-DC converter interfaced with the PV array [4]. The solution of overcoming power quality problems such as harmonics, feeding lead/lag reactive power and load unbalancing can be easily achieved with the use of active shunt compensator. The modest design, fast and stable operation make active shunt compensators very fascinating solution for load compensation over passive compensators [6]. The solution is even more attractive and cost effective when the same VSC is suitably controlled to achieve twin objectives of feeding real as well as reactive power [7].

III.PROPOSED METHOD

In this paper, a novel structure of notch filter is developed particularly for the operation of a grid integration of solar PV system. This fractional order notch filter (FONF) is primarily used to extract fundamental weight component from the distorted load currents. The active power requirements of load/grid along with attributes of active shunt compensator such as harmonics alleviation, reactive power burden and load unbalancing are demonstrated using FONF control. A comparative simulation study and test results validate significant advantages for a precise control by reducing an overall integral square error of the system.

Major contributions in this paper are summarized as follows.

- Development of fractional order notch filter (FONF) for grid integrated solar photovoltaic (PV) system.
- The FONF controller is developed to extract fundamental active components from the distorted load currents and to alleviate PQ problems such as harmonics, reactive power burden on the system and load unbalancing.
- Real time implementation of grid integrated PV system developed in the laboratory. Performance of FONF controller is validated on a developed prototype.
- Testing system operation in various modes such as during daytime when the sun light is available. It feeds active power to the grid/load along with taking care of certain ancillary services related to PQ. Moreover, during night, the system works as power quality compensator, taking care of several PQ issues.
- Performance parameters of FONF control for solar PV system are compared with integer order notch filter (IONF), normalized least mean square (NLMS) and normalized least mean fourth (NLMF) based control techniques [30]-[31].
- Superior performance of proposed control is demonstrated in terms of integral square error, computational complexity, fundamental weight convergence, harmonics compensation and sampling time.

2.1 SYSTEM DESCRIPTION

Fig. 1 shows a schematic diagram of 3-phase AC mains with small line impedance (Rs-LS) feeding the linear/nonlinear loads connected to it. Small ripple filter (Rf-Cf) is connected at PCC, which are used to supress high frequency components generated from switching of semiconductor devices. The PCC voltages (vs), grid currents (is), load currents (il), DC link voltage (Vdc), PV array voltage and PV current (VPV and IPV) are sensed using Hall-Effect voltage and current sensors.

The FONF based control algorithm is implemented using dSPACE DS-1202 MicroLab Box and detected voltages and currents are entered using analog to digital converter (ADC) channels of controller interfacing box.

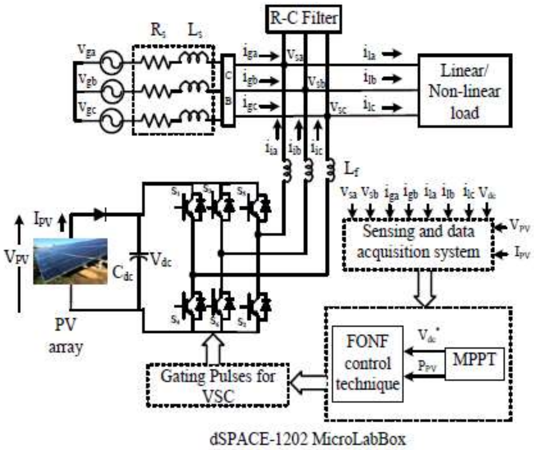


Fig. 1 System configuration of grid connected solar PV system.

A. Fractional Notch Filter Based Control Technique

To achieve twin objectives of grid integrated solar PV system for feeding load/grid along with certain ancillary functions viz. eliminating the harmonics, a fractional order-based notch filter based control strategy is deployed here. It also serves the load balancing and reactive power compensation. A novel fractional order notch filter is designed for obtaining the active constituents of load current for achieving the desired objectives. The fractional calculus control theory deals with a generalized form of both the integer and non-integer order controllers and filters. According to Riemann-Louville [32], a fractional derivative and integral function are given as,

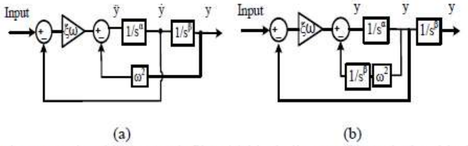
$$\frac{d^\alpha}{dt^\alpha}f(t) = \frac{1}{\Gamma(1-\alpha)}\frac{d}{dt}\int_0^t (t-\tau)^{-\alpha} f(\tau)dt$$

Where Γ(·) is the gamma function, α is power of fractional order integrator used in a fractional order notch filter (α<0). The Laplace transform of (1) with zero initial condition gives,

$$L_0\{d_t^\alpha f(t)\} = s^\alpha F(s)$$

B. Structure of Fractional Order Notch Filter

Based on a definition and Laplace transformation of fractional derivative and integral term, a fractional second order notch filter with two fractional integral terms is proposed. The structure of fractional order notch filter is given in Fig. 2(a). The equivalent block illustration of fractional order notch filter (shown in Fig. 2(a)) can be represented in the form of cascaded loop as shown in Fig. 2(b).



(a) (b)

Fig. 2 Fractional order notch filter (a) block diagram (b) equivalent block diagram.

After solving the inner loop, the forward transfer function (TF) of the block illustration (Fig. 2(b)) is expressed as,

$$G_{OL} = \frac{\xi\omega\, s^\beta}{s^{\alpha+\beta} + \omega^2}$$

Where GOL is open loop TF of the filter, α and β are the fractional parameters, ξ is the damping factor and ω is the natural frequency. The outer loop (Fig. 2(b)) with unity feedback combined with the forward loop TF given in (3) provides the overall transfer function of fractional order notch filter (FONF) and it is represented as,

$$G_{FON} = \frac{\xi\omega\, s^\beta}{s^{\alpha+\beta} + \xi\omega\, s^\beta + \omega^2}$$

Where GFON is the overall TF of the fractional notch filter. The complete TF of

FONF consists of two fractional parameters α and β, which can be varied in the interval (0, 2).

III.SIMULATION RESULTS

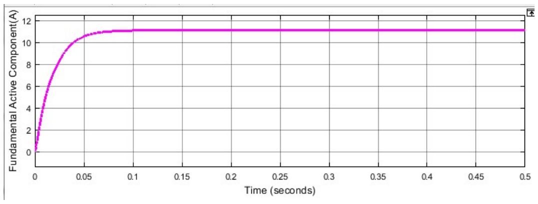


Fig. 3.1 Convergence of fundamental active components using FONF(a) steady state

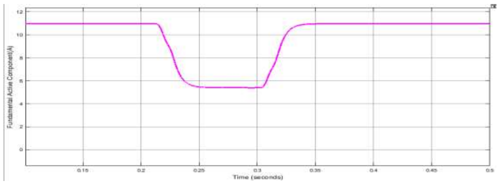
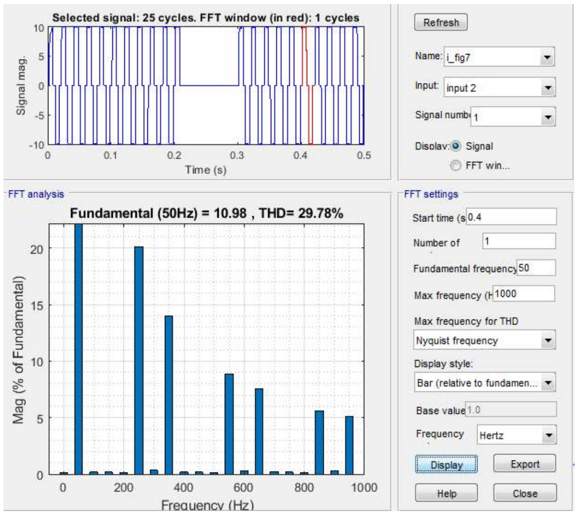


Fig. 3.2 Convergence of fundamental active components using FONF, NLMS and NLMF (b) unbalanced loading conditions.



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Name: i_fig7

Input: input 2

Signal numb 1

Display: ● Signal ○ FFT win...

Fundamental (50Hz) = 10.98 , THD= 29.78%

Start time (s 0.4

Number of 1

Fundamental frequency 50

Max frequency (H 1000

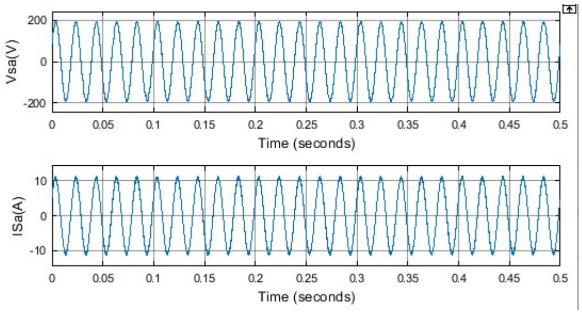
Max frequency for THD: Nyquist frequency

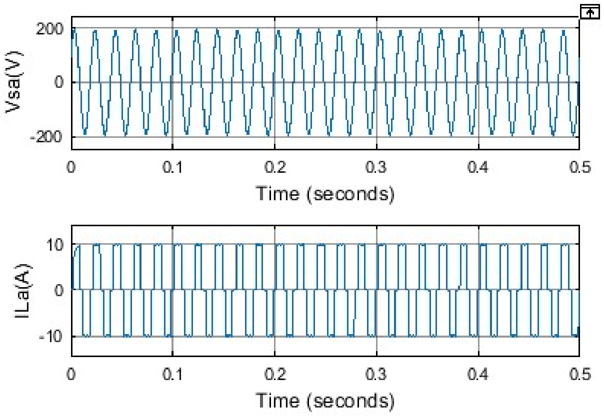
Display style: Bar (relative to fundamen...

Base value 1.0

Frequency Hertz

Fig. 3.3 Harmonic spectra of (a) grid current iga using (d) load current ila.





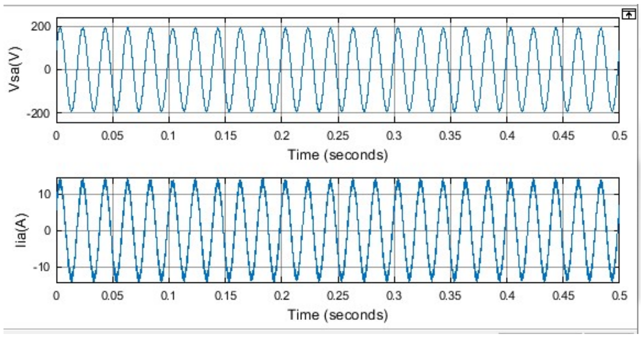
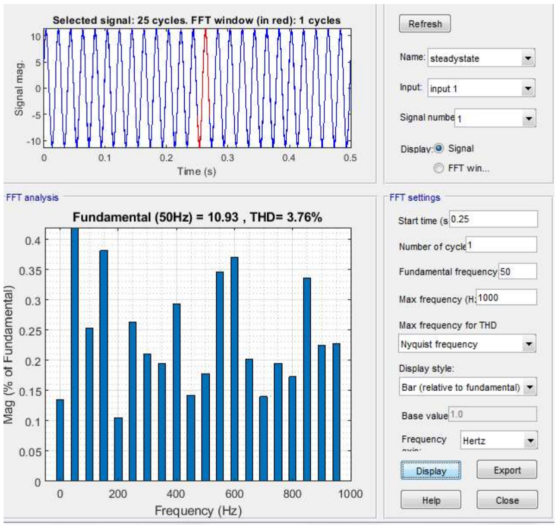


Fig. 3.4 Steady state performance of grid tied solar PV system (a) voltage at point of common interconnection vsa, and grid current iga(c) vsa, load current ila (e) vsa, converter current iia



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Name: steadystate

Input: input 1

Signal numbe 1

Display: ● Signal ○ FFT win...

Fundamental (50Hz) = 10.93 , THD= 3.76%

Start time (s 0.25

Number of cycle 1

Fundamental frequency 50

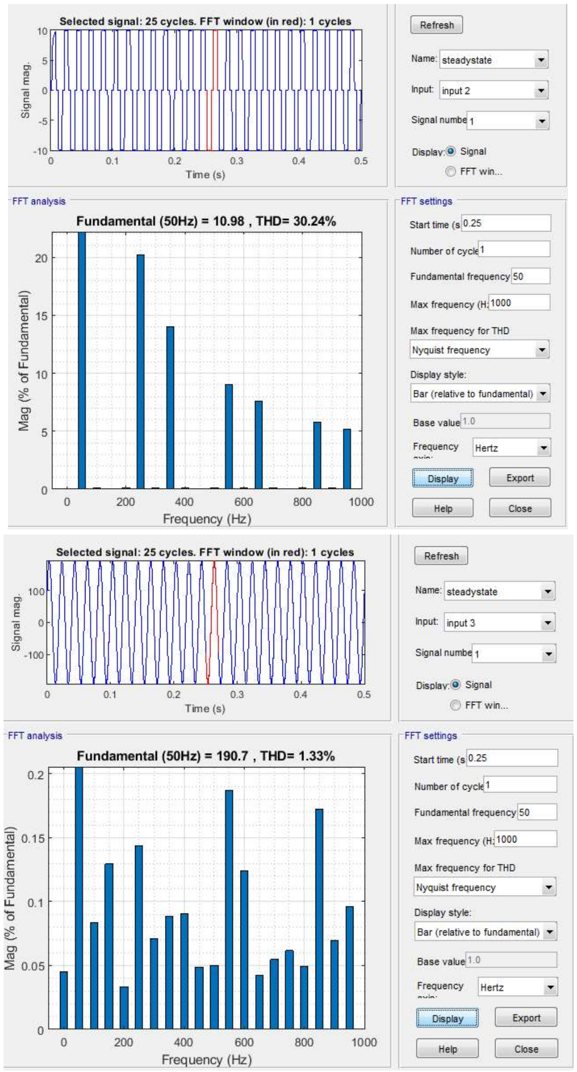
Max frequency (H 1000

Max frequency for THD: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value 1.0

Frequency Hertz



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Name: steadystate

Input: input 2

Signal numbe 1

Display: ● Signal ○ FFT win...

FFT analysis

Fundamental (50Hz) = 10.98 , THD= 30.24%

FFT settings

Start time (s 0.25

Number of cycle 1

Fundamental frequency 50

Max frequency (H 1000

Max frequency for THD: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value 1.0

Frequency axis: Hertz

Selected signal: 25 cycles. FFT window (in red): 1 cycles

Name: steadystate

Input: input 3

Signal numbe 1

Display: ● Signal ○ FFT win...

FFT analysis

Fundamental (50Hz) = 190.7 , THD= 1.33%

FFT settings

Start time (s 0.25

Number of cycle 1

Fundamental frequency 50

Max frequency (H 1000

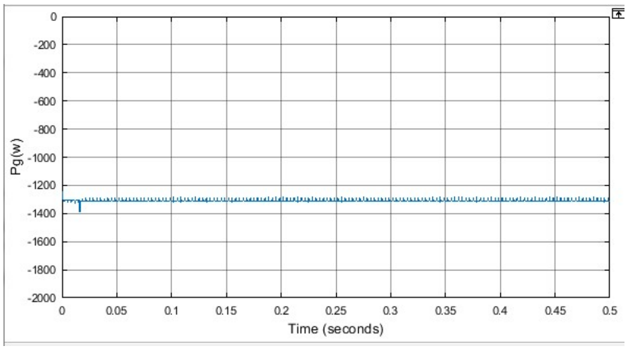
Max frequency for THD: Nyquist frequency

Display style: Bar (relative to fundamental)

Base value 1.0

Frequency axis: Hertz

Fig. 3.5 Steady state performance of grid tied solar PV system (b) harmonics pectrum of iga (d) harmonic spectrum of ila(f) harmonic spectrum of vsa.



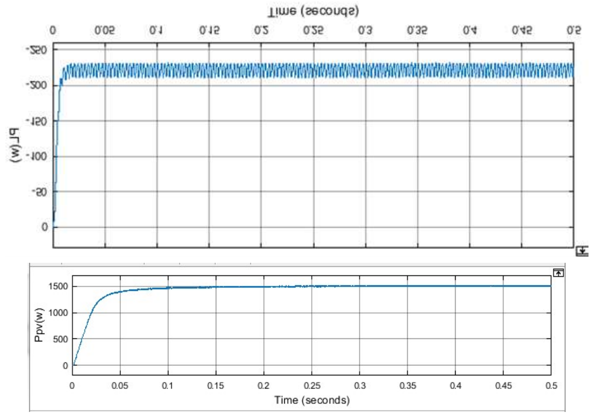
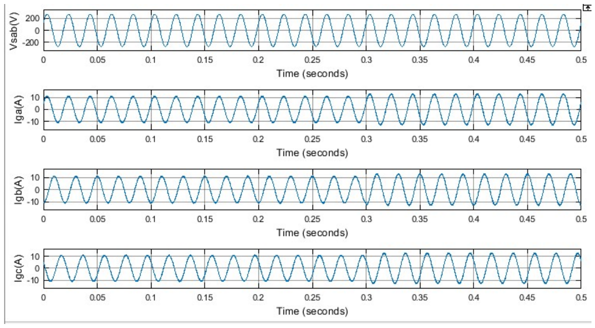


Fig. 3.6 Steady state performance of grid tied solar PV system (a) grid power, Pg, (b) load power, PL and (c) solar PV power, Pi.



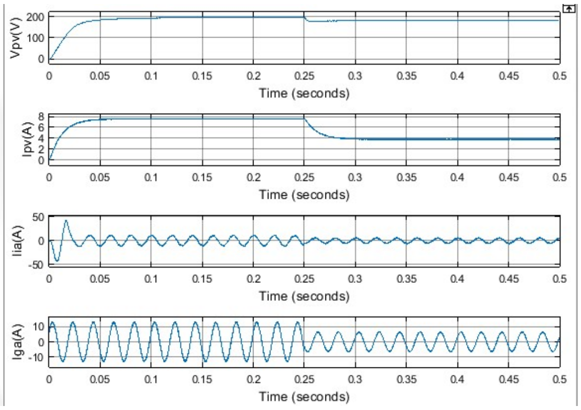


Fig. 3.7 Performance of the system under changing variable irradiance condition (a) PV voltage (VPV), PV current (IPV), phase „a‟ of converter and grid current under decreased solar irradiance

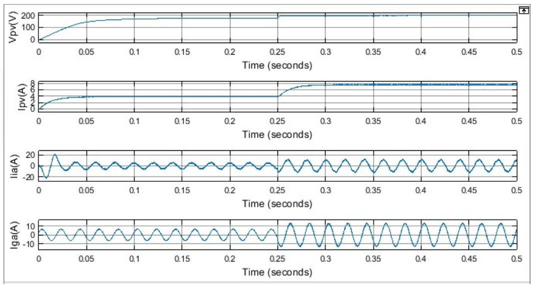
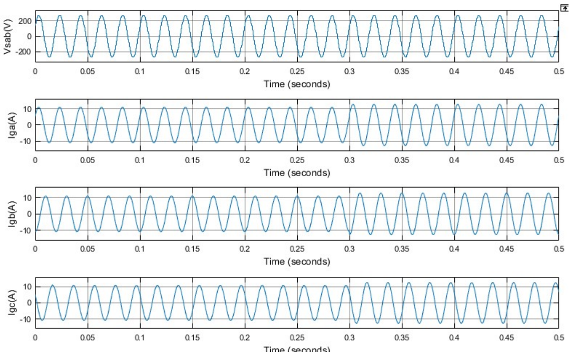
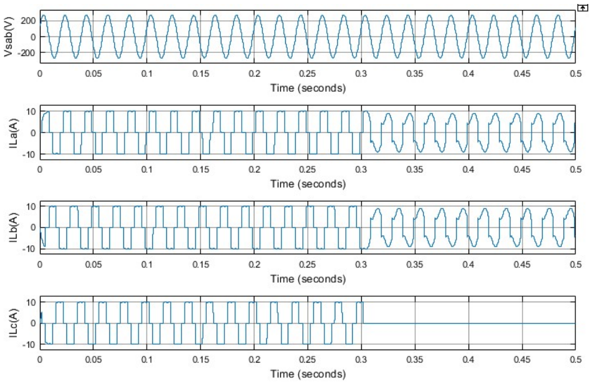


Fig. 3.8 Performance of the system under changing variable irradiance condition (b) PV voltage (VPV),PV current (IPV), phase „a‟ of converter and grid current under increased solar irradiance condition.

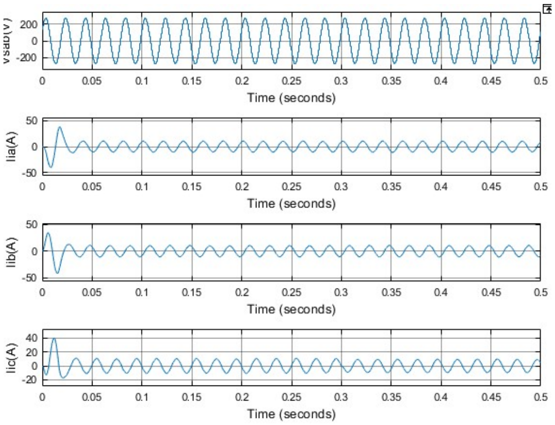
PROPOSED SIMULATION RESULTS:



3.9 Grid voltage , Grid current



3.10 Grid voltage ,Load current



3.11 Grid voltage, VSC current

V.CONCLUSION

In this study we offer a FONF-fed solar system with a fuzzy logic controller. Delivering active electricity to the load/grid and fixing current-related power quality issues at PCC are the twin goals of the grid-connected PV system that is governed by the FONF. Numerous power quality issues, such as harmonic distortion in grid current, reactive power demand of the load, and imbalanced load currents, have been resolved by the developed fuzzy logic control system. It has been demonstrated that the FONF+FLC control is suitable for altering the integrator power used in the notch filter and achieving an asymmetrical gain response curve, which is not possible with an integer order notch filter. In addition, this control reacts faster than a notch filter of integer order. The FONF controller's performance has been verified under both balanced and unbalanced load conditions, taking into account variations in sun irradiation. The FONF controller can maintain grid current at 3.2% THD, in accordance with the IEEE-519 standard for grid-connected PV systems, based on simulation findings.

VI.REFERENCES

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