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

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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]

\[ P_m = C_p(\lambda, \beta) \frac{\rho A}{2} V_{wind}^3 \]  

(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:

\[ C_q = \frac{C_p}{\lambda} \]  

(2)

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

(3)

\[ \lambda = \frac{R \star \omega}{V_{wind}} \]  

(4)

\[ C_p(\lambda, \beta) = C_1 * \left( \frac{C_2}{C_1} - C_3 * \beta + C_4 \right) * e_\lambda \]  

(5)

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

\[ \frac{1}{\lambda_i} = \frac{1}{\frac{1}{\lambda} + 0.08 \star \beta - \beta^3 + 1} \]  

(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]

\[ I = I_{pv,cell} \left[ \exp \left( \frac{q \star V}{d \star k \ast T} \right) - 1 \right] \]  

(7)

\[ I_d = I_{pv,cell} \left[ \exp \left( \frac{q \star V}{A \star k \ast T} \right) - 1 \right] \]  

(8)

\[ I_o = \frac{I_{dc,cell} + K_I \ast \Delta T}{\exp \left( \frac{V_{oc,cell} + K_I \ast \Delta T}{a \ast V_t} \right) - 1} \]  

(9)

Where, \( I_{pv} \)=Photovoltaic current, \( I_o \)=Saturation current of PV array, \( V_t = (N_s*k*T)/q \) is thermal voltage of PV array consists of \( N_s \) cells connected in series, \( I_{pv}=I_{pv,cell} \ast N_{pp} \), \( I_o=I_{dc,cell} \ast N_{pp} \) and \( V=V_t \ast N_s \) where \( N_{pp} \) is total array are in series and \( N_s \) is total array are in parallel. By using these \( N_{pp} \) and \( N_s \) 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]](image-url)
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.

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]

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

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

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 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_p-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.

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