

PERFORMANCE ANALYSIS OF I_d - I_q ACTIVE FILTER IN GRID INTERFACED WIND/PV HYBRID ENERGY SYSTEM

Nagendra K

Research Scholar, Department of EEE, SET, Jain University Karnataka -562112, India. Mobile: +91- 9538959386

Email: kbnagendra@gmail.com

N Krishnamurthy

Professor, Department of EEE, SET, Jain University Karnataka -562112, India.

Kamala N

Associate Professor, Department of EEE, SET, Jain University Karnataka -562112, India.

Raghu N

Trupti V.N

Research Scholars, Department of EEE, SET, Jain University Karnataka -562112, India.

Abstract: Present days the energy crisis is major threat in the country. Moreover the per capita energy plays a important role in growth of any nation. Due to industrialization and living standards the energy demands increasing day to day [1] & [2]. The existing fossil fuels which are used to generate energy to meet current energy demand and those are formed due depletion of biomass, living beings under earth from many years. So these sources will over within few years and not belongs to renewable sources. Researches started concentrating towards renewable energy sources (RES) to meet energy demand due to advantages of their abundant nature [3] & [4]. Among renewable energy sources the wind energy, photovoltaic (PV) are major contributors for energy generation from RES. RES outputs are not constant throughout the operation due to change in inputs like wind seep, temperature and irradiation. To maintain grid interfacing standards to connect these RES outputs, power electronic interface is used [5] & [6]. Power electronic devices will induce harmonics into network due to their nonlinear nature. So power quality as become major issue during connection RES to grid. The modeling and simulation of grid connected wind/PV energy system is implemented in this paper. I_p - I_q control is implemented to control active filter and RES is fed through it. Power quality performance has been studied using modeled system.

Keywords: Wind energy system, PV system, Power flow, Total harmonic distortion (THD) and Active filters.

1. Introduction

More nonlinear loads like electronic converters cause poor power quality in power systems. Harmonic currents due to nonlinear loads will

distort the voltage waveform and resulting into poor power quality with more THD at common coupling of all generating sources to utility grid. Both distorted electrical quantities like current and voltage will cause very poor quality at end users. Conventionally the passive filters are used to mitigate harmonics in interfacing network. The problem of passive filters will cause resonance with supply during different frequencies which are generated at output of RES due to variable environmental parameters. Implementation of active filter in power system is best solution compare to passive filter to mitigate harmonics and resulting into good quality power at end users. The sensing methods which are used in power networks are dynamic once and they sense existing power quality problems and operate to mitigate the same. They are mainly three types they are series, shunt and hybrid active power filters. Series filters are used to mitigate voltage qualities. Shunt filters are used to compensate reactive components, current harmonics and unbalanced conditions. Hybrid filters gives the result of both filters. Here the work is to implement I_p - I_q controlled active filter with series passive filter to get good responded output from RES fed filter interfaced with grid.

2. Modeling of wind/PV system

2.1 Wind turbine model

The kinetic energy from wind speed is converted to mechanical energy by the use of wind turbine. The output is connected to electrical generators to

generate electricity. The model of wind turbine system is done using the following equation and same is implemented by using SIMULINK. [7] [8] & [9]

$$P_m = C_p(\lambda, \beta) \frac{\rho A}{2} V_{wind}^3 \quad (1)$$

Where P_m is mechanical power output; C_p is Performance coefficient; C_q is the torque coefficient. The relation between C_p and C_q is written as:

$$C_q = \frac{C_p}{\lambda} \quad (2)$$

$$T = \frac{P_m}{\omega} = \frac{1}{2} \rho \pi R^3 C_q(\lambda, \beta) V_{wind}^2 \quad (3)$$

$$\lambda = \frac{R * \omega}{V_{wind}} \quad (4)$$

$$C_p(\lambda, \beta) = C_1 * \left(\frac{C_2}{\lambda_i} - C_3 * \beta + C_4 \right) * e^{-C_5} + C_6 \quad (5)$$

Where, $C_1=0.5176$, $C_2=116$, $C_3=0.4$, $C_4=5$, $C_5=21$ and $C_6=0.0068$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08 * \beta} - \frac{0.035}{\beta^3 + 1} \quad (6)$$

The Torque T is fed to PMSG to generate energy. By the use of boost converter, regulated DC output has been obtained.

2.2 PV model

By using basic equations of semiconductor theory the PV model has been implemented as follow: [10]

$$I = I_{pv,cell} - \frac{I_{o,cell} * \left[\exp\left(\frac{q * V}{a * k * T}\right) - 1 \right]}{I_d} \quad (7)$$

$$I_d = I_{o,cell} * \left\{ \exp\left[\frac{q * V}{A} * k * T\right] \right\} - 1 \quad (8)$$

$$I_o = \frac{I_{sc,n} + K_I * \Delta T}{\exp\left(\frac{(V_{oc,n} + K_V * \Delta T)}{a * V_t}\right) - 1} \quad (9)$$

Where, I_{pv} =Photovoltaic current, I_o =Saturation current of PV array, $V_t = (Ns*k*T)/q$ is thermal voltage of PV array consists of N_s cells connected in series. $I_{pv}=I_{pv,cell}*N_{pp}$, $I_o=I_{o,cel}*N_{pp}$ and $V=V_t*N_{ss}$ where N_{pp} is total array are in series and N_{ss} is total array are in parallel. By using these N_{ss} and N_{pp} the generated power level can be increased or decreased.

The above model is modeled using MATLAB/SIMULINK. The output is connected to one more boost converter to get regulated DC output. [11]

The regulated output of wind from wind and PV is connected to common DC link. Dc link is connected to active filter to interface RES with grid to feed power. [12] & [13]

3. Shunt active power filter

Implementation of active filter involves three steps. One is reference currents to be generated, second one is to design to compare the actual signals with reference signals to generate switching signals to control active filter inverter. Third stage is to implement inverter using IGBT switch to feed compensating currents to common coupling point in power network.

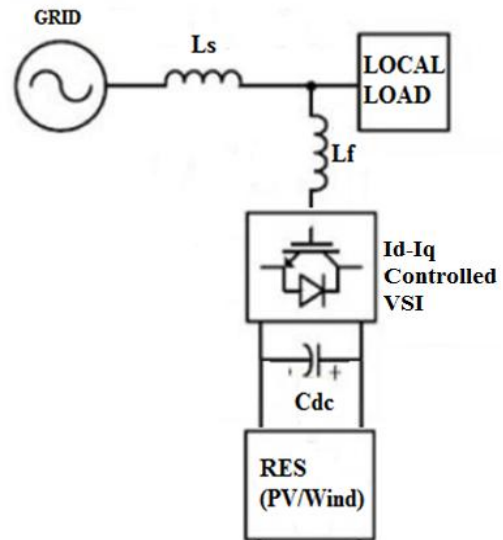


Fig. 1 Block diagram of shunt active filter [14]

Fig. 1 shows a typical active filter network. In this present work the shunt active filter is used to feed generated energy to grid and local load using Id-Iq technique.

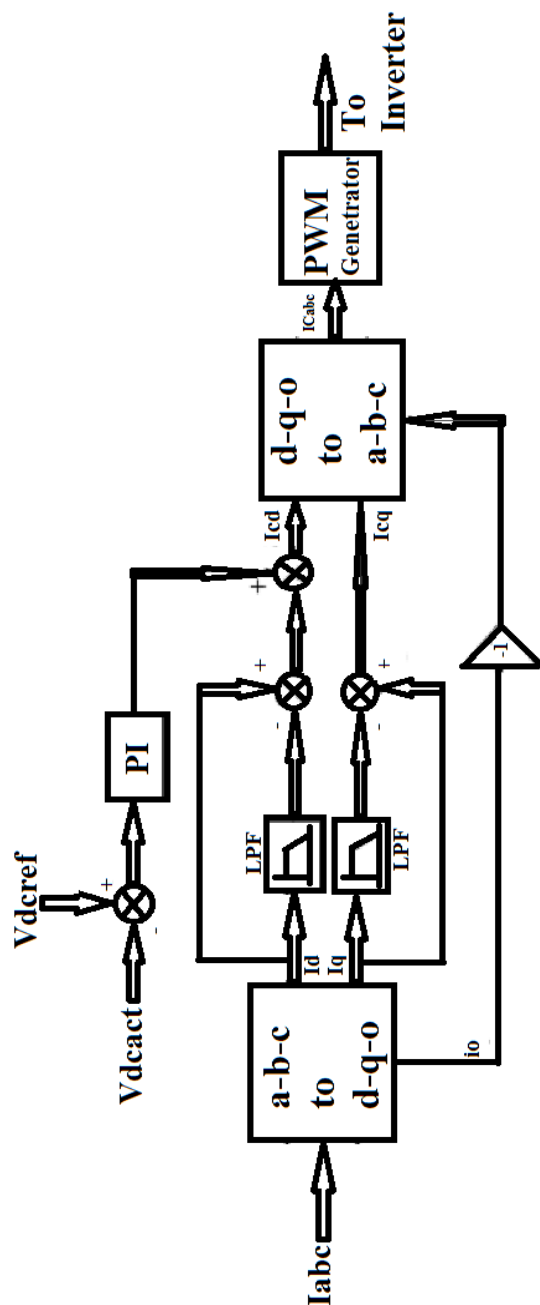


Fig. 2 Id-Iq Control strategy

In Fig. 2 the Id-Iq control is used to control inverter and it is simple gives yielding good results. Id-Iq method is used for extracting harmonics and it is simple technique with better response. [14]

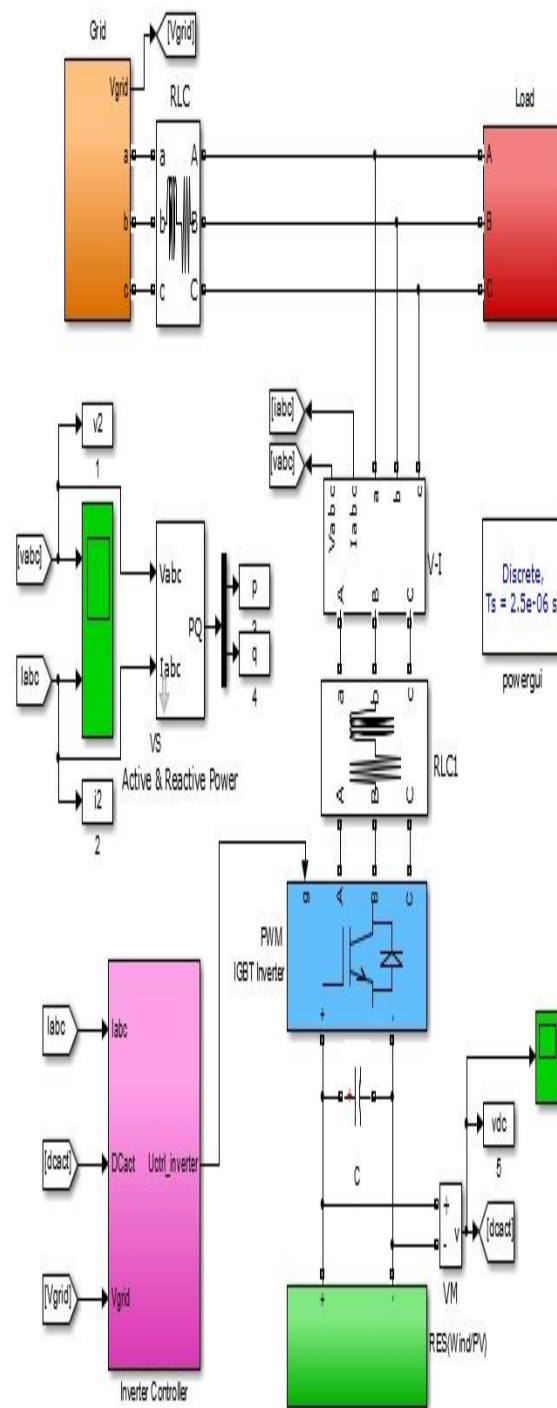


Fig. 3 Simulated diagram of Id-Iq controlled grid interface inverter with RES

In Fig. 3 simulated model is shown, the grid connected to local loads and the regulated RES energy is fed to the grid through PQ controlled inverter.

4. Results and discussions

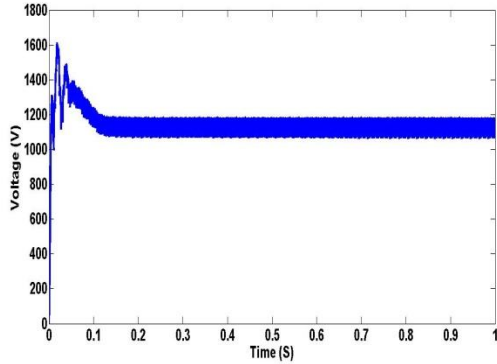


Fig. 4 DC link Voltage

In Fig. 4 the DC voltage throughout the simulation is constant during steady state and it is within voltage limit of 10% variation.

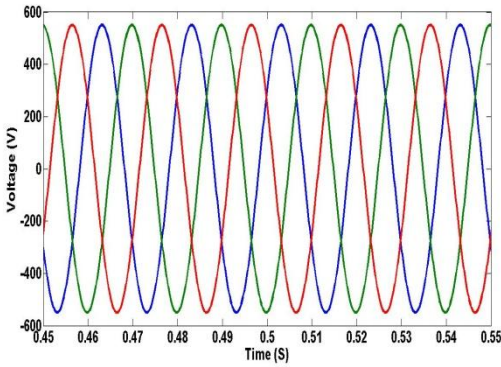


Fig. 5 Grid Voltage

Fig. 5 shows balanced voltage output waveform at grid. It is nearly sinusoidal in nature.

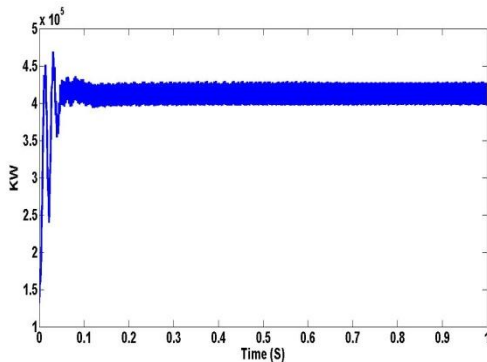


Fig. 6 Active Power

Fig. 6 shows active power from wind energy and PV energy sources. Both outputs are connected

using boost converter regulated output together produces around 400KW power from RES.

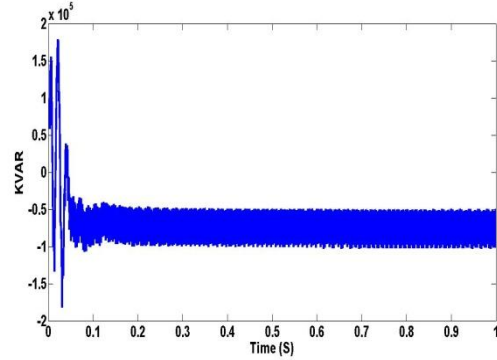


Fig. 7 Reactive Power

Fig. 7 shows reactive power consumed for boost converter components and DC link capacitor.

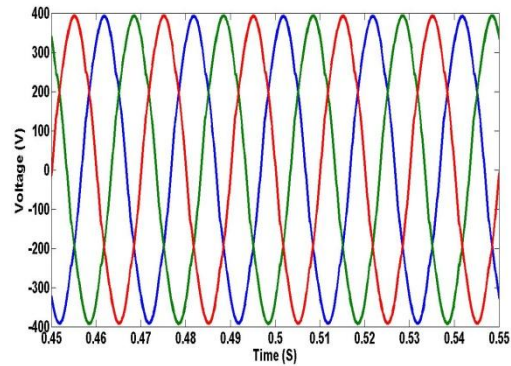


Fig. 8 Inverter Voltage

Fig. 8 shows voltage output waveform from inverter output the voltage quality has been increased due to filter and it is nearly sinusoidal wave.

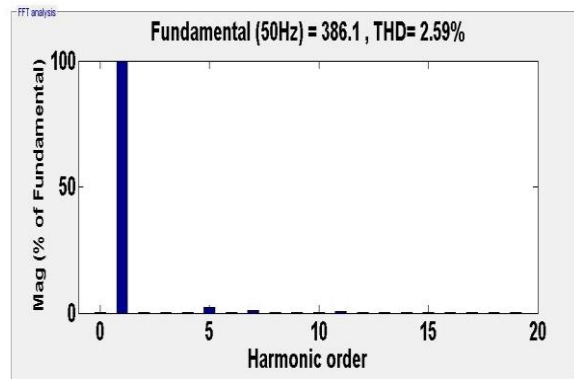


Fig. 9 Inverter Voltage THD

Fig. 9 shows THD analysis of output voltage at active filter and it is having value of 2.59% which results good poor power quality. This THD value is within the limit as mentioned in grid interfacing standard.

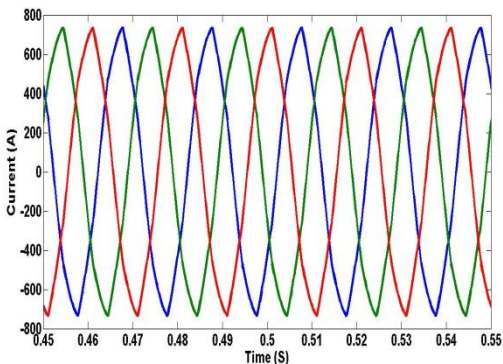


Fig. 10 Inverter current

The Fig. 10 shows current waveforms from inverter output and it is nearly sinusoidal wave due to filtering effect which intern improve voltage quality.

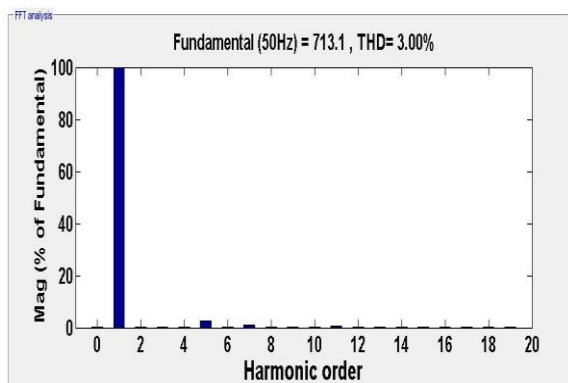


Fig. 11 Inverter Current THD

Fig. 11 shows THD analysis of output current at active filter and it is having value of 3.00% which results good poor power quality. This THD value is within the limit as mentioned in grid interfacing standard.

CONCLUSION

Model of DC shunted grid interfaced PV/wind system has been made using MATLAB/SIMULINK. I_d - I_q control strategy is implemented to control active filter tuned PI controllers. The THD value of voltage and current

generated from RES also measured and the results are well within the limits specified in IEEE <5%. The fuzzy controller can be used to study performance and improve power quality values.

REFERENCE

- [1] Akshay B. Zade, Asha Gaikwad, Ku. Prachi M. Jeevane, Ganesh Lohote.: *Hybrid Solar and Wind Power Generation with Grid Interconnection System for Improving Power Quality*. In: International Conference on Power Electronics, Intelligent Control and Energy Systems IEEE, 2016.
- [2] Md. Nurunnabi, N. K. Roy.: *Grid Connected Hybrid Power System Design Using HOMER*. In: 3rd International Conference on Advances in Electrical Engineering, December, IEEE, 2015.
- [3] Nagendra K, Krishnamurthy N, Raghu N, Trupti V.N.: *Analysis of AC-shunted grid interfaced hybrid Photovoltaic/wind energy system using dynamic Simulation model*. In: Journal of Electrical Engineering, Mar 31, 2016.
- [4] Sajib Chakraborty, S M Salim Reza, Wahidul Hasan.: *Design and Analysis of Hybrid Solar-Wind Energy System Using CUK & SEPIC Converters for Grid Connected Inverter Application*. In: IEEE PEDS, 2015.
- [5] Sara Ghaem Sigarchiana, Anders Malmquista, Torsten Franssona.: *Modeling and control strategy of a hybrid PV/Wind/Engine/Battery system to provide electricity and drinkable water for remote application*. In: ISES Solar World Congress, 2013, Energy Procedia 57 1401 – 1410, 2014.
- [6] Seddik Bacha, Damien Picault, Bruno Burger, Ion Etxeberria-Otadui, Joao Martins.: *Photovoltaics in Microgrids: An Overview of Grid Integration and Energy Management Aspects*. In: IEEE Industrial Electronics Magazine 03/ 9(1):33-46, 2015.
- [7] Alejandro Rolan, Alvaro Luna, Gerardo Vazquez and Gustavo Azevedo.: *Modeling of a Variable Speed Wind Turbine with a Permanent Magnet Synchronous Generator*. In: IEEE International Symposium on Industrial Electronics, 2009.
- [8] Mubashar Yaqoob Zargar, Mairaj-ud-Din Mufti, Shameem Ahmed Lone.: *Modelling and Control of Wind Solar Hybrid System Using Energy Storage System*. In: International Conference on Computing, Communication and Automation, IEEE, 2016.
- [9] Nagendra K, Krishnamurthy N, Raghu N, Sowjanya reddy, Sai Mahesh.: *Modeling and simulation study of permanent magnet synchronous generator based wind turbine system in micro grid applications*. In: Vol 1, issue 5, IJARIE, ISSN-(O)-2395-4396, 2016.
- [10] Sunil Patel, Nayana Prajapati.: *Grid Connected Solar and Wind Hybrid System*. In: International Journal for Innovative Research in Science & Technology, May 2016.

- [11] B. M Hasaneen and Adel A. Elbaset Mohammed.: *Design and Simulation of DC/DC Boost Converter*. In: IEEE Power System Conference, 2008.
- [12] Nagendra K, Vinatha U, Krishnamurthy N, Raghu N.: *Performance study of grid connected wind and photovoltaic hybrid energy system under variation of generation*. In: The Journal of CPRI, Vol. 10, No. 3, pp. 501-506, September 2014.
- [13] Nagendra K, Karthik J, Keerthi Rao C, Kumar Raja Pemmadi.: *Modeling simulation and performance study of gridconnected photovoltaic energy system*. In: International Journal of Research –Granthaalayah, Vol.5 (Iss.4: RACEEE), April, 2017.
- [14] Jayasankar V N, Vinatha U.: *Implementation of Adaptive Fuzzy Controller in a Grid Connected Wind-Solar Hybrid Energy System with Power Quality Improvement Features*. In: Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTS E), 2016.