# SLIDING MODE CONTROL BASED WIND ENERGY POWER GENERATION

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***Abstract:***

To grow the needs for the energy, the purpose of renewable resources to serve the purpose has increased. This article was just a light to the resolution to the crisis that is looming over us. We are introduced design a controller in the direction of improving the effective of Wind energy systems.

The concept was referred by a sliding mode control methodology, i.e., the system under control has been driven towards a sliding mode by tuning the arguments of the controller. In this loop, the parameter of the controller was adjusted such that a zero learning error level has reached in one dimensional phase space defined on the output of the controller.

***Keywords-*** Sliding mode control, Wind energy conversion systems(WECS), Induction generator, Simulation.

## I. INTRODUCTION

Wind energy conversion systems (WECS's) have in the past two decades been the object of strong interest as viable source of electrical energy. Various electromechanical schemes for generating electricity from the wind have been suggested, but the main drawback is that the resulting system is highly nonlinear, and thus a nonlinear control strategy is required to place the system in its optimal generation point. Among others, sliding mode control has been proposed as feasible control alternative.

Earliest notion of Sliding Mode Control (SMC) strategy was constructed on a second order system in the late 1960s by Emelyanov [1]. The work stipulated that a special line could be defined on the phase plane, such that any initial state vector can be driven towards the plane and then be maintained on it, resulting in the error dynamics being forced towards the origin. Since then, the theory has greatly been improved and the sliding line has taken the form of a multidimensional surface, called the sliding surface around which a switching control action takes place. In Variable Structure Control, the existence of observation of noise constitutes a prime difficulty. This is due to the fact that the ideal sliding control requires very fast switching on of the input, which cannot be provided by real actuators, and the input depends on the sign of a measured variable, which is very close to zero. This makes the control signal extremely vulnerable to measurement noise and may lead to unnecessarily large control signals. To alleviate these difficulties, the microcontroller is used which is pre programmed as per the requirement.

## II. PRINCIPLE

The basic underlying logic is to design a technique for the control of voltage generated from a self-excited three-phase induction generator using a DC/DC converter. The speed of the wind turbine that drives the induction generator that may be regulated or unregulated. During the voltage build up process, there is a variation in flux linkage of the induction generator. The terminal voltage of induction generator in controlled using sliding mode control (SMC) technique. The SMC is an appropriate robust control method or a specific class of non-linear system. The salient feature of SMC is that system states are forced to remain on a user chosen switching surface. Application of this technique governs the sliding equations to remain insensitive to the class of parameter variations and disturbances. The switching surface chosen is asymptotically stable and ensures sliding mode motion. For sliding mode motion, it is essential that the trajectories are directed towards the switching surface S=0 from either side of its vicinity. This technique accepts challenges over complexity of other practical systems, requirement of high quality and accurate designing, speed of designing, robustness, reliability and safety arising from the design. In this control theory, the dynamics of a non-linear system is altered via application of high frequency switching control. Further the performance is enhanced by eliminating the limitations of the converter output voltage via efficient programming of micro controller. The microcontroller is so programmed to maintain the output level to set point voltage. This is get through by producing a PWM in the microcontroller and its width is adjusted as per the requirement.

The ac power output from Induction generator is controlled by boost converter to effectively maintain the dc voltage level. The voltage source PWM inverter is used to interface the system with the electrical utility. The magnitude of the PWM inverter has been controlled to enhance the stability of the dc voltage. Simulation results show the superior stable control system and high efficiency.

## III. SLIDING MODE CONTROL:

*A. Background:*

Nonlinear system model imprecision may come from actual uncertainty about the plant (e.g., unknown plant parameters), or from the purposeful choice of a simplified representation of the system's dynamics. Modeling inaccuracies can be classified into two major kinds: structured (or parametric) uncertainties and unstructured uncertainties (orunmodeled dynamics). The first kind corresponds to inaccuracies on the terms actually included in the model, while the second kind corresponds to inaccuracies on the system order. Modeling inaccuracies can have strong adverse effects on nonlinear control systems. One of the most important approaches to dealing with model uncertainty is robust control.

The typical structure of a robust controller is composed of a nominal part, similar to a feedback control law, and additional terms aimed at dealing with model uncertainty.

Sliding mode control is an important robust control approach. For the class of systems to which it applies, sliding mode controller design provides a systematic approach to the problem of maintaining stability and consistent performance in the face of modeling imprecision. On the other hand, by allowing the tradeoffs between modeling and performance to be quantified in a simple fashion, it can illuminate the whole design process.

*B. Sliding Surfaces:*

This section investigates variable structure control (VSC) as a high-speed switched feedback control resulting in sliding mode. For example, the output voltage from Induction generator is compared with the voltage set in the microcontroller and accordingly switching is made using MOSFET driver circuit (in this case). The purpose of the switching control law is to drive the nonlinear plant's state trajectory onto a prespecified (user-chosen) surface in the state space and to maintain the plant's state trajectory on this surface for subsequent time. The surface is called a switching surface. When the plant state trajectory is "above" the surface, a feedback path has one gain and a different gain if the trajectory drops "below" the surface. This surface defines the rule for proper switching. This surface is also called a sliding surface (sliding manifold). Ideally, once intercepted, the switched control maintains the plant's state trajectory on the surface for all subsequent time and the plant's state trajectory slides along this surface.

The most important task is to design a switched control that will drive the plant state to the switching surface and maintain it on the surface upon interception. A Lyapunov approach is uesd to characterize this task. Lyapunov method is usually used to determine the stability properties of an equlibrium point without solving the state equation. Let V(x) be a continuously differentiable scalar function defined in a domain D that contains the origin. A function V(x) is said to be positive definite if V(0)=0 and V(x)>0 for x. It is said to be negative definite if V(0)=0 and V(x)>0 for x. Lyapunov method is to assure that the function is positive definite when it is negative and function is negative definite if it is positive. In that way the stability is assured.

## IV. SLIDING MODE CONTROL BASED WIND GENERATION SYSTEM:

A simple block-diagram of sliding mode control based wind generation system is shown in Fig. 1. In this Figure, there are few main parts: wind profile, wind turbine, induction generator, PIC microcontroller, LCD display, Keypad and MOSFET driver, MOSFET, DC-DC converter(sliding mode control components)

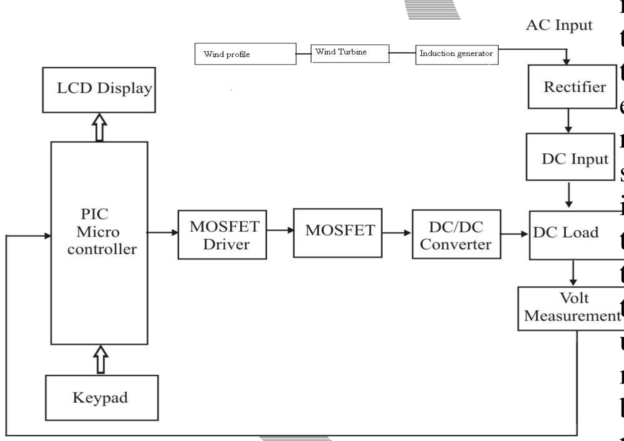


*Fig 1. Block diagram of sliding mode control based wind generation system*

*A. Wind Profile:*

Wind speed changes continuously and its magnitude are random over any interval. To simulate the wind speed, it is common to assume that the mean value of the wind speed is constant for some intervals (for example every 10 minutes).
The International Electro-technical Commission has recommended the use of Rayleigh probability distribution for the wind profile to determine the ten-minute mean.

To simulate a wind profile, sinusoidal fluctuations are usually added to the randomly changing mean value. A typical expression for the wind velocity, v, is:

$$v=x(1-0.05\cos(2\pi t/20)-0.05\cos(2\pi t/600)$$

where x is the random number produced by Monte Carlo simulation.

*B. Wind Turbine:*

Here we employ improved vertical axis wind turbines with enhanced conversion of wind kinetic energy to mechanical energy. These turbines are typically of long axis type, allowing large column of air to be harnessed. The vertical axis turbines are designed to be employed as a cost effective power source in any wind condition. The turbine is coupled with Self excited Induction Generator.

*C. Induction Generator:*

The induction generator is generally simpler, cheaper, more reliable, and perhaps more efficient than either the ac generator or the dc generator. The induction generator and the PM generator are similar in construction, except for the rotor, so complexity, reliability, and efficiency should be quite similar for these two types of machines. The induction generator is likely to be cheaper than the PM generator by perhaps a factor of two, however, because of the differences in the numbers produced. Induction motors are used very widely, and it may be expected that many will be used as induction generators because of such factors as good availability, reliability, and reasonable cost.

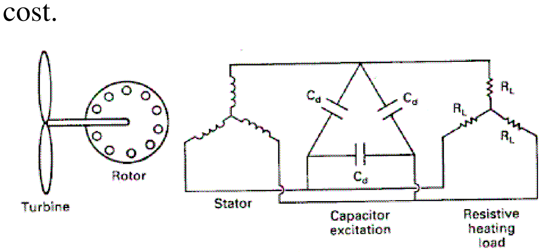


*Fig2. Self excited Induction generator*

*D. PIC Microcontroller:*

The microcontroller that has been used for this is from PIC series. PIC microcontroller is the first RISC based microcontroller fabricated in CMOS (complimentary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory. The main advantage of CMOS and RISC combination is low power consumption resulting in a very small chip size with a small pin count. The main advantage of CMOS is that it has immunity to noise than other fabrication techniques.

PIC(16F877):Various microcontrollers offer different kinds of memories. EEPROM, EPROM, FLASH etc. are some of the memories of which FLASH is the most recently developed. Technology that is used in pic16F877 is flash technology, so that data is retained even when the power is switched off. Easy Programming and Erasing are other features of PIC 16F877.

Here microcontroller is programmed for maintaining the output level to set point voltage. This may get through by producing a PWM in the microcontroller. The width of the pulse is varied over output voltage getting.

*E. Keypad, LCD display:*

The output voltage is changed by means of keypad connected to the microcontroller and is displayed using LCD display.

## V. **FUNCTION**:

The output voltage is measured through potential transformer. The output from potential transformer is then amplified and then given to analog to digital converter. That digital output is processed in the microcontroller. It will check the set voltage over the output voltage obtained from the induction generator of wind turbine and produce the PWM pulse according to that. This pulse is given to MOSFET driver circuit. In MOSFET circuit, we turn on the MOSFET according to pulse ON period. It will produce dc output which is given to rectifier circuit. Then the rectified dc voltage is taken as output. We are using sliding mode control technique to improve the power.

## VI. **CONTROL OBJECTIVES IN A SLIDING MODE WIND GENERATION SYSTEM**

The control objective in a Sliding mode control wind generating system is to take into account all three control aspects, i.e. rise, output power and efficiency.

The first control objective is to limit the voltage rise. This can be achieved by controlling the PWM converters in a Sliding mode configuration.

The second control objective is to capture maximum power from the wind. In Fig. 3, a typical power versus speed curve of a wind turbine is plotted. For a given wind speed, the mechanical output power of the wind turbine is maximum at a particular rotor speed. The best way to control the rotor speed is to change the frequency of the induction machine terminal voltage using the PWM rectifier. The current controlled PWM rectifier allows the change of terminal voltage frequency without affecting the system frequency.

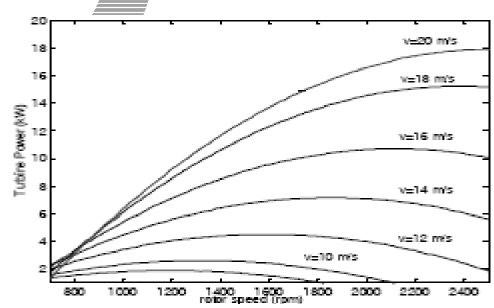


*Fig 3. A typical power Vs Speed curve in wind turbine*

The third control objective is to maximize the induction machine efficiency. The efficiency of an induction generator is a function of the rotor speed and the flux. As the optimum rotor speed at each instant is determined by the power speed characteristics of the wind turbine, the only way to improve the efficiency is to adjust the flux. During light load running conditions, the machine rotor flux can be reduced to reduce the core loss and therefore increase efficiency. When the rotor flux is decreased, the stator current should be increased to keep the torque or speed constant, but any increase in current results in higher copper loss. Power loss (core loss plus copper loss) vs. flux characteristics at different speed (torque) levels for a 20Hp, 220V, 60Hz, 4-pole induction machine is shown in Fig. 4.

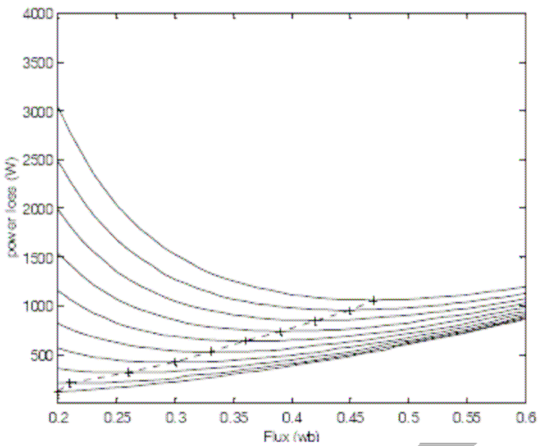


*Fig4. Power loss vs flux for different rotor speeds*

For a given torque (rotor speed) the optimum efficiency (minimum power loss) is obtained for a particular flux.
Fig. 4is obtained by first considering a range of variations for flux and torque. For each torque and flux, the direct and quadrature currents and therefore the magnitude of the current can be calculated. The copper loss can be calculated by $P_{cu} = R_s \cdot |Is|^2$ and the core loss can be approximated by: $P_{core} = K_c \cdot |\varphi|^2$.

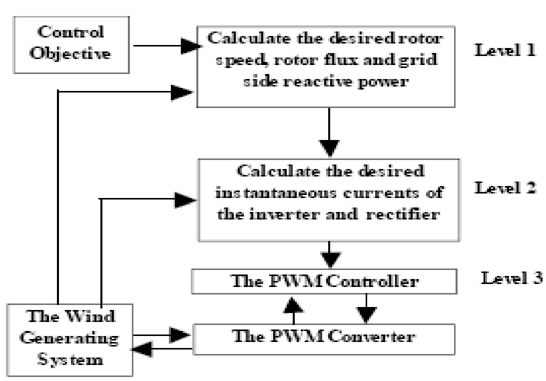


*Fig 5. General structure of the controller*

VII. **CONCLUSION:**

A complete sliding mode control based wind generation system has been described. Thus there is control of wind turbine with change in wind velocity which in turn causes change in voltage. A sliding mode control is developed which develops a compromise between conversion efficiency and torque oscillation smoothing. The resultant sliding dynamics is completely robust to uncertainties in the electrical variables and parameters.

For variations in the resulting voltage due to changes in wind velocity is controlled by means of MOSFET circuit(boost converter) and hence voltage is maintained stable employing the concept of sliding mode. Since employing this technique improves the power, efficiency is also increased.

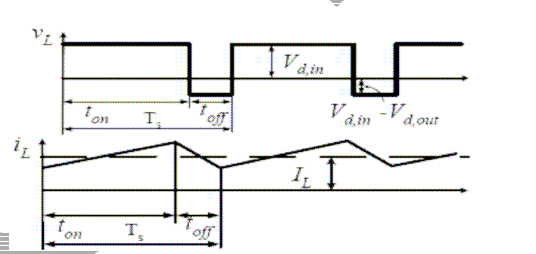


*Fig 6.Steady state waveform of boost converter*

Microcontroller is so programmed to effectively control the DC link voltage to be around the reference value (say 730V). Controlling the DC link voltage to be constant ensure the energy balance between the input and output power. The control system has the following commands:

| | | |
|---|---|---|
| If $V_{d,out} > 730$ Then: | Increase modulation index $m_a$ | Decrease duty ratio $D$ |
| If $V_{d,out} < 730$ Then: | Decrease modulation index $m_a$ | Increase duty ratio $D$ |

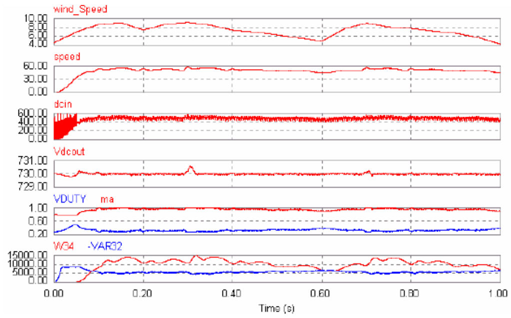


*Fig 7. Waveforms obtained on application of sliding mode technique*

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