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IOT BASED MONITORING FOR WIND ENERGY SYSTEM WITH FUZZY & PID CONTROLLER

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Abstract:

Wind energy has become a second dominating source in the world renewable energy generation. Conversion and distribution of the wind energy have brought technology revolution by developing advanced wind energy conversion system (WECS) including multilevel inverters (MLI). The conventional rectifier produces ripples in their output waveforms while MLI suffers from voltage balancing issue across dc-link capacitor. This paper proposes a simplified proportional integral derivative (PID)-based space vector pulse width modulation (SVPWM) to minimize the output waveform ripples, resolve the voltage balancing issue and produce betterquality output waveforms. On the other hand, WECS experiences various types of faults particularly in the dc-link capacitor and switching devices of the power converter. These faults, if not detected and rectified at early stages, they may lead to catastrophic failures to the WECS and continuity of power supply. This paper proposes a new algorithm embedded into the proposed PID-based SVPWM controller to identify the fault location in the power converter in real time. Since most wind power plants are located in remote areas or offshore, WECS condition monitoring needs to be developed over the internet of things (IoT) to ensure system reliability. In this paper, an industrial IoT algorithm with associated hardware prototype is proposed to monitor the condition of WECS in real time environment.

***Index Terms* – Arduino Nano, 1x16 LCD, Regulated Power Supply, Transformers, Rectifiers, Voltage Regulator, Resistors, LED, ESP8266 WiFi Module, Switches.**

I. INTRODUCTION

With the increasing population in the world, the demand for electrical energy is also increasing rapidly. To meet the electrical demand the pressure for using fossil fuels had also increased worldwide. But the use of excessive fossil fuels to meet the worldwide energy demand lead to adverse environmental effects like global warming, acid rain and air pollution and also responsible for skin cancer. To overcome these adverse effects the use of Renewable Energy Sources had urged the scientists and engineers worldwide since renewable energy resources are eco-friendly and doesn't cause any harm to the environment. Wind Energy is the second most dominating energy source after the hydropower generation. For the generation of electricity through wind energy various advanced Wind Energy Conversion Systems (WECS) are developed for producing high capacity power with less occupying space. A Pulse Width Modulation (PWM) is used in the wind energy conversion system to suppress the ripples in output waveforms. Multi Level Inverter (MLI) is used for converting the mechanical energy of wind energy into electricity energy. It is also used because of some of its advantages that include less stress on switching devices, more utilization of the dc-link power, and better power quality. However, MLI exhibits some drawbacks such as voltage balancing issue along with the complexity of the used hardware and software. Neutral point clamped inverter (NPCI) also suffers from voltage balancing issue. The unbalanced neutral point voltage leads to unbalance in the dc-link voltage and vice versa. To overcome such challenges, e development of IoT projects which needs to be strictly maintained to develop IoT projects. The standards of internet protocols are mainly divided into three categories such as wireless personal area network (WPAN), wireless local area network (WLAN) and cellular network. From the above discussion, the main contributions of this paper can be summarized below:

Proposing a new PI-based SVPWM controller to suppress the ripples of the converter dc-link voltage and resolve the voltage balancing issue across the dc link capacitors.

Developing and embedded algorithm to monitor the condition of dc-link capacitors and switching devices of the power converters of WECS.

Proposing an industrial IoT algorithm associated with hardware prototype to monitor the condition of WECS in real time.

II. IOT (INTERNET OF THINGS) TECHNOLOGY

The **Internet of Things** (**IoT**) describes physical objects (or groups of such objects) with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the internet or other communications networks. Internet of things has been considered a misnomer because devices do not need to be connected to the public internet, they only need to be connected to a network and be individually addressable.

The field has evolved due to the convergence of multiple technologies including computing, commodity sensors, increasingly powerful embedded systems, and learning. Traditional fields of embedded systems wireless sensor networks, control systems, automation (including home and building automations), independently and collectively enable the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home ", including devices and appliances (such as lighting fixtures, thermostats , home security systems , cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers . IoT is also used in healthcare systems.

III. WIND ENERGY

Wind power production has been under the main focus for the past decade in power production and tremendous amount of research work is going on renewable energy, specifically on wind power extraction. Wind power provides an eco-friendly power generation and helps to meet the national energy demand when there is a diminishing trend in terms of non - renewable resources. This paper reviews the modeling of Wind Energy Conversion Systems (WECS), control strategies of controllers and various Maximum Power Point Tracking (MPPT) technologies that are being proposed for efficient production of wind energy from the available resource.

WIND ENERGY CONVERSION SYSTEM

The generators used for the wind energy conversion system mostly of either doubly fed induction generator (DFIG) or permanent magnet synchronous generator (PMSG) type. DFIG have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and grid. In DFIG the converters have to process only about 25-30 percent of total generated power (rotor power connected to grid through converter) and the rest being fed to grid directly from stator. Whereas, converter used in PMSG has to process 100 percent power generated, where 100 percent refers to the standard WECS equipment with three stage gear box in DFIG. Majority of wind turbine manufacturers utilize DFIG for their WECS due to the advantage in terms of cost, weight and size. But the reliability associated with gearbox, the slip rings and brushes in DFIG is unsuitable for certain applications. PMSG does not need a gear box and hence, it has high efficiency with less maintenance. The PMSG drives achieve very high torque at low speeds with less noise and require no external excitation. In the present trend WECS with multi brid concept is interesting and offers the same advantage for large systems in future.

To achieve high efficient energy conversion on these drives different control strategies can be implemented like direct torque control (DTC) field oriented control (FOC). The FOC using PID controller has linear regulation and the tuning becomes easier. The wind turbine electrical and mechanical parts are mostly linear and modeling will be easier. The blade aerodynamics of the wind turbine is a nonlinear one and hence the overall system model will become nonlinear. The wind energy conversion system which will be modeled as shown in Fig. 1 may not be optimal for extracting maximum energy from the resource and hence various optimization techniques are used to achieve the goal.

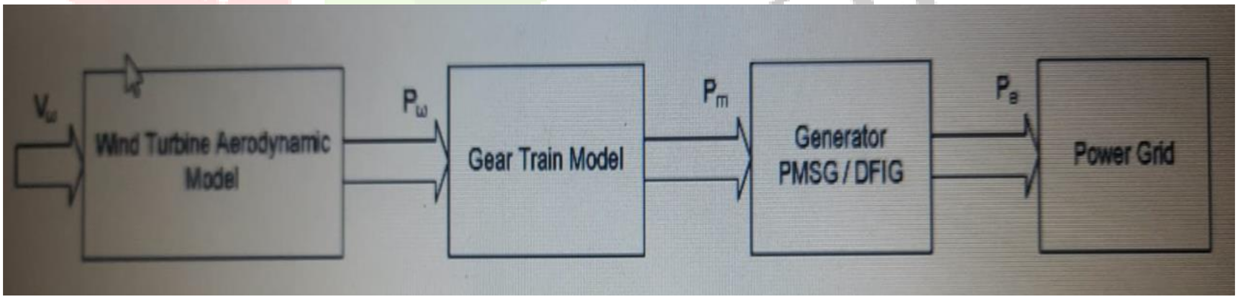

Figure 1: WECS Block Diagram

IV. PID CONTROLLER

A proportional–integral–derivative controller (PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively), hence the name. In practical terms, PID automatically applies an accurate and responsive correction to a control function

The distinguishing feature of the PID controller is the ability to use the three control terms of proportional, integral and derivative influence on the controller output to apply accurate and optimal control.

In this model:Term P is proportional to the current value of the SP − PV error. For example, if the error is large and positive, the control output will be proportionately large and positive, taking into account the gain factor "K". Using proportional control alone will generally result in an error between the setpoint and the actual process value because it requires an error to generate the proportional response. The controller cannot adjust the system unless there is an error present.

Term I accounts for past values of the SP − PV error and integrates them over time to produce the I term. For example, if there is a residual SP − PV error after the application of proportional control, the integral term seeks to eliminate the residual error by adding a control effect due to the historic cumulative value of the error. When the error is eliminated, the integral term will cease to grow. This will result in the proportional effect diminishing as the error decreases, but this is compensated for by the growing integral effect.

Term D is a best estimate of the future trend of the SP − PV error, based on its current rate of change. It is sometimes called "anticipatory control", as it is effectively seeking to reduce the effect of the SP − PV error by exerting a control influence generated by the rate of error change. The more rapid the change, the greater the controlling or damping effect.

V. FUZZY CONTROLLER

A fuzzy control system is a control system based on fuzzy logic— a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively.

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.

The most common shape of membership functions is triangular, although trapezoidal and bell curves are also used, but the shape is generally less important than the number of curves and their placement. From three to seven curves are generally appropriate to cover the required range of an input value, or the "universe of discourse" in fuzzy jargon.

As discussed earlier, the processing stage is based on a collection of logic rules in the form of IF-THEN statements, where the IF part is called the "antecedent" and the THEN part is called the "consequent". Typical fuzzy control systems have dozens of rules.

Consider a rule for a thermostat:

IF (temperature is "cold") THEN turn (heater is "high")

This rule uses the truth value of the "temperature" input, which is some truth value of "cold", to generate a result in the fuzzy set for the "heater" output, which is some value of "high". This result is used with the results of other rules to finally generate the crisp composite output. Obviously, the greater the truth value of "cold", the higher the truth value of "high", though this does not necessarily mean that the output itself will be set to "high" since this is only one rule among many. In some cases, the membership functions can be modified by "hedges" that are equivalent to adverbs. Common hedges include "about", "near", "close to", "approximately", "very", 45 "slightly", "too", "extremely", and "somewhat". These operations may have precise definitions, though the definitions can vary considerably between different implementations. "Very", for one example, squares membership functions; since the membership values are always less than 1, this narrows the membership function. "Extremely" cubes the values to give greater narrowing, while "somewhat" broadens the function by taking the square root.

In practice, the fuzzy rule sets usually have several antecedents that are combined using fuzzy operators, such as AND, OR, and NOT, though again the definitions tend to vary: AND, in one popular definition, simply uses the minimum weight of all the antecedents, while OR uses the maximum value. There is also a NOT operator that subtracts a membership function from 1 to give the "complementary" function.

There are several ways to define the result of a rule, but one of the most common and simplest is the "max-min" inference method, in which the output membership function is given the truth value generated by the premise.

Rules can be solved in parallel in hardware, or sequentially in software. The results of all the rules that have fired are "defuzzified" to a crisp value by one of several methods. There are dozens, in theory, each with various advantages or drawbacks.

The "centroid" method is very popular, in which the "center of mass" of the result provides the crisp value. Another approach is the "height" method, which takes the value of the biggest contributor. The centroid method favors the rule with the output of greatest area, while the height method obviously favors the rule with the greatest output value.

The diagram below demonstrates max-min inferencing and centroid defuzzification for a system with input variables "x", "y", and "z" and an output variable "n". Note that "mu" is standard fuzzy-logic nomenclature for "truth value":

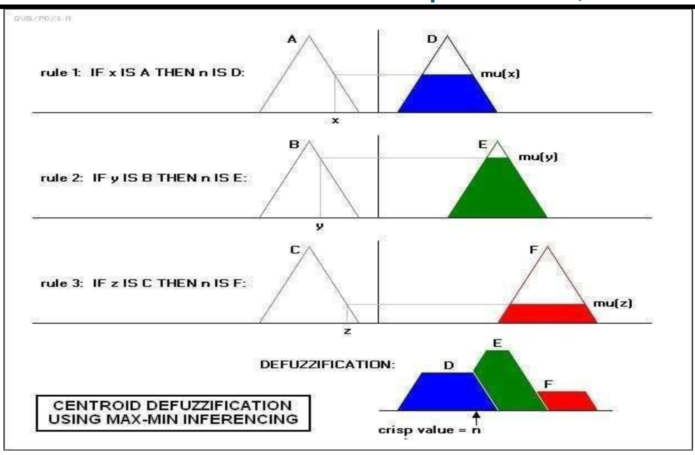

Figure 2: Defuzzication graph

Notice how each rule provides a result as a truth value of a particular membership function for the output variable. In centroid defuzzification the values are OR'd, that is, the maximum value is used and values are not added, and the results are then combined using a centroid calculation.

Fuzzy control system design is based on empirical methods, basically a methodical approach to trial-and-error. The general process is as follows:

Document the system's operational specifications and inputs and outputs. Document the fuzzy sets for the inputs. Document the rule set. Determine the defuzzification method. Run through test suite to validate system, adjust details as required. Complete document and release to production.

V. ARDUINO NANO

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source. The Nano is inbuilt with the Atmega328P microcontroller. The ATmega328 has 32 KB, (also with 2 KB used for the bootloader. The ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

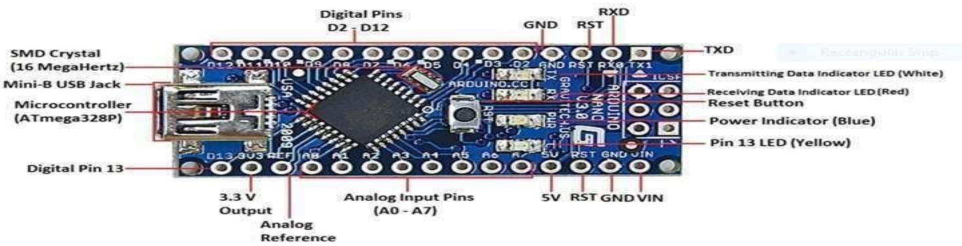

Figure 3: Arduino Nano Board

Arduino Nano	Specifications
Analog I/O Pins	8
Architecture	AVR
Clock Speed	16 MHz
DC Current per I/O Pins	40 milliAmps
Digital I/O Pins	22
EEPROM	1 KB
Flash Memory	32 KB of which 2 KB used by Bootloader
Input Voltage	(7-12) Volts
Microcontroller	Atmega328P
Operating Voltage	5 Volts
PCB Size	18 x 45 mm
Power Consumption	19 milliAmps
PWM Output	6
SRAM	2KB
Weight	7 gms

Table 1: Arduino Nano Specifications

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the analogReference() function. Analog pins 6 and 7 cannot be used as digital pins.

The Arduino Nano can be programmed with the Arduino software (download). Select "Arduino Duemilanove or Nano w/ ATmega328" from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Arduino Nano comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar.

VII. ESP8266 WiFi MODULE

The ESP8266 WiFi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your WiFi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

HOW TO PROGRAM ESP8266

1. Connect the USB-UART adapter to ESP8266 as follows: VCC -> VCC, GND -> GND, RX -> TX and TX -> RX.
2. Pull the GPIO0 pin to GND.
3. Connect the adapter to the computer.
4. Run a program for flashing via UART, e.g. ESPEasy.
5. Select the appropriate COM port and binary file you want to upload.

Figure 4: Pin Description of ESP8266

3V3: - 3.3 V Power Pin.

GND: - Ground Pin.

RST: - Active Low Reset Pin.

EN: - Active High Enable Pin.

TX: - Serial Transmit Pin of UART.

RX: - Serial Receive Pin of UART.

GPIO0 & GPIO2: - General Purpose I/O Pins. These pins decide what mode (boot or normal) the module starts up in. It also decides whether the TX/RX pins are used for Programming the module or for serial I/O purpose.

VIII. MATLAB

Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building. Matlab is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or Fortran.

SIMULINK

Simulink is a software add-on to matlab which is a mathematical tool developed by The Math works,(http://www.mathworks.com) a company based in Natick. Matlab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries. Various toolboxes for 55 different techniques, such as Fuzzy Logic, Neural Networks, dsp, Statistics etc. are available with Simulink, which enhance the processing power of the tool. The main advantage is the availability of templates / building blocks, which avoid the necessity of typing code for small mathematical processes.

IX. RESULT

In this prototype, the amount of electricity which is obtained by conversion of wind energy into electrical energy using rectifiers can be seen in our mobile devices anywhere anytime, through which the IOT based constructed prototype is connected to our mobile devices. We can also see the rectified output without ripples of converter DC-LINK and voltage imbalance at the Neutral Point Clamped Inverter.

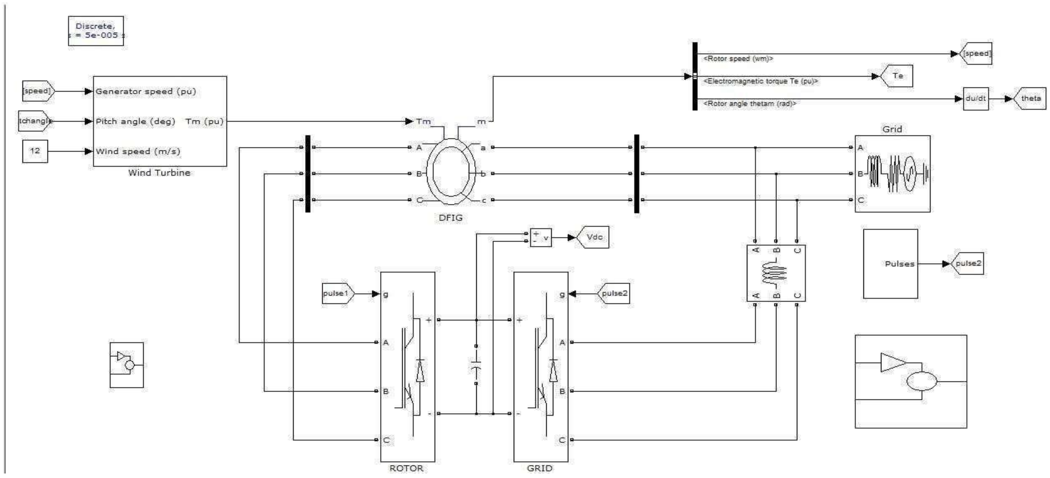

Figure 5: Simulation File

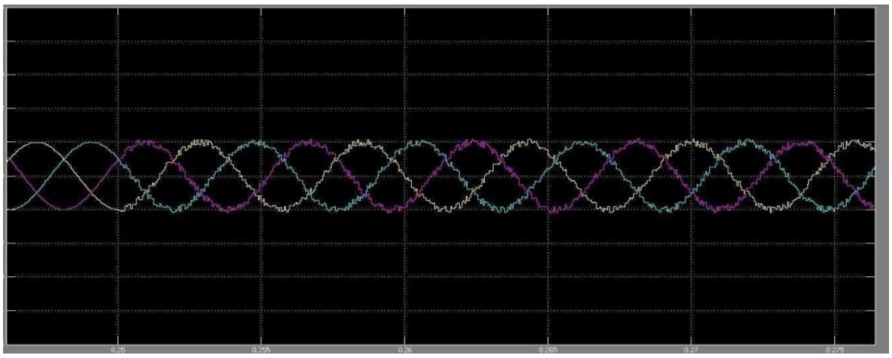

Figure 6: Simulation Result 1

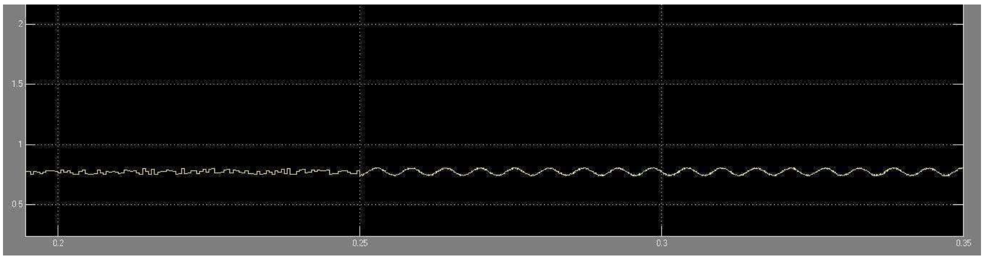

Figure 7: Simulation Result 2

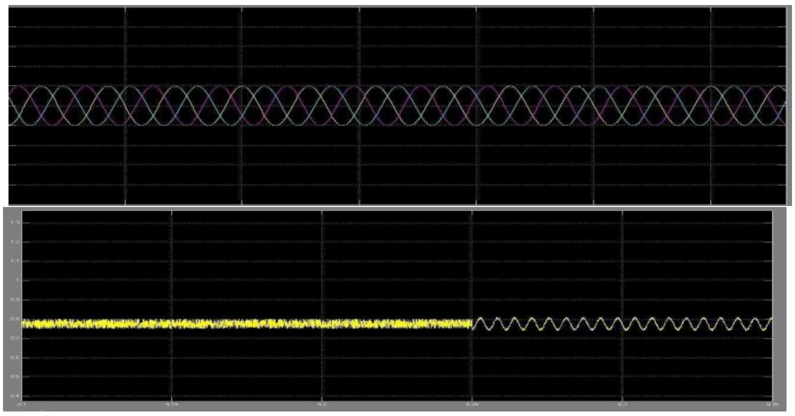

Figure 8: Simulation Result 3

X. CONCLUSION

Regarding the controllers for the WECS, is still the most important and challenging topic of research as there are various controllers had been proposed by various researchers has been discussed in this paper. As there are lot of ongoing developments takes place at various stages of WECS, it is noted that the most suitable (optimized) solutions to extract maximum power of the installed system is ad-hoc, rather than generalized solution. The overview of this information highlights the current research progress in the field of wind energy conversion system and this will be helpful for the new researchers to focus on the above area.

XI. FUTURE SCOPE

Wind Energy is the fuel which is obtained for free from the nature. It is eco-friendly and doesn't harm environment by releasing any carbon emissions unlike fossil fuels. For producing electricity through wind energy, Wind Energy Conversion System is used. Now a days, this Wind Energy Conversion System is developed based on smaller in size and larger in capacity. This type of development needs advanced technologies. This usage and development of advanced technologies will provide path in developing the Wind Energy Conversion System in enormous way. This development also leads to development of various sectors in future.

The usage of Wind Energy gives sustainable electricity. This type of usage of sustainable electricity will not damage the environment and we can gift clean environment for our future generations.

Recently discussions had held in COP26 by international countries by both developed and developing countries to reduce carbon emissions and global warming. To reduce these emissions and global warming they obtained many resolutions. One of the resolutions is usage of renewable energy sources which are emission free. So in this way, usage of wind energy which is a renewable energy source will make india emission free, clean electricity producing country. This leads to the development of our country in various sectors in various ways in future.

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