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Grid Connected Wind Power Generation Controlled by FLC

Venugopal Reddy Bodha*, A. Srujana and O. Chandra Sekhar*****

Abstract: This paper defines a novel design method of controlling the wind power generation system. The main problems associated with wind power generation are variable availability of wind, tower shadow effects and wind shear which cause fluctuations in generated voltage and currents in wind mills. These fluctuations may produce flickers in network voltages, results in synchronization failure. These problems are greatly overcome by operating the voltage source converter (VSC) based DC link with fuzzy logic controller proposed here, which can control reactive power effectively and enhances the system performance.

Keywords: Wind turbines, power converters, fuzzy controllers, VSC-DC link.

1. INTRODUCTION

It is a known fact that fossil fuel energy sources presented by nature to mankind are exhaustible one day or the other as they are available in limited quantity. Owing to this, the international oil price, coal and gas production are going high beyond their threshold. Because of this implied fact, renewable sources of energy are in huge demand complemented by the advantage of absence of hazardous emissions like carbon dioxide and sulphur dioxide. Water, wind, sun energy and biofuels are the various renewable energy sources contributing to current energy demand. But initial cost associated with hydroelectric power plants is huge and also the plants operational time is very high to reach its maximum efficiency. Similarly sun energy can only be extracted effectively only in the presence of sun. Therefore it is highly impractical to set up solar power plants in places of heavy rainfall or poor sunlight. These reasons along with its attributes like low operation cost, pollution free nature made wind energy a promising alternative to conventional sources of power. Modelling and improved simulation methods were developed along with advances in wind generation [1]. Many new technologies such as pitch control and variable speed control methods have been tested and put forward since then. Asynchronous and synchronous ac machines are the main generators that are used in the wind turbines [2]. A wind turbine extracts kinetic energy from the wind and converts it to mechanical energy which is fed as an input to generator whose output is electrical energy.

In Wind Energy Conversion System (WECS) grid side converter uses vector control technique using traditional PI controller [3]. Numerous researchers have done extensive work to make the dc link capacitor voltage constant regardless of any occurrence of grid faults. New techniques have been applied to make the performance of the grid side even better. The extensive study regarding power or amount of energy available in the wind that can be converted to useful mechanical and then finally transforming into electrical form of energy. The terms such as tip speed ratio and also the betz coefficient have been defined and the equation described in [4] shows that the term power coefficient is highly nonlinear because it changes with the change in the wind speed. The paper [5] represents a parabolic path which depicts the relationship between output power and wind speed. Various controlling techniques are applied to control the functions of the wind turbine [6]. The performance and modelling equations of a double fed induction generator

* Research Scholar, EEE Dept, KL University, Vaddeswaram, Guntur. *Email: venugopalreddyphd@gmail.com, Contact No: 9347590794*

** Principal & Professor in EEE Dept, Sri Venkateswara Engineering College, Suryapet. *Email: srujanaa@yahoo.com*

*** HOD & Professor in EEE Dept, KL University, Vaddeswaram, Guntur. *Email: sekhar.obbu@gmail.com*

have been governed by the nptel lectures and paper [7]. After studying various control techniques, finally a PI control method was implanted to make the *dc* link voltage constant. However the system suffers from variations in voltage as it is difficult to tune the PI control, a new improved technique was applied known as the fuzzy logic control technique.

2. WIND POWER GENERATION

Basically wind turbines are of two types one is fixed speed and the other one is a variable speed wind turbine. Out of these variable speed wind turbine (VSWT) can facilitate a wide range of power generation. The permanent magnet synchronous generator (PMSG) based wind farms have high efficiency and it is having a high fault ride through capability [8]. The back-to-back conversion set was included in the integration of PMSG based WECS in between the rotor of PMSG and grid. Due to variable speed wind turbine utilization, frequency is the effecting factor. This can be overcome by controlling the back to back set firing pulses [9]. This can give a constant frequency of the variable speed machine. The vector control technique is used in PMSG, it can facilitate a variety of operations among real and reactive power, and WECS is shown in fig1. Variable wind turbines are using two controlling methods to extract maximum power from available wind speeds; one is tip speed ratio control (TSR) and pitch angle control [10]. Pitch angle control can adjust the blade to change the angle of attack to extract maximum energy. With combination of these reactive power controls are used to monitor power generation. The conventional PI controller is used to perform error controlling action [11]. PI can take some delay time to reach steady state. Fuzzy is proposed as it can perform better than PI due to its rule base operation.

The main disadvantages of WECS are the power fluctuation, the main cause for those power fluctuations are variation in available wind speed and yaw errors [12]. Variable speed wind turbine is widely used as a prime mover input for WECS than fixed speed wind turbine due its high power conversion efficiency. The operating range of variable speed wind turbine is from cut-in to cut-off (example: 5-16 m/s). Along this range all wind variations are considered for power conversion. These power variations can exhibit fluctuation on voltage of the network. The fluctuating voltage can cause flicker effect on grid integrated power system. The variable speed wind turbines can control the variations in wind speed, effectively than fixed speed wind turbine.

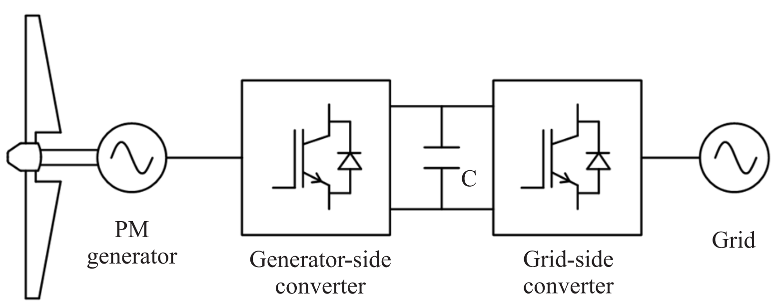

Figure 1: Variable-speed wind-energy conversion system

The wind variations are continuously monitored and controlled by using pitch angle control (β) and tip speed ratio control (α). By using these two controlling techniques prime mover output can manage continuously by creating air turbulence on blades. The flicker effect can control up to some extent, and other is by controlling reactive power.

Here voltage source converter (VSC) based back-back DC link is used in wind power integration. These VSC's have some special advantages, among that the main is it can facilitate to control active and reactive power individually.

3. PROPOSED METHOD

Voltage source converter (VSC) based DC link back-back wind energy conversion system with fuzzy logic controller is proposed in this work. VSC-DC link transmission can be easily implemented in multi-terminal topologies. VSC-DC link offers advantages as they can recover and stabilize rated *ac* voltage and frequency without introducing expensive electronic equipment (STATCOM or SVC). The WECS is equipped with a variable-speed PMSG and it is connected to the grid through power electronic interface which consists of 2 VSCs, Grid side converter and Generator side converter. The voltage fluctuations are minimized by controlling the converters input signals. The signals to the converters are given through fuzzy logic controller.

Fuzzy controller has been suitably involved in the designing of the fuzzy inference system (FIS). In the present system, the designing has been implemented with the mamdani type technique that maps the input characteristics to input membership functions. Fuzzy inference is applicable to only modeling system whose structure is designed by the users is as shown in Figure 2.During calculations, the variations in the variables are modified with a gradient vector, which has been used as reference to the FIS to measure the input/output data in correspondence with the pre-determined parameters. The controller takes measured values as inputs to do a particular task. To maintain PMSG synchronism with grid, the voltage, phase angle and frequency are same for these two. This can be achieved by comparing measured values with reference value. The measured PMSG voltages and currents are compared with reference values, then the error between these two and change in error taken as an input to FLC controller.

The reactive power control can be achieved by converters which are operates in specified time intervals then only desired controlled power generation is possible. Fuzzy is an auto tuner, it tunes the PI values automatically and controls the output exactly based on error and designed member ship function.

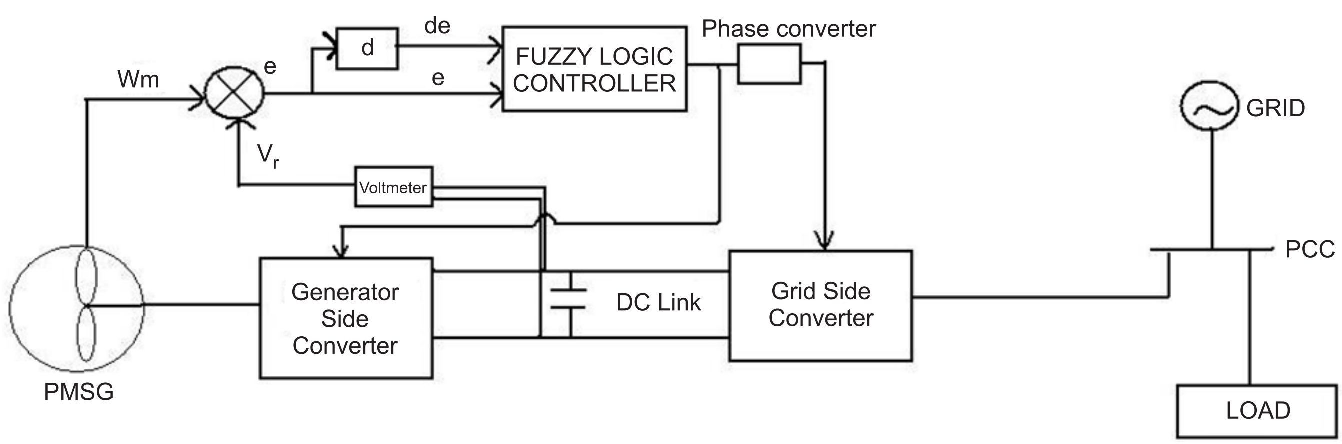

Figure 2: Block Diagram of Proposed Method

Fuzzy logic controller (FLC) is rule based system; the rules are framed to perform complex functions in various fields of applications including error reduction. The most probably mamdani type of FLC is used. Which attempts to minimize error based on membership functions and fuzzy rules by adjusting each value of a network proportional to the derivative of error with respect to that value.

Seven linguistic variables for each input variable are used. These are NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZR (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The control rules subject to the two input signals and the output signals are listed in Table 1. Inputs and output all are normalized in the interval of [–1, 1] as shown in below Figure 3.

Table 1
Control Rules of the FLC

de / *e*	*NB*	*NM*	*NS*	*ZR*	*PS*	*PM*	*PB*
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZR	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

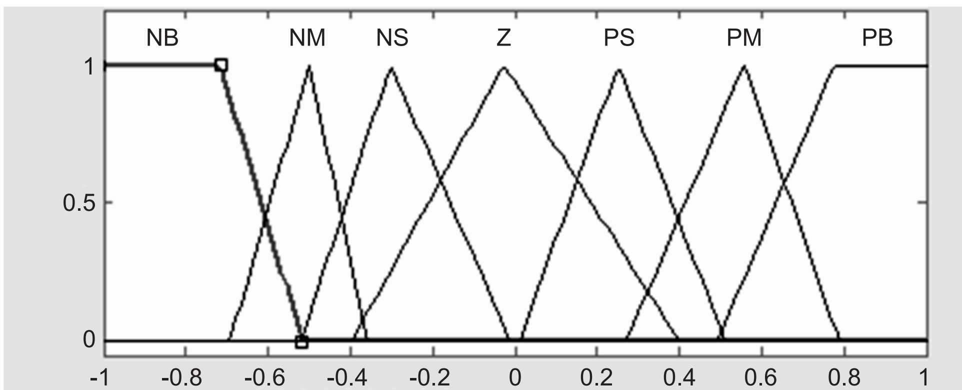

Figure 3: Membership functions of Output

These fuzzy rules are obtained from the basic knowledge about the entire system. In this, each control input contains seven fuzzy sets so that it has at most 49 fuzzy rules. These rules define the relationship between input and output, and thus explains the control strategy.

4. SIMULINK RESULTS

The complete schematic diagram of grid connected WECS is shown in Figure 4. Here PMSG is used to generate electrical output. The proposed system is simulated in MATLAB/Simulink.

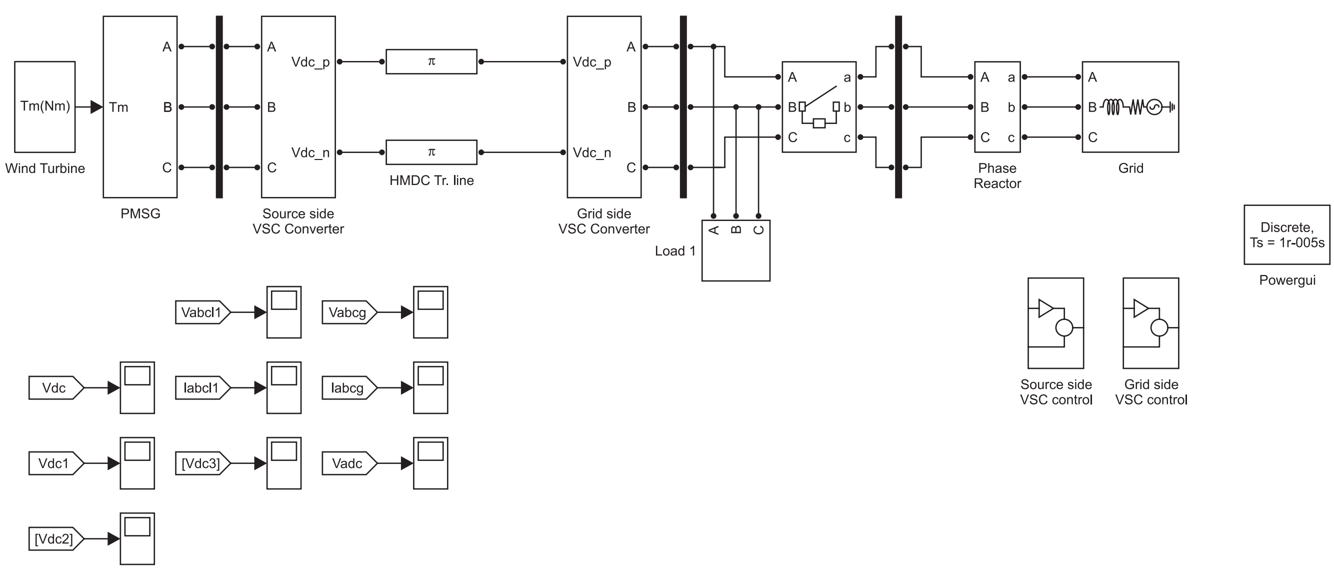

Figure 4: Schematic diagram of grid connected wind energy conversion system

The Output waveforms of the wind power generation voltages, grid voltage and load voltages and currents are shown in following Figure 5, Figure 6, Figure 7, and Figure 8.

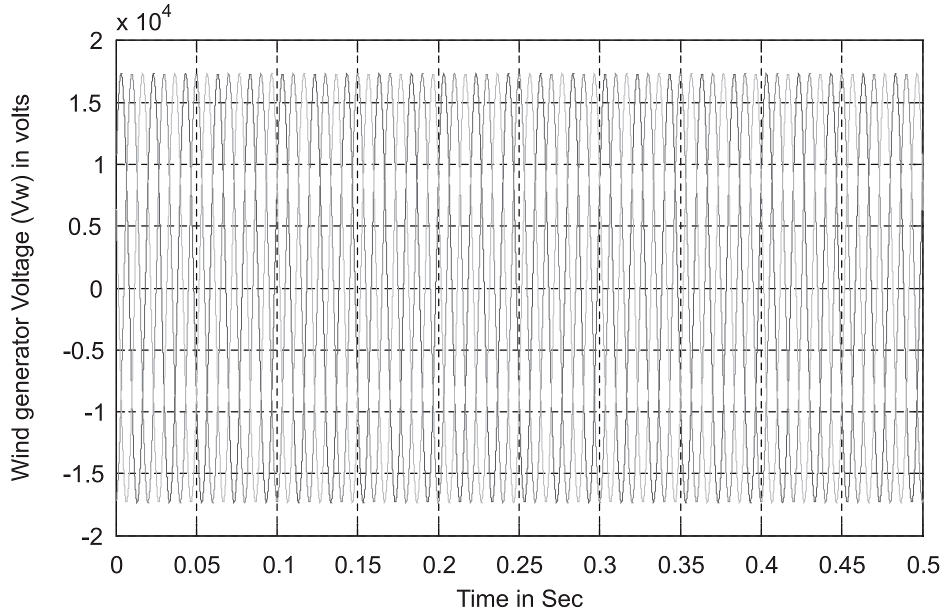

Figure 5: Fuzzy controlled output voltage of wind power generation

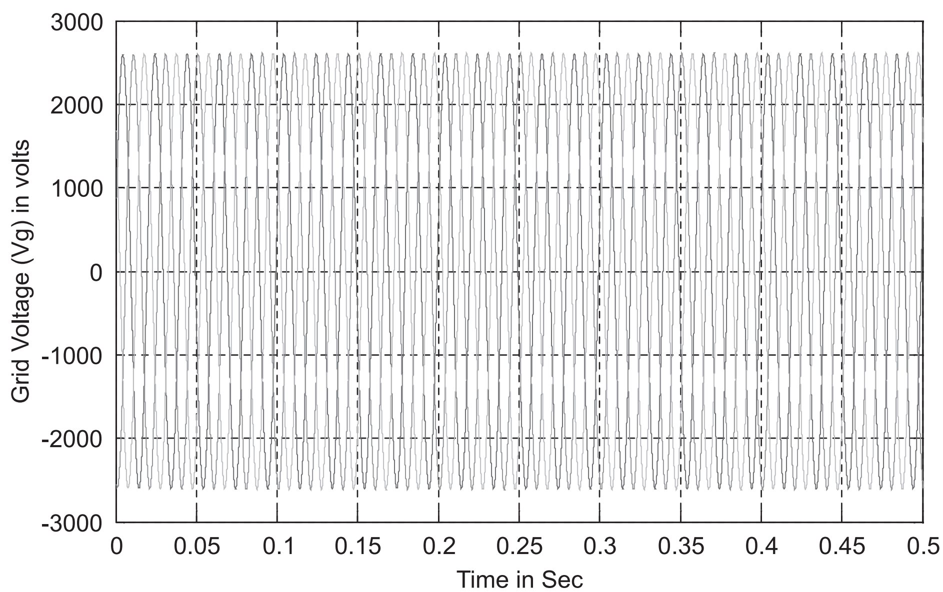

Figure 6: Grid voltage

By observing the results it is clear that, a constant controlled wind power generation (generation side) is achieved by employing fuzzy proposed scheme. Voltage flickers, voltage dips at load voltage is removed at load side.

As shown in Figure 9, the conventional PI control method produces the system dynamic response with overshoot 15% where as the proposed FLC system reduces the overshoot, there by increases the dynamic response of the system.

5. CONCLUSTION

The variable speed WECS was integrated with grid using VSC-DC link. The variable speed wind turbine can controls variations in wind speed by using pitch angle and TSR. It can perform up to some extent only,

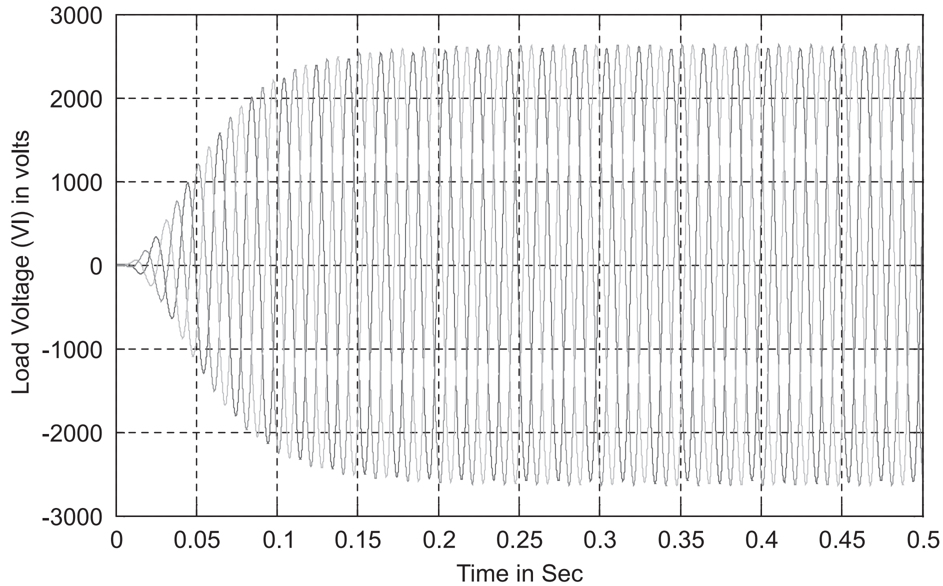

Figure 7: Load voltage

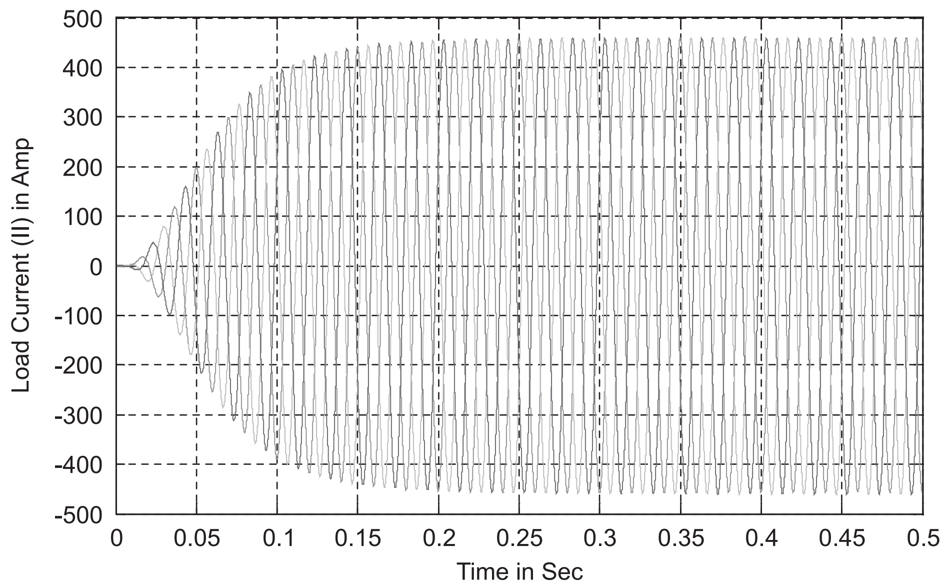

Figure 8: Load current

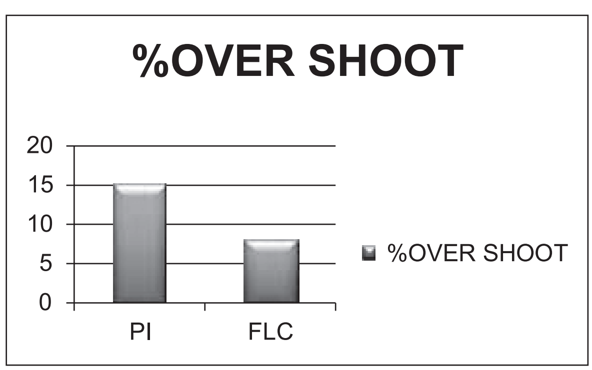

Figure 9: Comparison of conventional PI and FLC

so to mitigate or to reduce flicker effect formation in grid integrated WECS network, by controlling the reactive power of the system. Here VSC system was introduced for integration, it can facilitate to control active and reactive power individually. The VSC converter can control an effective inner current controller and an outer voltage control loop. Basically PI controllers are used for error control for control loops. The PI based controller can reduces the flicker effect in grid integrated system. The proposed system introduces fuzzy logic controller (FLC) for error mitigation, due to its fast acting, high stability and error closer to zero, system performance was increased significantly. The simulation results were obtained which validates the features of the proposed work.

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