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# Design and Simulation of DFIG based Wind Energy System using AI EMS

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***Abstract: Renewable energy sources are considered to be an unpredictable resource especially in wind turbines; rapid variation in wind speeds cause power fluctuations leads to interrupt the power system stability during the high-level power operation. To overcome these issue energy storage systems such as Battery storage is added to balance the grid and helps to balance the generated power and the power demand. The battery system is also used to mitigate the power fluctuations and helps to give more power to balance the load requirement. The proposed (EMS) Energy Management System integrates with the Artificial Neural Network for operation of both battery and wind system depending upon the demand need. In the case of the battery management system, the intelligent controllers help to control the State of Charge (SoC) limits of the battery to make sure the required time of charging and discharging. The proposed Artificial Intelligent Controller acts as an Energy Management System and Battery Management System as well as it is used for power balance generation and load also efficiently mitigating the voltage fluctuation during variation in the load. MATLAB is used for the simulation process since it contains the features of Artificial Intelligence which can in turn function as switching device.***
***Keywords: Renewable energy sources, Battery Storage, Energy management system, State of charge, Artificial neural network etc.***

## I. INTRODUCTION

Existing models of micro generation systems with integrated lead–acid battery storage are combined with a battery lifetime algorithm to evaluate and predict suitable sized lead–acid battery storage for onsite energy capture. Three onsite generation portfolios are considered: rooftop photovoltaic (2.5 kW), micro-wind turbine (1.5 kW) and micro combined heat and power (1 kW). With no embedded energy storage, the dwelling exports energy when the micro generation system generates excess power leading to a high level of generated export throughout the year. It presents an original control algorithm for a hybrid energy system with a renewable energy source, namely, a polymer electrolyte membrane fuel cell (PEMFC) and a photovoltaic (PV) array. A single storage device, i.e., a super capacitor (ultra-capacitor) module, is in the proposed structure. The main weak point of fuel cells (FCs) is slow dynamics because the power slope is limited to prevent fuel starvation problems, improve performance and increase lifetime. The very fast power response and high specific power of a super capacitor complements the slower power output of the main source to produce the compatibility and performance characteristics needed in a load.

## II. LITERATURE REVIEW

An easy way to comply with IJRASET paper formatting requirements is to use this document as a template and simply type your text into it. An energy management and control of grid-connected Hybrid Renewable Energy System (HRES) describes a Wind Turbine (WT) and hybrid energy storage system based on hydrogen technology (fuel cell), and battery. DC/DC converters are used to connect all the energy sources and storage system to a common DC bus. The output of DC bus is integrated to the national grid through three phase inverter to increase the continuity of power. HRES is working under classical-based supervisory control algorithm [1-9]. The wind is used the primary energy source to satisfy the load demands. The fuel cell is used to ensure long-term energy balance by using the hydrogen technology. The battery is utilized as a backup and high energy density device to keep the DC-bus voltage constant.

An energy management strategy used to control the output of the 100 megawatt-level battery energy storage stations (BESS), thus to increase the ability of the large scale BESS for autonomous distribution of real time power. Based on the strategy of multi-agent particle swarm optimization, the real time power of the power converter system (PCS) has been calculated. Meanwhile, the layered structure consisting of main-agent [10-15], sub area agent, and PCS agent for the BESS are developed. The measured data of the wind power station is used to carry out a simulation analysis for large scale wind farm and BESS hybrid generation systems.

A control scheme for a standalone micro grid having a non-dispatchable fixed-pitch variable-speed wind generator (WG) and battery energy storage (BES). The WG is directly interfaced at the point of common coupling (PCC) and the BES is interfaced at the PCC via a bidirectional dc-ac converter [16-20]. The unique aspect of the control strategy is that the BES not only regulates the PCC voltage and frequency by active-reactive power compensations, but also ensures proper synchronization and disconnection of the WG during wind velocity variations.

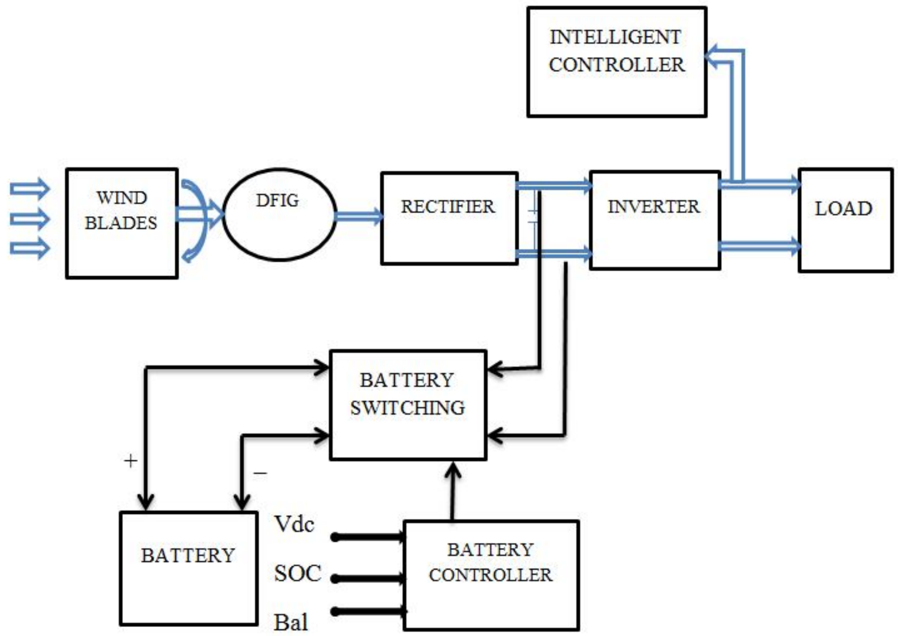


Fig. 1: Existing Wind Energy System

The illustration of Existing wind energy system is shown in Fig.1. The energy management system work is based on an intelligent switching logic algorithm for the energy storage system. The algorithm generates dynamic references for each subsystem and effectively utilized all renewable energy sources and battery storage system according to different wind speed and load conditions.

## III.PROPOSED SYSTEM

The doubly-fed induction generator (DFIG) system is a popular system in which the power electronic interface controls the rotor currents to achieve the variable speed necessary for maximum energy capture in variable winds. Because the power electronics only process the rotor power, typically less than 25% of the overall output power, the DFIG offers the advantages of speed control with reduced cost and power losses.

Double-fed induction generator (DFIG), a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly, but there are problems with efficiency, cost and size. A better alternative is a brushless wound-rotor doubly-fed electric machine.

The principle of the DFIG is that stator windings are connected to the load and rotor winding are connected to the converter via slip rings and back-to-back voltage source converter that control both the rotor and the load currents. Thus rotor frequency can freely differ from the load frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the load from the stator independently of the generator's turning speed. The control principle used is either the two-axis current vector control or direct torque control (DTC). DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator.

Energy Management system (EMS) is combination of hybrid sources such as Wind Energy Conversion System (WECS) using Doubly Fed Induction Generator (DFIG) machine and Lithium acid battery with loads, the entire system is load connected .The battery storage system is connected to DC link through a bi- directional converter for demand compensation and the system is working under load connected mode of operation.

The battery controller is used to control the battery charging and discharging operation to provide optimized battery utilization and intelligent controller controls the inverter switching according to load requirement. Energy management system is based on an intelligent switching logic algorithm for the energy storage system. The main drawback of the Intelligent Controller is that it contains restricted input, lower speed and longer time for the execution. In order to overcome the issue Artificial Neural Network has been implemented which rectifies the outcomes of the previous controller.

A wind turbine is a device that converts the wind's kinetic energy into electrical energy. Wind turbines are manufactured in a wide range of sizes, with either horizontal or vertical axes. It is estimated that hundreds of thousands of large turbines, in installations known as wind farms, now generate over 650 gigawatts of power, with 60 GW added each year. They are an increasingly important source of intermittent renewable energy, and are used in many countries to lower energy costs and reduce reliance on fossil fuels. One study claimed that, as of 2009, wind had the "lowest relative greenhouse gas emissions, the least water consumption demands and the most favourable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas. The first automatically operated wind turbine, built in Cleveland in 1887 by Charles F. Brush. It was 60 feet (18 m) tall, weighed 4 tons (3.6 metric tonnes) and powered a 12 kW generator.

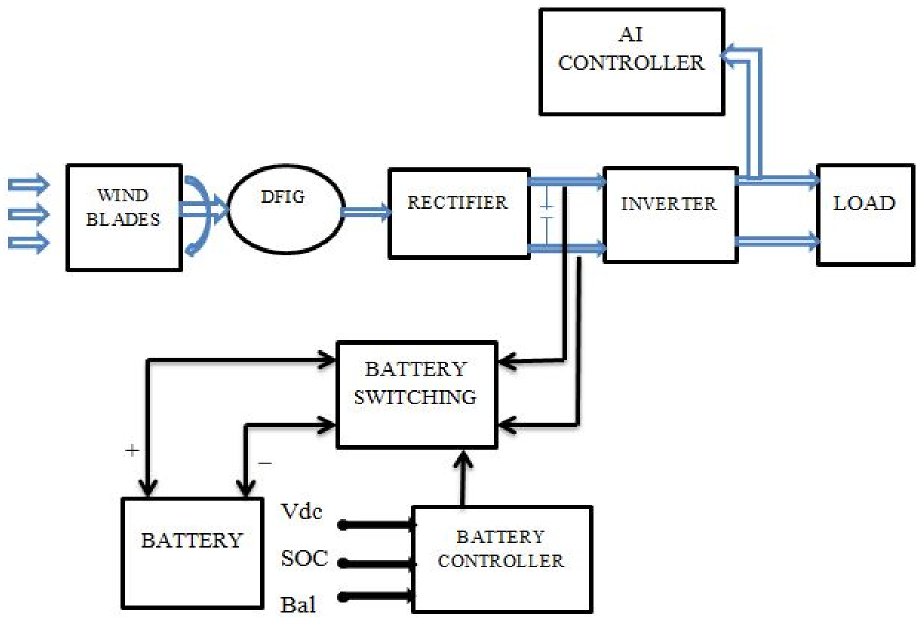


Fig. 2: Proposed Wind energy System

The proposed (EMS) Energy Management System in Fig.2 integrates with the Artificial Intelligent controller for operation of both battery and wind system depending upon the demand need. EMS charges the battery on the account of the load when there is a heavy slope in Battery State of Charge (SOC). It generates dynamic references for each subsystem and effectively utilized all renewable energy sources and battery storage system according to different wind speed and load conditions. The proposed system has an efficient power flow with better reliability and power quality.

Wind turbines can rotate about either a horizontal or a vertical axis, the former being both older and more common. They can also include blades, or be bladeless. Vertical designs produce less power and are less common. Large three-bladed horizontal-axis wind turbines (HAWT) with the blades upwind of the tower produce the overwhelming majority of wind power in the world today. These turbines have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a yaw system. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.

Vertical-axis wind turbines VAWTs have the main rotor shaft arranged vertically. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable. It is also an advantage when the turbine is integrated into a building because it is inherently less steerable. Also, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance. However, these designs produce much less energy averaged over time, which is a major drawback.

Wind Power Density (WPD) is a quantitative measure of wind energy available at any location. It is the mean annual power available per square meter of swept area of a turbine, and is calculated for different heights above ground. Calculation of wind power density includes the effect of wind velocity and air density. Wind turbines are classified by the wind speed they are designed for, from class I to class III, with A to C referring to the turbulence intensity of the wind.

A doubly-fed induction machine is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in wind power applications. First, as the rotor circuit is controlled by a power electronics converter, the induction generator is able to both import and export reactive power. This has important consequences for power system stability and allows the machine to support the load during severe voltage disturbances (low-voltage ride-through; LVRT).

Second, the control of the rotor voltages and currents enables the induction machine to remain synchronized with the load while the wind turbine speed varies. A variable speed wind turbine utilizes the available wind resource more efficiently than a fixed speed wind turbine, especially during light wind conditions. Third, the cost of the converter is low when compared with other variable speed solutions because only a fraction of the mechanical power, typically 25–30%, is fed to the load through the converter, the rest being fed to load directly from the stator. The efficiency of the DFIG is very good for the same reason.

### *A. DFIG based Wind Turbine*

The wind turbine equation represents the combination of battery power and load power. The rectifier voltage is varied depending upon the DC link voltage.

$$PWT_{ref} = Pb_{at,c} + P_{load} \quad (1)$$

Where, $PWT_{ref}$ is the reference limited power of WT generator.

$Pb_{at,c}$ is the charging power of ESS

$P_{load}$ is the load demand of the micro load

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification, since it "straightens" the direction of current. Physically, rectifiers take a number of forms, including vacuum tube diodes, wet chemical cells, mercury-arc valves, stacks of copper and selenium oxide plates, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches.

A bridge rectifier is a full wave rectifier consisting of a bridge with a similar rectifier in each of the four arms. A bridge rectifier will help to make sure that the current going to the DC path circuit is always at the correct polarity.

An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility load. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. The device is controlled by the MPPT algorithmic program supports the wind speed variation to extract the utmost wind power. The mechanical wind power equation is represented

$$P_{wind} = \frac{1}{2\rho} S_t C_p(\lambda, \beta) V^3 \quad (2)$$

The optimum rotational speed with maximum tip speed ratio is determined as λmax, According to the operation theory of wind turbine; the maximum output power of wind generator depends on the optimal tip speed ratio λopt. In terms of this, the MPPT is controlled to track the maximum power of the wind turbine and the battery charging voltage in such a way, the optimal power $P_{opt}$ equation can be determined as

$$C_{P\max} = C_{P(\lambda\max)} \quad (3)$$

$$K_{opt} = \frac{1}{2\rho} * \pi * C_{p\max} * \frac{R^5}{\lambda^3} \quad (4)$$

$$P_{opt} = K_{opt} * \Omega^3{}_{opt} \quad (5)$$

The MPPT controller compares the speed, torque and voltage to provide the reference current for the generator. The reference and Ia are compared in the current controller block which helps to convert the current to pulse generation to provide the pulse for the switch present in the boost converter.

Bad weather conditions lead to critical variation in wind speed leads to unbalance in the wind power generation system, due to unbalance electrical supply from the power generation is ensures power reduction to the electrical load. In this case to overcome the load outages the use of an energy storage system such as the battery is required to maintain the DC link voltage. If the wind power is abundantly available then the battery is under the charging condition.

If wind speed decreased due to weather change then wind power generation is reduced leads to discharge the battery power .The Lithium battery is considered to most efficient ESS which is used in proposed method due to its quick charging support and effectiveness The battery characteristics depend upon the state of charge (SOC) and its equation is represented as

$$\text{State of Charge} = 100^* \left(1 - \int Ib(t)dt\right) \quad (6)$$

From the equation, Ib is said to be the current from the battery (A) and Q is the maximum charge capacity of the battery represented (Ah).To control the Bi-directional converter the intelligent controller is used, the pulses are well modulated and sent to the Bi-directional converter for its proficient switching operation. The switches are operated depends upon the load requirement and wind power generation. The primary mode is said to be the charging mode for buck operation, and secondary mode is boost operated. The DC-DC bidirectional converter is used in this proposed work which guaranteeing the battery charging or discharging in optimized way.

The primary obligation of the Artificial Intelligent controller is to minimization of voltage and frequency fluctuation at the PCC point, guaranteeing the balance between the generation and demand and better utilization of battery by the controlled SOC. The intelligent EMS is presented alienated in two control strategies. The first strategy is operated based on three phase voltage. The second strategy is operated based on PLL by having the frequency and phase as an input points of confinement esteems and settles on the HRES operation modes and the second block is Battery Management System which explains the various conditions of the battery conditions under different SOC and various loading condition.

The ANN controller works like human brain. It has number of artificial neurons that behave as a human brain. The reference tracking error information is given through a suitable scaling factor as input to the ANN to produce the control pulses for the inverter. A constant operating frequency is achieved in both online and offline modes to control the inverter. The functional mapping estimation of ANN controller provides high level of fault tolerance. Knowledge on inverter model is not needed for ANN controller, but, the functional behaviour of inverter should be precisely known while designing the ANN controller.

The ANN controller is used for controlling the inverters smooth switching operation. The power flow of the load-side converter is controlled in order to maintain the power and dc-link voltage at the reference value. PLL is operated depends upon the load voltage and frequency, where the controller controls the inverter side voltage by controlling the inverter switching by using genetic algorithms which enable the most appropriate rules for the solution of a problem and select it. So, they send their ‘genetic material’ to ‘child’ rules, in order to operate the converter depends upon the demand. On the chance of the voltage and frequency variance is lesser or more than their cut-off points, it will be important to seclude the wind generator from the network and work in the independent mode of operation to meet the heap prerequisite.

In this work, the SOC value of battery is fixed from 40 to 90 percentage which is shown in [11].Depending upon the load requirement and the power generation the battery is operated under 4 states, Under state 1 this power is more sufficient to meet the load so that the battery is fully charged and the energy generated by wind is higher than the energy demand and SOC is above 90%. Under the state 2 condition of the battery is within 40 to 90 the battery is in charging state. By the variation in the SOC state the battery charging and discharging is varied. The required power ΔP can be determined as

$$\Delta P = \left(\left(P_{wind} + P_{battery}\right) - P_{demand}\right) \quad (7)$$

Therefore, $P_{\text{wind}}$ is the wind power, $P_{\text{demand}}$ is considered to be the load power required.

## IV.RESULTS

The power generated by the wind energy is less than power consumed by the load at this scenario, the battery SOC is less than of 90%, so that battery discharges, so that the battery tries to balance the energy consumption.

The load requirement is lesser than generation the SOC is equal to 100%. The system operates in a charge battery mode.

The wind power nearly tries to meet the demand equally at this particular condition the battery is under semi discharge condition to completely balance the system.

If the wind speed is reduced to 2m/s the power generated by the DFIG is reached to nearly zero and the battery completely discharges its power to meet the load.

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Table 1. Comparison of Existing and Proposed System

| S.No | Fuzzy Logic | AI - ANN |
|---|---|---|
| Harmonic Distortion(THD) | 4.46% | 4.31% |

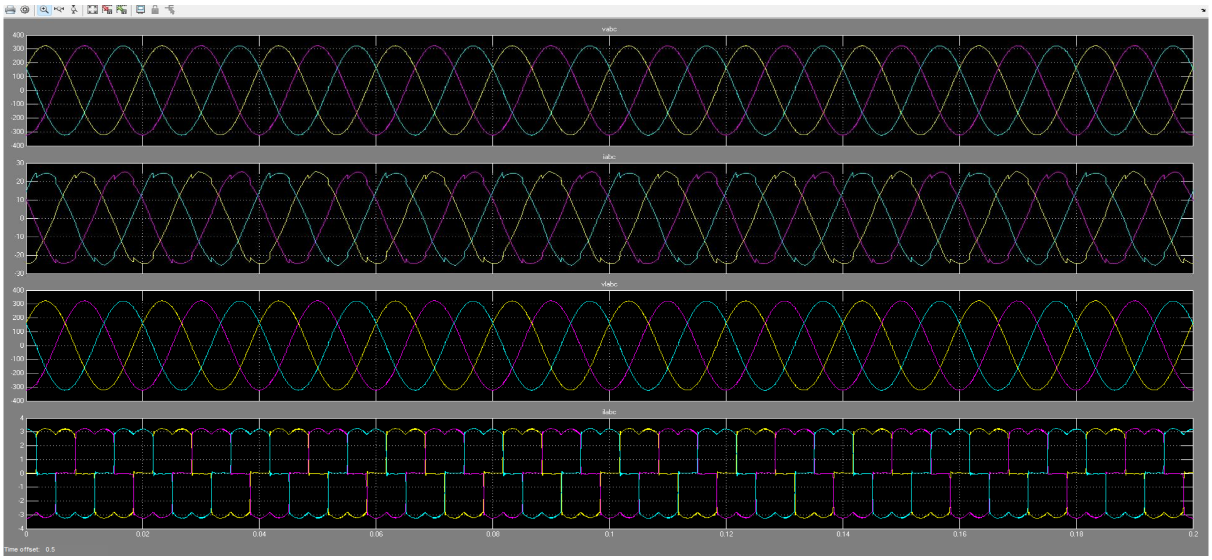

Fig. 3: Capability of the proposed DFIG has been emulated.

The simulated waveform of three phase input voltage ($V_{abc}$) and current ($i_{abc}$) along with the load voltage ($V_{labc}$) and load current ($i_{labc}$) is shown in Fig.3. The output waveform of a three phase rotor current ($i_{rabc}$) with the three phase grid voltage ($V_{gabc}$) and three phase grid current ($i_{gabc}$) has been simulated.Maximum line current depends upon the maximum power and the line voltage at GSC. The maximum possible power in the GSC is the slip power.

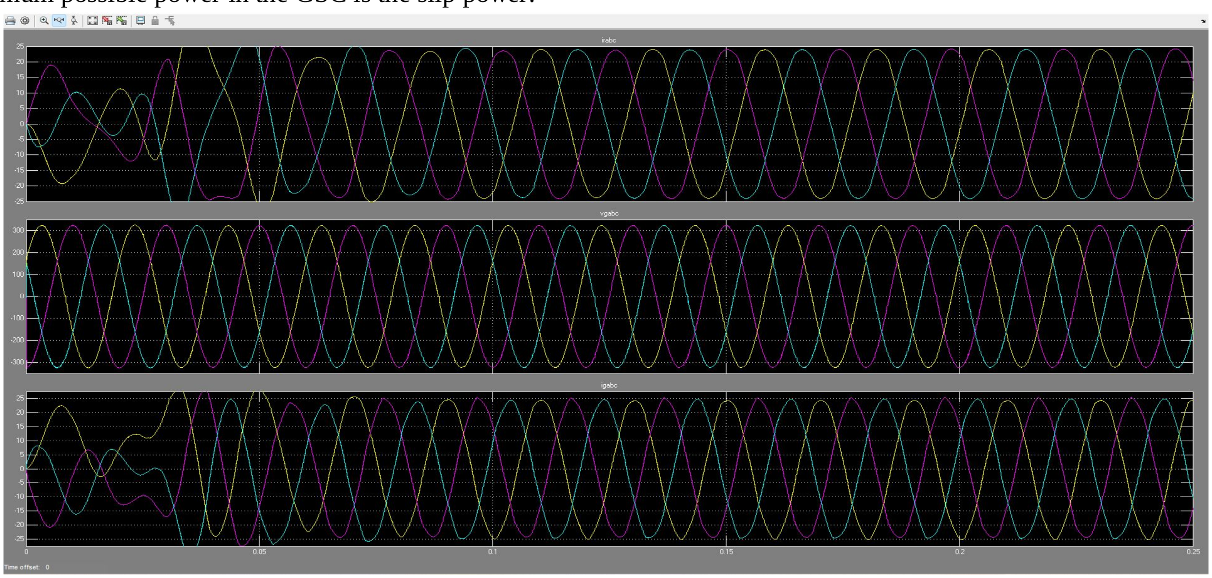

Fig. 4. Simulated output waveform4

Fig. 4 shows the simulated output waveform of a three phase rotor current ($i_{rabc}$) with the three phase grid voltage ($V_{gabc}$) and three phase grid current ($i_{gabc}$). The main purpose of RSC is to extract maximum power. Rotor current is selected such that maximum power is extracted for a particular wind speed. This can be achieved by running the DFIG at a rotor speed for a particular wind speed. The simulation result for load connected DFIG based wind system using Artificial Intelligent Controller has been obtained. The harmonic compensation is not so effective and Total Harmonic Distortion (THD) is not less than 5%. Which is illustrated in Fig.5.

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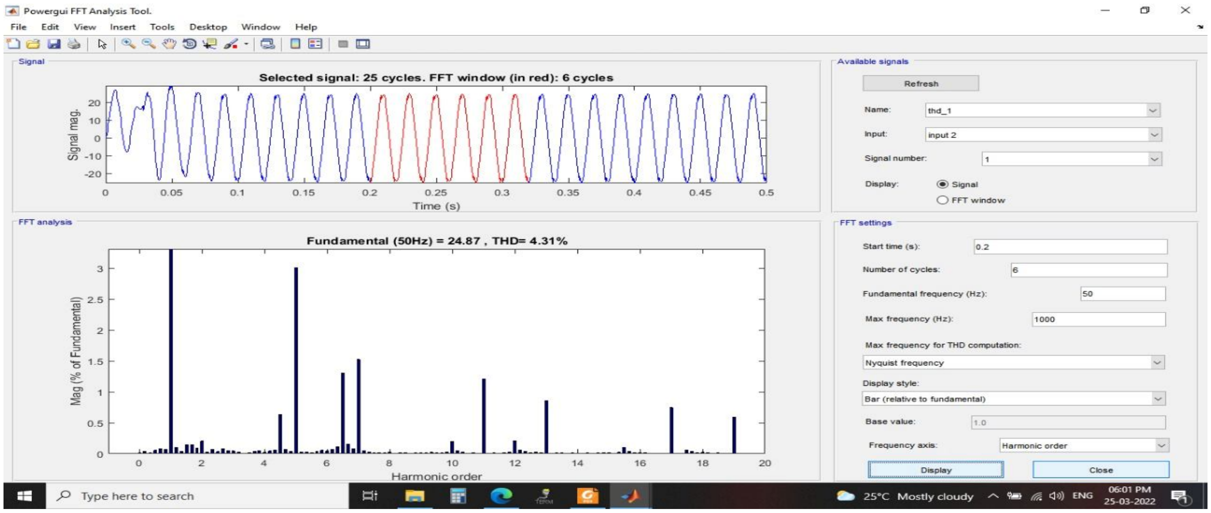


Fig 5. Harmonic spectra of Artificial Controller using ANN

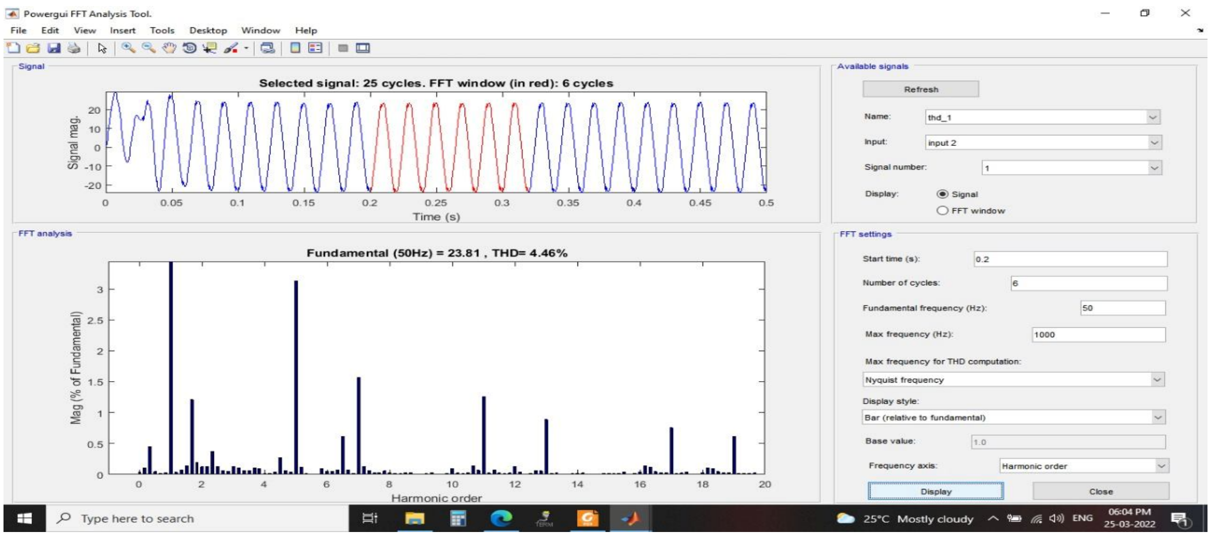


Fig 6: Harmonic spectra of Intelligent Controller using Fuzzy Logic

From Fig.6. it is clearly observed that the oscillations decrease and the proposed NN controller present minimal rising time, no overshoot and negligible steady-state error compared to fuzzy logic controller.

## V. CONCLUSIONS

The proposed work fulfils the need in variable load and wind speed conditions with satisfying the primary goal that load shedding is totally kept away and the load is totally meet. The main drawback of the intelligent controller using Fuzzy is of higher harmonic distortion. It is suitable for the problems which do not need high accuracy. Since mathematical concepts are used, it is difficult to understand for complex problems. This work proposes an Artificial Intelligent EMS strategy for hybrid energy sources such as DFIG based wind turbine and battery system, which is connected with variable loads and operated under the load-connected mode of operation. The EMS developed is capable to fulfill the variable load requirement and it also ensures the energy management system and effective utilization of ESS. The planned work is simulated using MATLAB software and the energy storage integration is done for the optimized energy management system.

All these drawbacks are rectified using Artificial Intelligent Controller which uses Artificial Neural Network. It tries to apply thinking process in human brain to solve problems. ANN includes learning process that involves learning algorithm and requires training data.

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