International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue-17
December 2017

Dynamic Voltage Control of Wind farm Using Thyristor Control Inductive Filtering Method

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Abstract:- *In the proposed concept fully tuned inductive filtering has been implemented; to enhance power quality thyristor controlled inductive filtering can be implemented. Nonlinear loads cause significant harmonic currents with poor input power factor(PF),which create serious problems at the power supply system. Traditionally, passive filters have been used to eliminate current harmonics of the supply network. Recently, thyristor-inductive filters (TIF).which contain several groups of passive filters, have been used to compensate reactive power. The compensation amount of TIF can be adjusted with the variation of load power. However, the parallel and the series resonance could occur between TIF and grid impedance a STATCOM model is also developed. simulation studies are carried out in the digsilent/power factory to illustrate the performance of the new TCS and TCR connected wind power system.the results indicate that the new approach can not only enhance the low-voltage ride-through capability of wind turbines. The simulink results are simulated by using MATLAB/SIMULINK software.*

Key words:- *Inductive Filtering Method ; STATCOM ; Grid connected system ; Wind Farm ; TCR and TSC.*

I. INTRODUCTION

In recent years the proportion of the grid connected wind farm in power system is increasing. In india for example, there are 5400 MW installed wind energy at the end of 2016.the influence of wind farms on the power system operation is becoming more and more important[1-3]. In wind power systems currently three main issues [4-6]; 1) Harmonics generated by voltage source converter(VSC)-based wind turbine generators flow through the wind farm transformer. than the harmonics will lead to a serious effect on the grid-connected transformer, such as loss,vibration , noise, etc.2) The output power variation caused by the wind speed will lead to the voltage fluctuation;3) The low voltage ride-through(LVRT) capability under the fault conditions.

The voltage stability problem, the reactive compensation devices are usually applied to compensate the reactive power that the wind farms are demanded. such as SVC,STATCOM and Capacitor banks[7].

Moreover, for the harmonic problem, the wind power system mainly adopt passive power filtering(PPF)method The passive power filtering method to reduce the harmonics and this harmonics are generated by the wind power system.

Unlike the traditional topology of grid connected wind power system with passive power filtering method and dynamic reactive compensation method.this paper proposed the thyristor control inductive filtering method [9]. This new method is used to improve the power quality of wind energy power systems. instead of STATCOM replace the TCS and TCR are reduced the total harmonic distortion(THD)

The total harmonic distortion is mathematical definition is:

$$THD = \frac{\sqrt{\sum_{n=2}^{2} I_{n\_rms}^{2}}}{I_{fund\_rms}} \quad (1)$$

Where In_rms = the rms current of the nth harmonic; Ifun_rms = the rms current of the fundamental frequency The amplitude of the harmonics are needed to calculate the THD, by using fourier analysis is:

$$V(t) = \frac{4}{\pi} \sum_{n=1,3,5}^{\infty} \frac{Sin(2n\pi ft)}{n} \quad (2)$$

In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. [8-9]. However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power

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and terminal voltage of an induction generator can be significantly affected [10-11].

Installation of wind energy conversion systems and rate of benefiting from the wind energy has greatly increased in last two decades. Especially in recent years, due to both a significant decrease in costs of wind power production and the technological developments in wind tribune production, contribution of wind energy in the electricity power production systems has increased rapidly [12-13]. The wind energy conversion system is a complex system that converts wind energy to mechanical energy and electric energy. Output power or moment of wind turbine is defined with basic factors such as wind speed, turbine shape, and dimension. The dynamic model of a wind turbine must contain parameters defining the behavior of wind turbine. With operation of so established wind turbine, it is possible to control the performance of wind turbine to obtain desired characteristics. In respect to wind power generation, turbines having different characteristics play important role in power generation

STATCOM can be effectively utilized to regulate voltage for one large rating motor or for a series of small induction motors starting simultaneously. Thyristor based svcloads draw large starting currents (5-6times) of the full rated current and may affect working of sensitive loads. Thyristor based systems were initially proposed for reactive power compensation and were used for voltage flicker reduction due to arc furnace loads. However, due to disadvantages of passive devices such as large size, fixed compensation, possibility of resonance etc., the use of new compensators such as STATCOM is growing to solve power quality problems. The use of STATCOM for solving power quality problems due to voltage sags, flickers, swell etc. has been suggested. The purpose of STATCOM is to provide efficient voltage regulation during short duration of thyristor based svc starting and thus prevent large voltage dips [14].

II. MAIN CIRCUIT TOPOLOGY OF THE NEW GRID CONNECTED WIND POWER SYSTEM

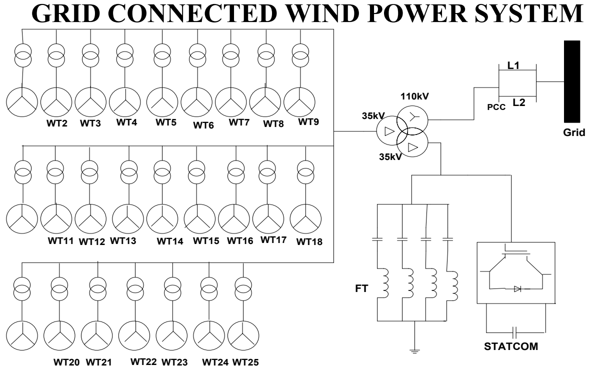

Fig.1. Main circuit topology of the grid connected wind power system

From above the fig.1 represents the main circuit topology of the grid connected wind energy power system. from above the figure 50MW wind farm contains of 25 double-fed induction generators(DFIG) and each double-fed induction generators has a rating of 2MW each wind turbine is connected to the wind farm internal 35kV cable net work via 2.2MVA; 0.69/35 kV transformer. the wind farm is connected to the grid connected transformer one of the secondary winding and the primary winding is connected to the grid and another winding is connected FT branches with STATCOM respectively. The point of common coupling(PCC) voltage should be regulated at the 110kV.

III. HARMONIC MODEL AND EQUIVALENT CIRCUIT MODEL

To study the filtering mechanism of the inductive method, the single-phase equivalent circuit model of the new grid connected transformer is established as shown in Fig.2, in which, the VSC-based wind turbine generators can be regarded as the voltage source. The harmonic current in the grid winding, secondary winding and filtering winding are the I1n, I2n and I3n respectively.

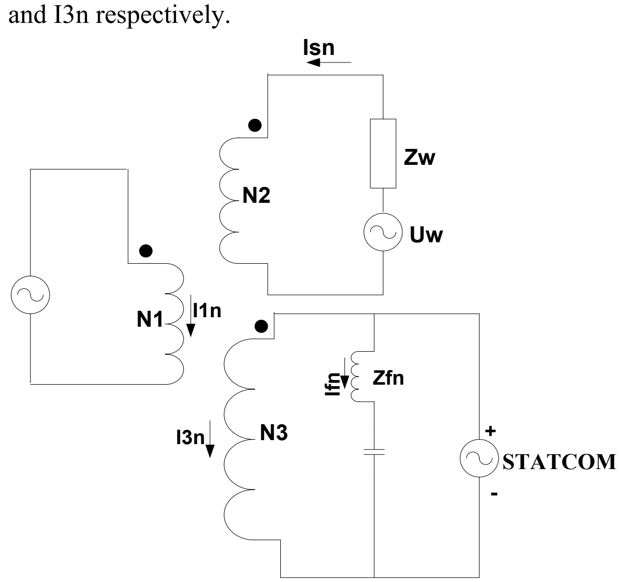

Fig.2. the single-phase equivalent-circuit model of the new grid connected transformer with FT branches

According to Fig.2, the equations of the harmonic current and voltage can be obtained:

$$\left.\begin{array}{l} U_{3n} = I_{fn}\angle_{fn} \\ I_{fn} = -I_{fn} \\ I_{2n} = I_{sn} \end{array}\right\} \quad (3)$$

Moreover, the magnetic-potential balance equation can be expressed as follows:

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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$$N_1 I_{1n} + N_2 I_{2n} + N_3 I_{3n} = 0 \tag{4}$$

Where N1, N2, N3 are the numbers of turns of the grid winding, the secondary winding and the filtering winding respectively. Then, according to the theory of the multi-winding transformer, the voltage transfer equations can be obtained:

$$\begin{aligned} U_{2n} - \frac{N_2}{N_1} U_{1n} &= -\frac{N_2}{N_1} Z_{21n} I_{1n} - \frac{N_3}{N_2} Z_{2n} I_{3n} \\ U_{2n} - \frac{N_2}{N_3} U_{3n} &= -\frac{N_3}{N_2} Z_{23n} I_{3n} - \frac{N_1}{N_2} Z_{2n} I_{1n} \end{aligned} \tag{5}$$

Where Z21n is the short-circuit impedance between the secondary winding and the primary winding; Z23n is the short-circuit impedance between the secondary winding and the filtering winding. They can be obtained by the transformer short-circuit test. Z2n is the equivalent impedance of the secondary winding and can be calculated by the short-circuit impedance, as shown in follows.

$$Z_{2n} = \frac{1}{2}\left(Z_{21n} + Z_{23n} - \frac{N_2^2}{N_3^2} Z_{32n}\right) \tag{6}$$

There are no harmonic current in the primary winding of the new grid connected transformer, thus we can obtain U1n≈0. According to the mathematic model, the current in the primary winding of the new grid connected transformer can be expressed as follows:

$$I_{1n} = -\frac{N_1 N_2 (Z_{3n} + Z_{fn})}{N_1^2 (Z_{3n} + Z_{fn}) + N_3^2 Z_{1n}} I_{sn} \tag{7}$$

From equation (7), it can be seen that as long as the Z3n and Z fn approximately equal or equal zero, the condition of the inductive filtering method can be satisfied. Thereby, there is no or few harmonic current in the grid (primary) winding, which reveals the filtering mechanism of the new grid connected transformer and related FT branches. Moreover, the special impedance design of the new grid connected transformer can make the equivalent impedance of the filtering winding (Z3n) approximately equal zero.

IV. REACTIVE POWER COMPENSATION CHARACTERISTIC

a) Phasor Analysis

In the new grid connected wind power system, FT branches and STATCOM can support voltage stability by compensating reactive power. According to the current distribution in the new grid connected transformer, as shown in Fig.3, we can obtain the phasor diagram of the secondary winding's voltage and current of the new grid connected transformer, as shown in Fig.4.

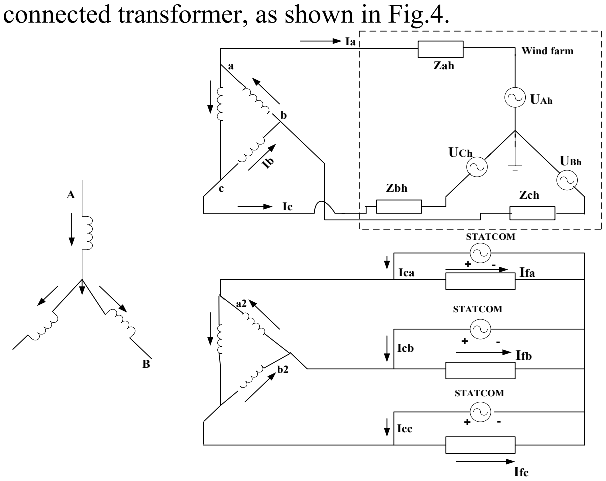

Fig.3. the current distribution of the new grid connected transformer

Taking the A-phase winding in Fig.4 as an example, assume the secondary winding current Ia lags the phase of the secondary winding voltage Ua by δ. Since the impedance of the FT branches is capacitive for the fundamental, when we carry out the FT branches and STATCOM, the phase current of the FT branches will lead 90º to the secondary winding voltage Ua. In addition, the currents Ica that the STATCOM injected lags the phase of the secondary winding voltage UA by 90º, also. Thus, we can obtain that the angle of the load-side I′ a (with the inductive filtering method and STATCOM) lags the secondary winding voltage Ua is smaller than δ. Hence, it is known that the FT branches and STACOM have reactive power compensation ability in the secondary winding, which means the FT branches and STATCOM can improve the power quality of the wind farms.

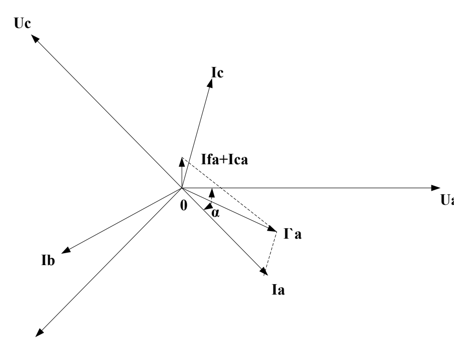

Fig.4 Phasor diagram of the voltage and current of the secondary winding

b) Control Scheme of STATCOM

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e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue-17
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The STATCOM and its controller are shown in Fig.5. It connects the filtering winding and can improve transient stability of power grid (Vac).

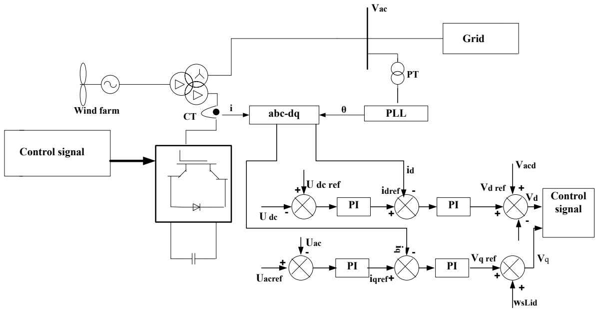


Fig.5. Schematic diagram of STATCOM controller

The STATCOM regulate voltage of the grid winding of the new grid connected transformer by controlling the reactive power injected into or absorbed from the power grid. In the Fig.5, an outer regulation loop contains an ac voltage regulator and a dc voltage regulator, while an inner regulation loop contains a current regulator. The control signal of STATCOM (e.g. Vd, Vq) can be obtained by the regulator loop and they are usually used by the PWM module to generate the pulse signals to drive IGBT of the STATCOM.

The objective of the STATCOM is primarily to keep the ac voltage constant. During the normal conditions, the grid voltage is stability and the reactive power flow from or to STATCOM is approximately zero. When the grid is under fault conditions, The STATCOM will inject amount of reactive power for the system instantly. Hence, this voltage control strategy reacts immediately to a sudden voltage variation and is well-suitable for fault condition operation in the grid connected wind power system.

V. MATLAB/SIMULINK RESULTS

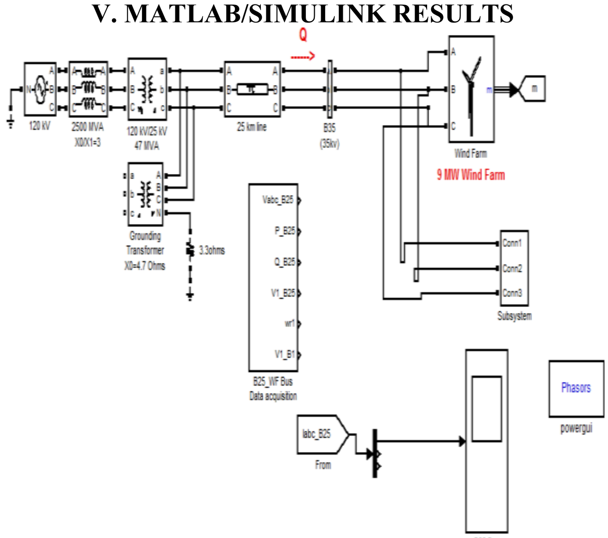
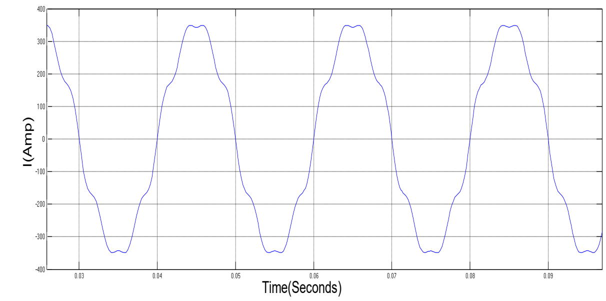
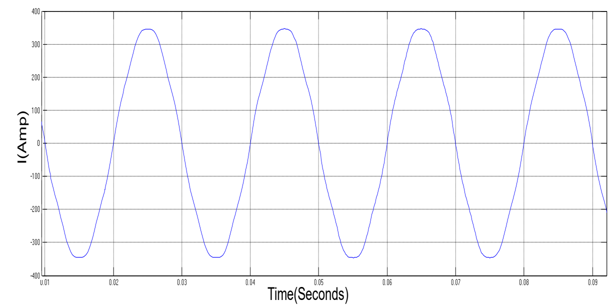


Fig.6 MATLAB/SIMULINK circuit of the grid connected wind power system



(a)



(b)

Fig.7. Current in the grid winding of the new grid-connected transformer. (a) Without inductive filtering method. (b) With inductive filtering method

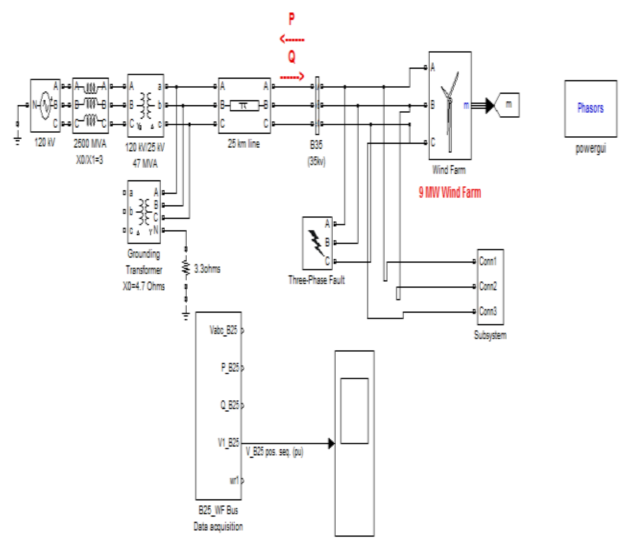
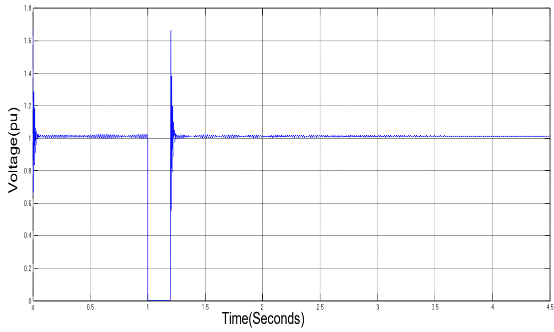
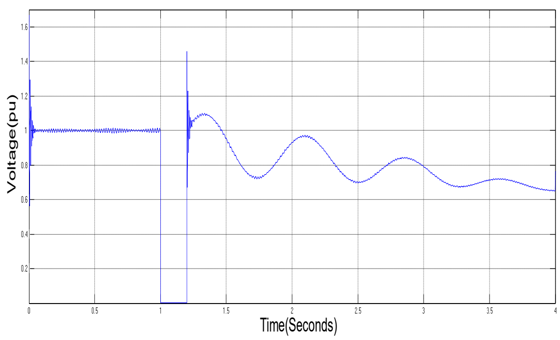


Fig.8 MATLAB/SIMULINK circuit of the grid connected wind power system with and without STATCOM



(a)



(b)

Fig.9. Magnitudes of the voltage at the PCC (a) with and (b) without STATCOM

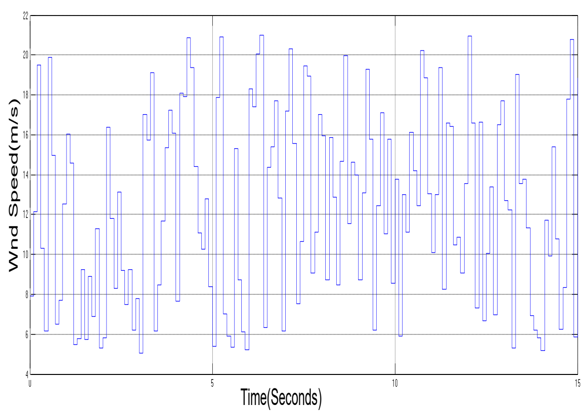


Fig.10. Wind speed vs. time for the wind farm

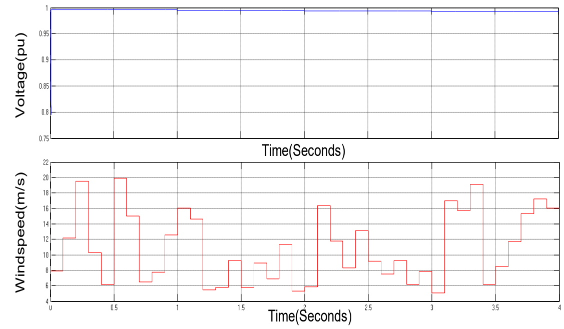


Fig.11. Magnitudes of the voltage at the PCC with and STATCOM

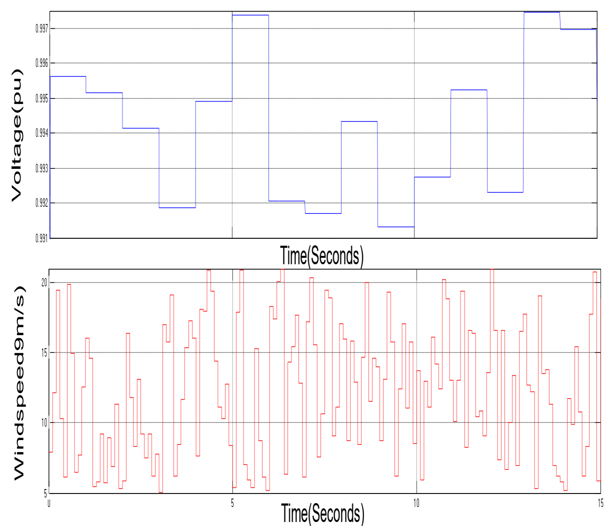


Fig.11.1 Magnitude of the voltage at the PCC without STATCOM

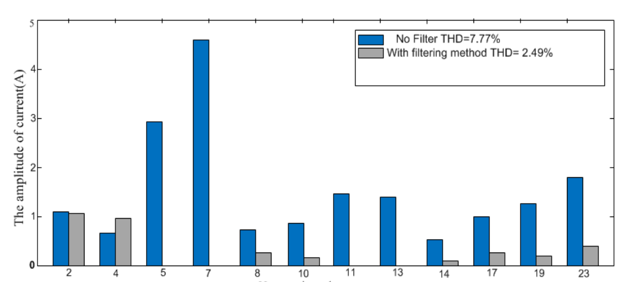


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Fig.12. FFT results on the current waveform of with and without inductive filter method

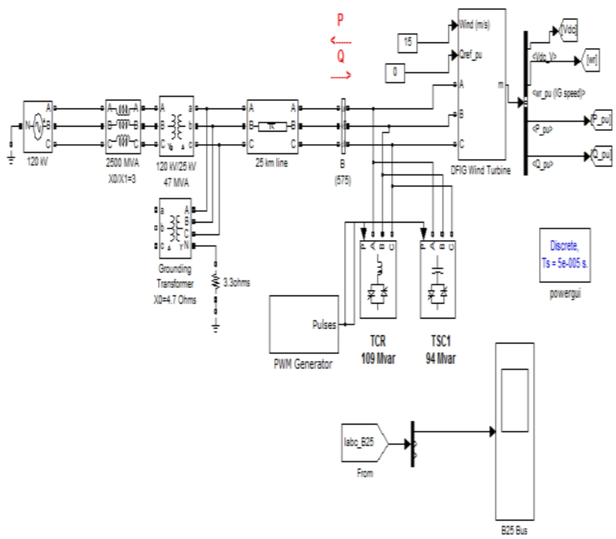

Fig.13 MATLAB/SIMULINK circuit of the grid connected wind form with TCR and TSC inductive filters

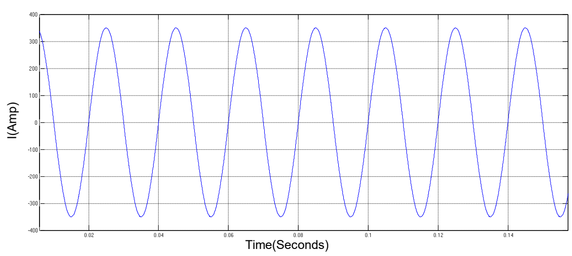

Fig.14 Output waveform of the inductive filtering TCR and TSC method

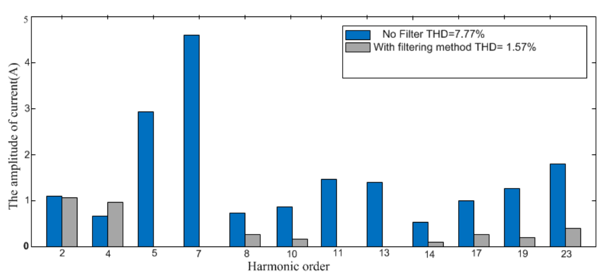

Fig.15 THD plot of the inductive filtering TCR and TSC method

VI. CONCLUSION

A model of wind frame thyristor based TCR and TCS controller has been developed using Simulink tool of standard MATLAB software. To propose with thyristor TCR and TCS controller of voltage dip with and without STATCOM controller. This dip is very large and it may affect the functioning of other sensitive equipment connected at PCC Model of STATCOM system applied in shunt configuration has been developed The STATCOM control utilizes two PI controllers for regulating DC link voltage and also the ac terminal voltage at PCC. When the wind speed varies in a large range. Moreover, voltage in case of the grid fault, and therefore, enhanced the low-voltage ride through capability of the wind farm.The operation of the control system developed for theSTATCOM in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the system, thus it gives an opportunity to enhance the utilization factor of transmission line.

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