Artificial Neural Network to Control the Grid Integration of Solar Photovoltaic and Wind Systems

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***Abstract*—**Renewable Energy Sources (RES) play an active role in standing against global warming and reduction of dependency on conventional energy sources. So in this project, the combination of solar (PV) and wind system is used. It consists of boost converter, three phase inverter, DFIG and solar PV system and wind turbine. For solar PV system Maximum Power Point Tracking (MPPT) controller is implemented to track the maximum power. From solar PV system, the output voltage is given to the boost converter and it is connected to inverter. Output of inverter is connected to grid. The pitch angle controller is used for wind turbine because to accelerate wind turbine faster and connected to reduce harmonics, increase the efficiency and performance of the system.

Keywords*—PV panel, Doubly Fed Induction Generator (DFIG), Wind energy conversion system (WECS), Rotor Side Control (RSC), Grid Side Control (GSC), Artificial Neural Network (ANN), %THD.*

I. INTRODUCTION

Renewable Energy Sources (RES) are solar (PV) and wind energy systems as input sources. As name we said these sources are regenerated, i.e., supply is unlimited also called as “In-exhaustible sources of energy” because from them generate indefinite energy. These sources constitutes energy from sun, energy from wind, flowing of water, ocean waves.etc. Renewable energy source are non-losting sources, because environment is non-lost.

In this project using solar and wind energy system. Integrating the solar and wind systems [1], to reduce the need of fossil fuel leading to increase in the sustainability of the power supply. In today’s world increasing the population, then need of electricity increases. It causes to decrease non renewable energy sources like coal, water, etc. Integration of RES is probably the biggest thrust for a smart grid deployment in India.

Solar and wind energy sources are crucial and primary factors of a cleaner and greener energy future. Smart Grid (SG) superior capability of introducing new sources of energy to the grid clearly signifies the more distributed generation can be integrated into it.

Various advantages of solar is pollution free, it is directly converted to electricity from sun light. From solar getting DC voltage it is given to the input of boost converter to boosting voltage. DC is converted into AC by using inverter and it is fed to grid. From wind directly getting AC voltage it is directly connected to grid.

The double fed Induction generator is used in wind systems, to produce the constant Amplitude and frequency even at varying wind speed. It has variable speed constant frequency operation. It allows a speed range of 30% around the synchronous speed [2].

Artificial Neural Network control technique [3] is used at the output of inverter to reduce the harmonics; it leads to increase the efficiency and performance of the system.

In this paper, the performance of an ANN to control the grid integration of solar and wind system is analyzed. The complete system is stimulated in MATLAB/Simulink.

The paper comprised following parts they are, the system introduction is covered in section I, followed by system description in section II, in section III system modeling is presented, in section IV ANN modeling presented and in section V simulation results and total harmonic distortion is presented. In last concludes the paper in section VI.

II. SYSTEM DESCRIPTION

The block diagram of proposed system is shown in figure 1.

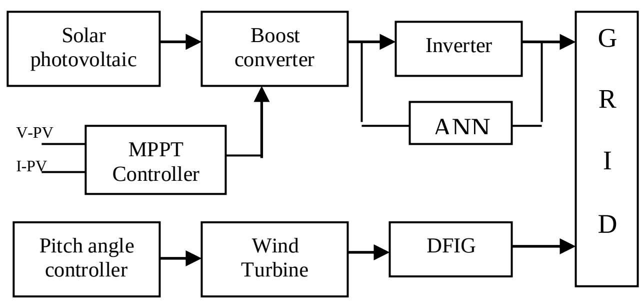

Figure1: Block diagram for proposed system

It consists of mainly three parts: 1) Solar PV system, 2) Wind turbine and 3) ANN controller.

1) Solar PV system

The equivalent circuit of a solar cell is shown in figure 2 [4]. By using Photovoltaic effect, the light energy of the sun is directly converted to electricity in PV system. The PV cell current is controlled by using the temperature and irradiation. The current is produced is high by increasing irradiation.

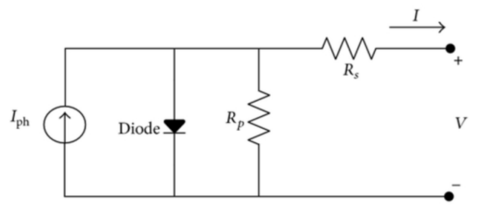

Figure 2: One diode model of solar cell

The short circuit current of I_{sc} is given by

$$I_{sc} = I = I_s - I_o\left(e^{(q(V+IRsc)/mkt)} - 1\right)$$

Where Io is the reverse bias saturation current, q is electron charge, m is the diode ideality factor, k is the Boltzmann's constant, and T is the cell temperature.

The series resistance is small and negligible, the open circuit voltage V_{oc} is given by:

$$V = V_{oc} = (mkt/q)\ln(1+(I_{sc}/I_o)) \quad \text{For } V = 0$$

The output power is given by:

$$P = V\left[I_{sc} - I_o(e^{(qv/mkt)} - 1\right)$$

1.1. MPPT Algorithm

Maximum Power Point Tracking control technique is used to track the maximum power. Here using Perturb and Observe method is used. Only voltage is sensed by using P & O algorithm. In this method power output system is checked by varying the V_s.

If voltage is increases then power is increases and also duty cycle (δ), otherwise start decreasing duty cycle, decreases voltage. If power is increases, duty cycle decreases. These steps continued till the power point reached [5]. The solar output voltage is connected to the boost converter.

1.2. DC- DC Converter

DC-DC Converter is also called as Boost Converter, is used for purpose of increasing the voltage. To maintain the constant output voltage the switching pulses are given by MPPT controller. The block diagram of boost converter shown in figure 3.

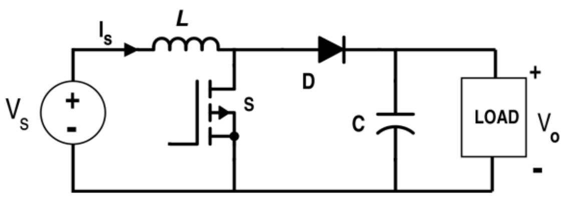

Figure 3: Block diagram of DC-DC converter

1.3. DC-AC Converter

DC-AC Converter is also called as an Inverter. It converts the Dc voltage into AC voltage. In this project three phase inverter is used. The block diagram of three phase inverter shown in figure 4.

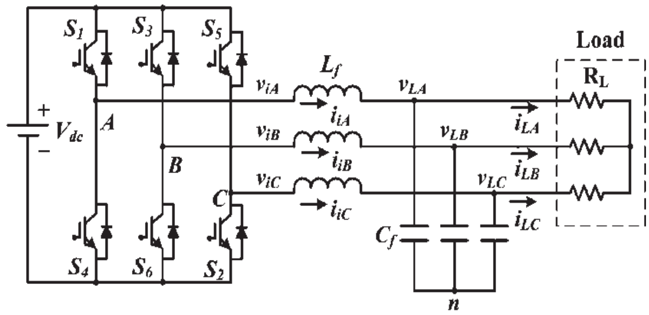

Figure 4: Block diagram of three phse inverter

III. WIND TURBINE MODELLING

Wind is air flow. When generation exceeds demanded load, generation must be reduced by controlling the pitch angle of blades. If generation is not enough to supply the load, a load shedding mechanism must be employed. Standalone operation requirements imply Wind Turbine (WT) must have active control through aerodynamic control and power electronics converters control [6].

These requirements based on Variable speed generators and pitch control. The DFIG arises as an attractive option, this is the dominant technology. Indirect stator oriented vector control scheme is used to provide constant voltage and frequency for variation of both load and wind speed.

Wind Turbine operates on a simple principle. The energy in the wind turns two (or) three propeller like blades around rotor. The rotor is connected to the shaft, which spins a generator to create electricity.

The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back to back voltage source converter that controls both the rotor and the grid currents. The DFIG rotors are typically wound with two to three times of the number of turns of the stator.

The DFIG block is taken from MATLAB library browser. This built by based on following modeling.

The generalized mechanical equation of the wind turbine

$$Js(dW_r/dt) + B_s\omega_r = T_m - T_e$$

Where, Js is the inertia of the shaft, Bs is friction coefficient, Tm is the torque with wind origin, T_e is the electromagnetic torque produced by the generator.

The generated torque is given by

$$T_m = P_m/\omega_m$$

Here P_m is the mechanical power,

$$P_m = 0.5\rho A C_p(\lambda,\beta)V^3$$

Where ρ is the density, A is the swept area, C_p is the coefficient of performance, λ is the Tip speed ratio.

$$\lambda = (\omega_m R/V^3)$$

Electromagnetic torque is expressed as

$$Te_m = Pm(I_{rd}\, I_{sq} - I_{rq}\, I_{sd})$$

The active power and reactive power taken by the machine can be represented by the following equations.

$$P_s = (3/2)(V_{ds}I_{ds} + V_{qs}I_{qs})$$

$$Q_s = (3/2)(V_{ds}I_{ds} - V_{qs}I_{qs})$$

dq transformation mathematical modeling

$$V_d = (2/3)(V_a{*}\sin\omega t + V_b{*}\sin(\omega t-(2\pi/3))+V_c{*}\sin(\omega t+(2\pi/3)))$$

$$V_q = (2/3)(V_a{*}\cos\omega t + V_b{*}\cos(\omega t-(2\pi/3))+V_c{*}\cos(\omega t-(2\pi/3)))$$

$$V_o = (1/3)(V_a+V_b+V_c)$$

IV. ARTIFICIAL NEURAL NETWORK CONTROL TECHNIQUE

Artificial Neural Network is an interconnected group of nodes, inspired by a simplification of neurons in a brain. Here, each circular node represents an artificial neuron and an arrow represents a connection from the output of one artificial neuron to the input of other [7]. The structure of artificial neural network is shown in figure5.

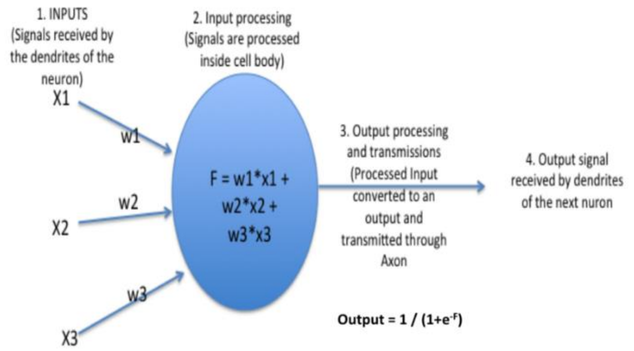

Figure 5: Artificial Neural Network structure

Here X1,X2 and X3 are inputs, W1,W2 and W3 are strength of the input signal.

$H_1 = (X_1{*}W_1) + (X_2{*}W_2) + B_1$

$H_2 = (X1{*}W3) + (X2{*}W4) + B2$

Activation Function at H_1 ⟶ $1/(1+ e^{-H1})$

Activation Function at H2 ⟶ $1/(1+e^{-H2})$

$Y_1 = (\text{Out } H_1{*}W_5) + (\text{Out } H_2{*}W_6) + b1$

$Y_2 = (\text{Out } H_1{*}W_7) + (\text{Out } H_2{*}W_8) + b2$

Total error formula: $e_{total} = \Sigma(1/2)(\text{Target} - \text{output})^2$

In this paper, ANN controller is used to decrease the harmonics and improve the performance of the system. It is connected at output of the inverter.

V. SIMULATION RESULTS

The Simulation diagram of Artificial Neural Network (ANN) is to control the grid integration of solar photovoltaic and wind systems shown in figure 6.

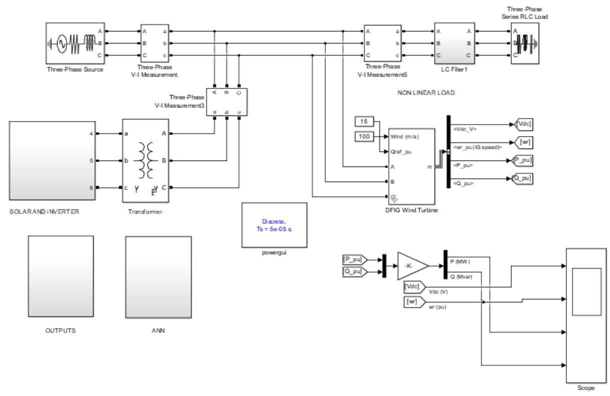

Figure 6: Simulink model of Grid integration with ANN controller

The solar and wind sources act as input sources and integrated to the grid. PV is used to generate the DC

voltage; in order to increase the voltage boost converter is used. Output voltage of boost converter is converted into AC by using inverter and it is connected to grid at 50Hz frequency.

Wind system is used to generate AC voltage and it is connected to grid through DFIG. Solar output voltage waveform is shown in figure 7. The solar output voltage is approximately 400volts.

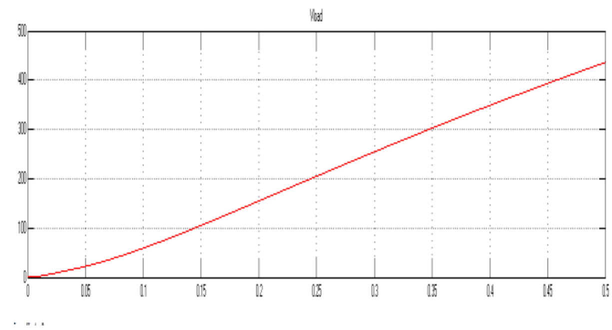

Figure 7: Output volatge of PV

This voltage is increased up to 430volts approximately by using boost converter. The output of boost voltage is shown in figure 8.

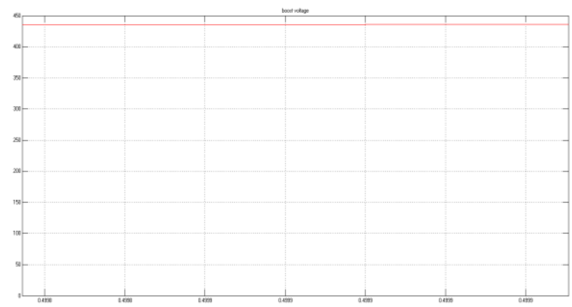

Figure 8: Output volatge of Boost converter

Three phase source voltage waveforms are shown in figure 9.

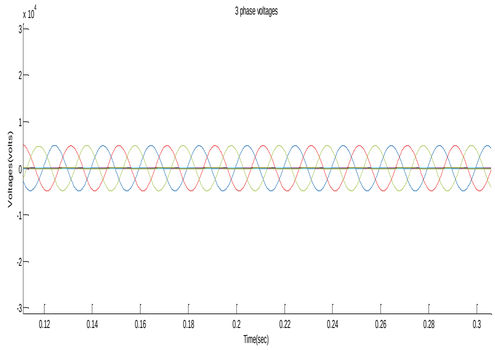

Figure 9: Three phase source voltage waveforms

Three phase load currents, three phase source currents and load voltage of output waveforms are shown in figure 10.

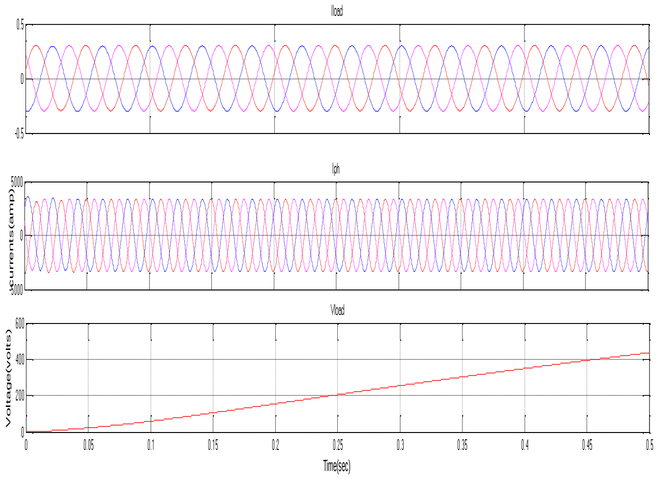

Figure 10: Three phase load currents, phase currents and load voltage waveforms

The performance of the system increased by reducing the harmonics. The percentage of Total Harmonics Distortion (%THD) is 1.07%.

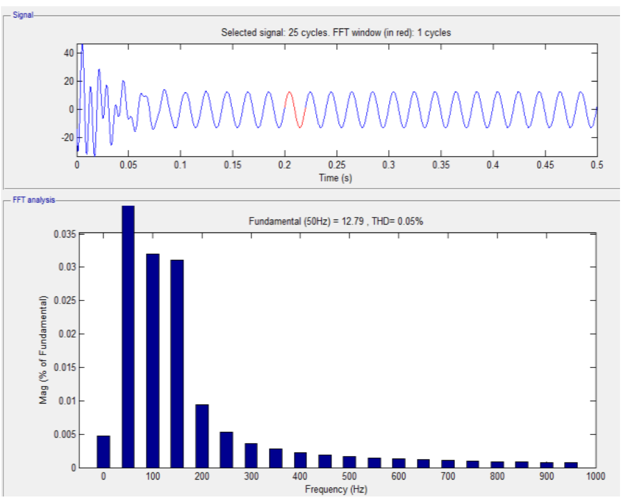

Figure 11: Total Harmonic Distortion of three phase currents

V. CONCLUSION

The solar PV and wind systems are integrated to the grid. Artificial Neural Network (ANN) is controlled the grid integration of solar and wind systems. Results improved the efficiency, performance of the system and reduce the harmonics by using the ANN controller. The Total harmonic distortion is 1.07%.

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