Design of Shunt Active Power Filter for a Wind-Hydro Hybrid System Connected To Two Back To Back Converters with an Energy Storage Battery System

N Raju khandavalli[1], G V Rammohan[2]

[1]M.Tech Scholar, [2]Assistant Professor, Department of Electrical and electronics Engineering,

KIET-2, Korangi, Kakinada, A.P, India

ABSTRACT : *This paper presents the design of Shunt Active power filter and simplified control of hybrid system (wind –hydel) system connected to two back-to-back converters in which one is connected to hydel turbine and the other is connected to wind turbine system through squirrel cage induction generators (SCIG) feeding three phase loads in isolated locations. The main objective of this work is to provide a better control algorithm for the VSC and to achieve maximum power tracking (M.P.T) through rotor speed control of the wind turbine driven S.C.I.G under varying speeds at the machine side and to control the magnitude and frequency of the voltage at load side and to eliminate the ripple content in the wave forms and to create the system balanced. The system also ensures in sending the power generate by* $SCIG_w$ *is complete to the load through the load-side converter and remaining power be store into ESBS. And at the identical time if the required active power of the load is more than the total power generated by* $SCIG_w$ *and* $SCIG_h$*. Then the deficit power is supplied by the ESBS. Simulation models of the proposed hybrid system with SAPF and the simulation results are obtained in MATLAB using Simulink and Sim Power System set toolboxes, with different load condition at different wind conditions*

Keywords-*small-hydel, squirrel-cage induction generator (SCIG), MPT, Voltage Source Converter (VSC.), Shunt Active Power Filter (SAPF).*

1. INTRODUCTION

At present most of the countries are conscious of global counsel problems. The majority familiar difficulties is the pollution from burning fossil fuels while produce the energy. Inside to reduce these difficulties energy possessions like wind, hydel, solar, biomass etc. have got to be optimistic promote. Exploitation of wind energy resources are the high-speed rising and the majority talented re source amongst the possessions due to its economically variable nature. Surrounded by the nearby renewable energy sources, mini hydel and wind energy contain the ability to get more advantage with each other. For power generation by mini hydel or micro hydel over and above wind systems, the acquirement of squirrel cage induction generators (SCIGs) be added outstanding due to its variety of advantages [5].At this instant the wind-turbine machinery is been escalating its collection since fixed speed to the direction of variable speeds. The variable-speed machines include lots of advantages. These be cooperative in dipping the mechanical stresses and constructive as of improved efficiency [4]. Usual energy based power systems are generally work with the grouping of Battery to sense of balances the power outages in the structure. Further in excess by the casing of stand-alone system lots of problems are arising in maintaining the proper active and reactive power due to drop in voltage and frequency[8]. So, here a new and flexible battery-based controller is proposed to control voltage and frequency in the Wind Energy Conversion Systems (WECS). However, Maximum Power Tracking (MPT) shall not be satisfied by this battery-based system employed with SCIG operating at constant speeds [7]. In the proposed system, there are two modes of operation. Here the two modes explain about, when the active power generated is greater the load power, then how it will be transferred to battery and the second mode is intended for suppose, the necessary active power meant for the load is more than the power generated by the wind and hydel turbine then how the battery make available the remaining power to the load through the load-side converter and is shown in Fig.1. Here ain state of dropping the harmonics a recent approach has also been proposed with the design of the VSC based APF in addition to reduce the converter kVA rating considerably. This design approach is called the SAPF, and is based on the amplification of some selected harmonic current components of the VSC by the participation filter, plus the control system, which is specifically designed for this intention.

The projected SAPF has been implement going on the primary industrial VSC based APF for the elimination of 11th and 13th current harmonics of source side and load side converters feed from Medium Voltage (MV) Hybrid system.

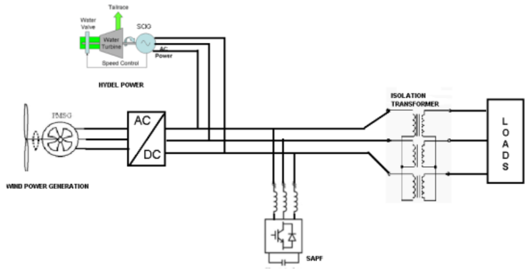


Fig. 1: Block diagram of Hybrid system

2. PRINCIPLE OF OPERATION

From the above shown Fig.1, the main purpose of the work is to design a shunt active power filter to eliminate the higher order harmonics and to provide a constant voltage to the load at constant frequency with the help of load-side converter. To improve the load-frequency and to make it constant, the additional active power should be transferred to the battery. Here, the design of the battery is such that it is capable of storing the excess active power and discharges back to the load at the time of power shortages [6]. At the same time the voltage is also set to be constant to balance the reactive power of the load by means of load side converter. In this work, to reduce the harmonics a VSC based APF is designed and a special control circuit is designed to generate the pulses to the VSC to reduce the harmonics [10].Again in order to achieve maximum power tracking (MPT) pitch angle controller was been used [9].As Pitch-angle controller with adjusting variable-speed wind turbines are gaining a lots of advantages these are mostly preferred. The pitch-angle reference, βref, is mainly controlled by three values called wind speed, Generator rotor speed and input generator power. Here, the calculated pitch angle will be controlled by the input generator power. The error signal in the generator power is sent to a PI controller and then the PI controller produces the reference pitch angle βref.There the new pitch-angle reference will be controlled by the input value of the generator power. The calculated reference power and generated power of the turbines are compared with each other and the error signal will be given to the PI controller. The output of the PI controller will produces the final reference value of pitch angle (βref) and will be given to the machine side converter.

3. MODELLING OF WIND-TURBINE AND HYDEL –TURBINE WITH SCIG'S

A wind turbine in Fig.2 is characterized by its power–speed characteristics [4]. For a horizontal turbine, the power produced, Pt, is

$$P = 0.5 \times A \times \rho \times C_p \times v^3 \qquad (1)$$

Where A = *Swept rotor area in* m^2

C_p = *Coefficient of power*

V^3 = *wind speed in m/s*

p = *Density of air in kg/*m^3

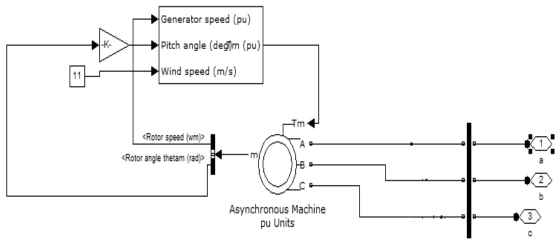


Fig.2 Simulink model of Wind Turbine

The power available in a flow of water depends its head and the discharge. The water powers a turbine, and its rotational movement is transferred through a shaft to an electric generator [9]. The power hydro generating unit in Fig.3 is given by

$$P_h = 9.81 \times 10^{-3} \times \eta_t \times \eta_g \times q \times h \qquad (2)$$

Where q = Flow of turbaned water,

η_t= Turbine efficiency,

η_g = Generator efficiency,

h = Water head.

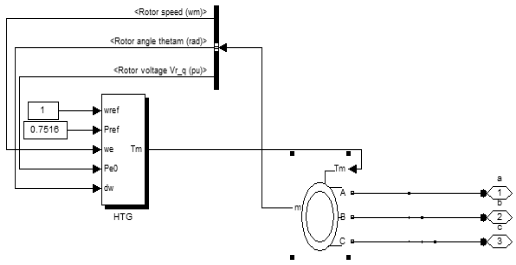


Fig. 3: Simulink model of Hydel turbine

4. SELECTION OF BATTERY

Lead acid batteries are used in many electrical systems to store or deliver energy. These are rechargeable and thevenin equivalent circuit is a simple way of demonstrating the behavior of battery voltage for small rating of hybrid renewable energy power generation.

5. MAXIMUM POWER POINT TRACKING:

In the proposed algorithm, the rotor speed (ω_{rw}) of $SCIG_w$ is determined from its rotor position (θ_{rw}).The tip speed ratio (λ_w) for a wind turbine of radius (r_w) and gear ratio η_w at a wind speed (v_w) of is defined as:

$$\lambda w = \omega_{rw}.\, r_w / \eta_w.v_w \qquad (3)$$

For MPT in the wind turbine generator system, the SCIGw should be operated at optimal tip speed ratio (**λ*w**).The tip-speed ratio determines the SCIG rotor set speed point for a given wind speed and the mechanical power generated at this speed lies on the maximum power lines of the turbine.For a horizontal turbine, the given flow chart is shown in fig.4 and the power produced, ***Pt***, is:

$$P_t = 0.5C_p(\lambda\omega, \beta).\rho.A.V_w^3 \qquad (4)$$

Where Cp =Coefficient of power,

p = Density of air,

A= Area of wind turbine and

Vw = Velocity of air.

β = Pitch angle

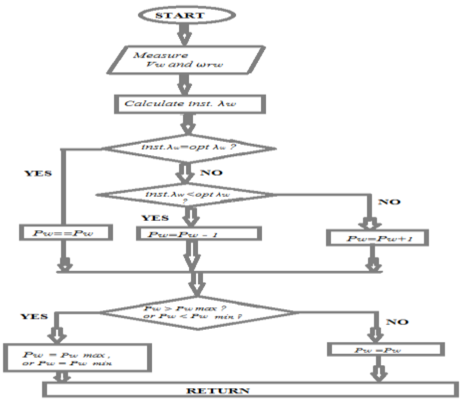


Fig 4 Flowchart for Maximum Power Tracking

6. GENERATION OF GATING SIGNALS TO CONVERTER

The rotor-speed error (ω_{rw} *error*) at the nth sampling instant as

$$\omega_{rw}\, error(n) = \omega^*_{rw}(n) - \omega_{rw}(n) \qquad (5)$$

This error is given to the Speed PI controller to get the reference q-axis SCIG w stator current is,

$$I^*_{qsw}(n) = I_{qsw}(n-1) + K_{p\omega}(\omega_{rw}\, error(n) - \omega_{rw}\, error(n-1)) + K_{i\omega}\, \omega_{rw}\, error(n). \qquad (6)$$

The reference d-axis SCIG w stator current (I^*_{dsw}) is determined from the rotor flux set point (ϕ^*_{drw}) at the nth sampling instant as

$$I^*_{dsw}(n) = \phi^*_{drw} / L_{mw} \qquad (7)$$

Where

L_{mw} = *magnetizing inductance of* $SCIG_w$

By d-q to abc transformation reference SCIG w stator currents are given by

$$i^*_{sw}a = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w) \qquad (8)$$

$$i^*_{sw}b = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w - 2\pi/3) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w - 2\pi/3) \qquad (9)$$

$$i^*_{sw}c = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w + 2\pi/3) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w + 2\pi/3). \qquad (10)$$

These references are compared with sensed ones to compute the error signals. By using of PWM technique to this error signals will be generated to the machine side VSC.

7. DESIGN OF SAPF

7.1 Estimation of Reference source current

It explains the necessary compensation standard of a shunt active power filter. It is proscribed to draw / supply a compensating current ic from / to the usefulness, so as to cancel the current harmonics on the AC side, and make the source current inside phase in the company of the source voltage**.** Figure.5. shows the different waveforms. Curve A is the load current waveform and curve B is the preferred mains current. Curve C shows the compensating current injects by means of the active filter containing all the harmonics, to build main current sinusoidal.

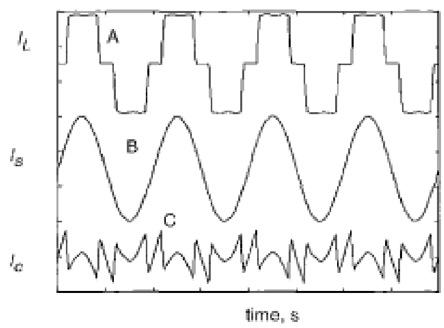


Fig 5 Shunt active power filter-Shapes of load, source and desired filter current waveforms

From Figure.5 the instantaneous currents can be written as

$$i_s(t) = i_l(t) - i_c(t) \qquad (11)$$

Source voltage is given by

$$v_s(t) = v_m \sin\omega t \qquad (12)$$

The peak value of the reference current I_{sp} be able to be expected through scheming the DC side capacitor voltage. Ideal compensation require the mains current to be sinusoidal as well as in phase with the source voltage, irrespective of the load current scenery. The desired source currents, after compensation, know how to give as

$I_{sa}^{*}=I_{sp}\sin\omega t$

$I_{sb}^{*}=I_{sp}\sin(\omega t-120^{0})$

$I_{sc}^{*}=I_{sp}\sin(\omega t+120^{0})$ (14)

7.2 Selection of L_c ,C_{dc} and V_{dcref}

The aspire of these apparatus is base on top of the following assumptions: (1) The AC source voltage is sinusoidal. (2)To design of L_c, the AC side line current distortion is unspecified to be 5%. . Permanent capacity of reactive power compensation of the active filter. The PWM converter is assumed to operate in the linear modulation mode (i.e.$0<m_a<1$**)** the amplitude modulation factor m_a is

$m_a=V_m(V_{dc}/2)$ (15)

Where $v_m=\sqrt{2}\ V_c$, and hence

$V_{dc} = 2\sqrt{2}\ V_{c1}$ for m_a=1.

The filter inductor L_c is also used to filter the ripples of the converter current, and hence the design of L_c is based on the principle of harmonic current

$I_{ch(mf\omega)=}V_{ch(mf\omega)/}m_f\omega L_c$ (16)

By solving (15), the value of $L_{c,}$ can be calculated .

The plan of the DC side capacitor is base on top of the principle of instantaneous power flow. the DC side capacitor C_{dc} can be found from equation

$$C_{dc} = \frac{\pi^{*} I_{clrated}}{\sqrt{3\omega V_{dc.p-p(max)}}} \quad (17)$$

8. SIMULINK OF HYBRID SYSTEM WITH SAPF AND PERFORMANCE PARAMETERS

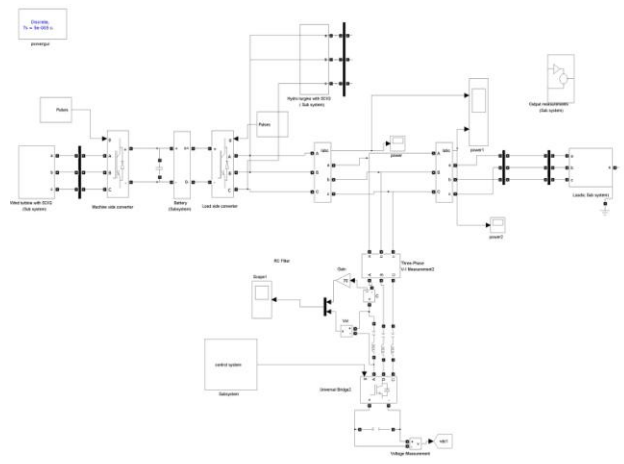
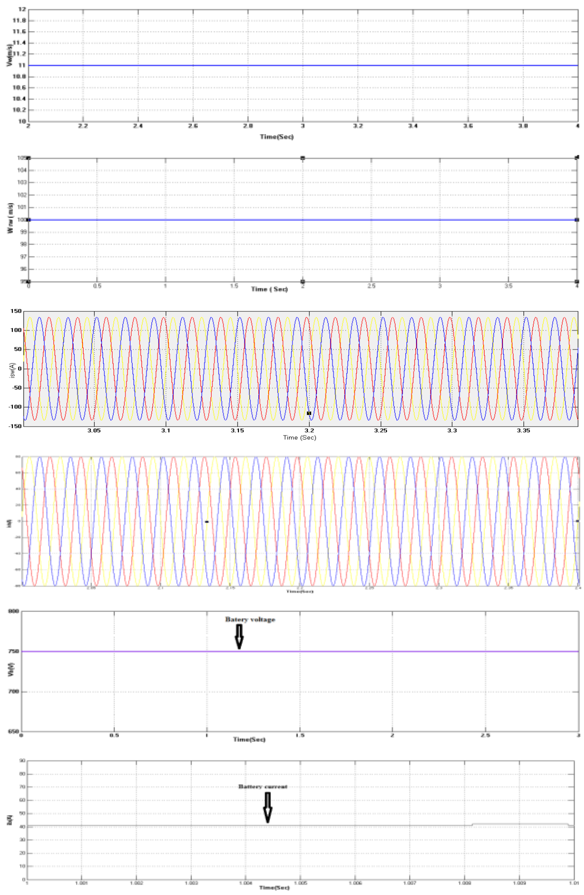
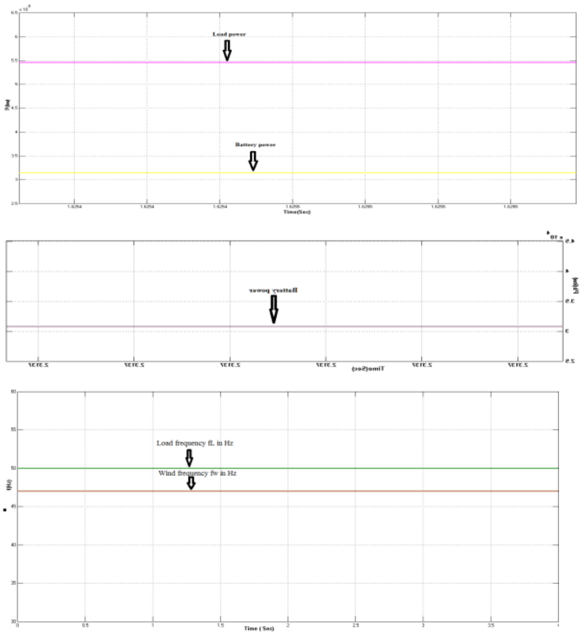
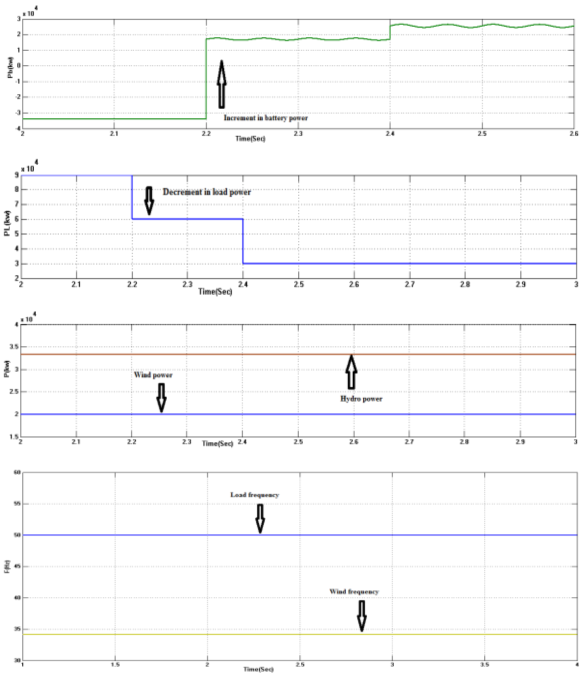


Fig.6: Simulation diagram of Hybrid system with SAPF

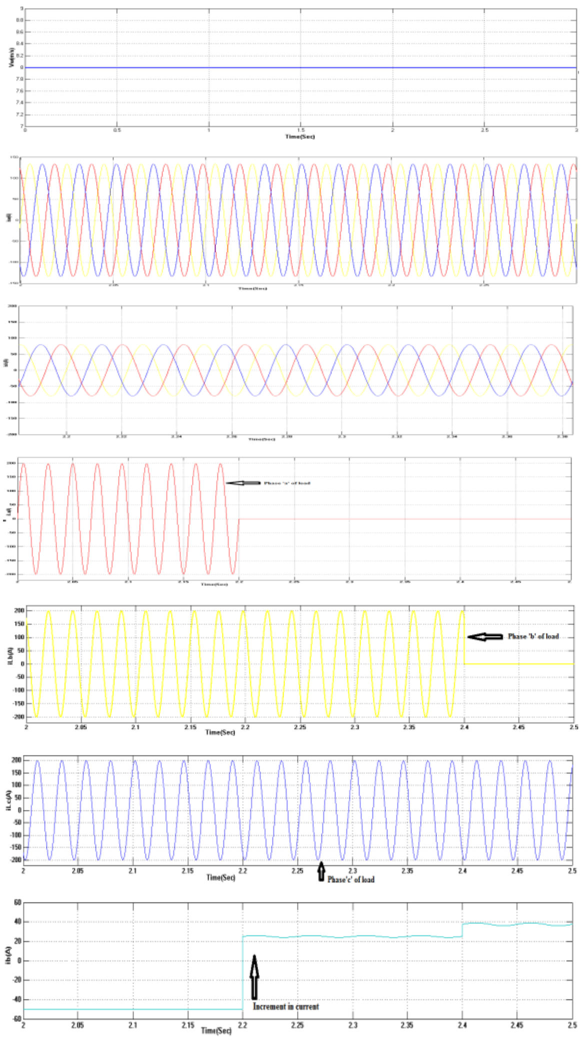
8.1 Performance of balanced three phase linear loads of 20kW and 10kVAR at wind speed of 11m/s







8.2 Performance of hybrid system with unbalanced loads



8.3 Performance of hybrid system with balanced /unbalanced nonlinear loads

In this case of Fig.8, the system is started with a three single phase diode bridge rectifier; every of 16 kW in addition to three single phase linear loads each of 5kw at wind speed of 10m/s.

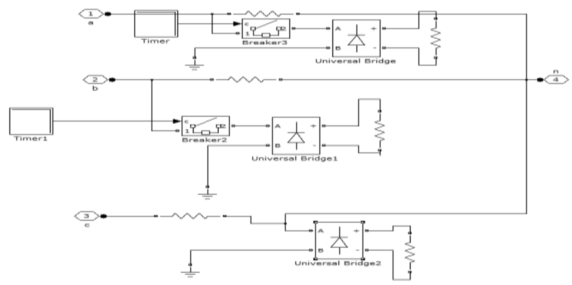
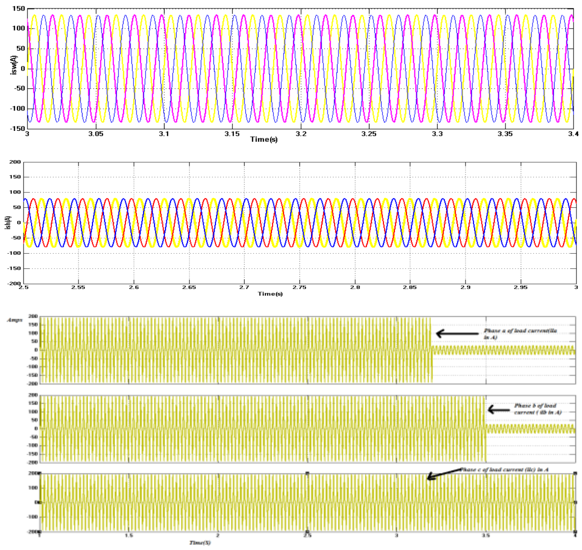
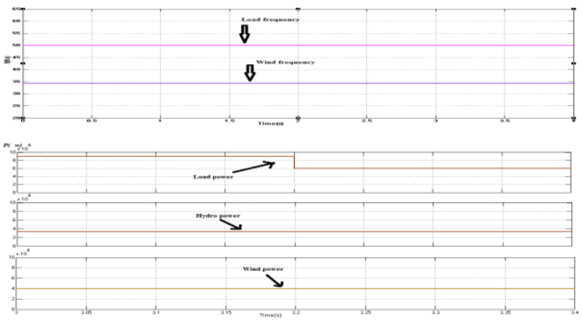


Fig.8: Simulink of balanced/unbalanced loads





8.4 Performance comparison and THD with and with out SAPF

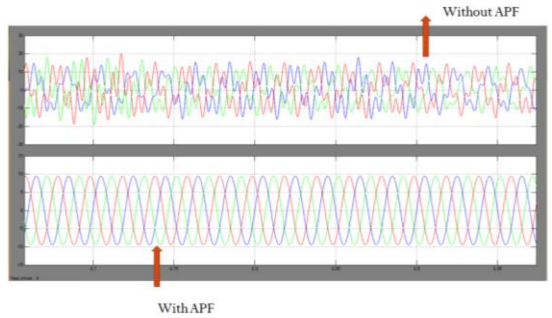


Figure 9 Load current waveforms with and with out SAPF

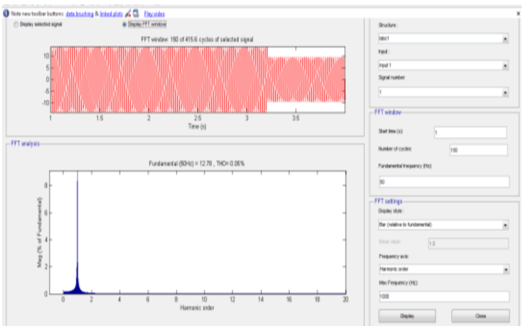


Figure 10 THD after using SAPF at Transformer primary side load currents

9. CONCLUSION

A three phase mini system of wind and hydel turbine associated to two squirrel cage induction generators is designed and modeled using MATLAB/SIMULINK. At this point, the pitch angle controller is provided by means of PI control method to maintain a constant voltage and frequency even with the change in load and a shunt active power filter is designed in such a way that all the higher order harmonics are eliminated and the load currents are perfectly balanced.

The system have been demonstrated in such a way that the proposed hybrid system performs adequately below different routine conditions by maintaining the constant voltage and frequency on load side by means of load side converter for different load circumstances at a variety of wind speed conditions ..

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