ISSN 2348 – 9928
IJAICT Volume 4, Issue 11, November 2017 Doi:01.0401/ijaict.2015.09.05 Published on 05 (11) 2017

FUZZY LOGIC ALGORITHM BASED TO REGULATE THE FREQUENCY IN RENEWABLE WIND ENERGY RESOURCES

Ms. N. Kavithamani
PG Scholar,

Ms. P. Priya,
PG Scholar,

Prof. N. R. Nagaraj
Associate professor,

Electrical and Electronics Engineering,
RVS College of Engineering and Technology,
Coimbatore, Tamilnadu, India

Abstract— ***The last decade the use of renewable energy source has greatly increased because of the integration of wind energy into power generation system and found to be in field of research at present. The wind farms are located at the areas of low wind speed so, their frequency regulation energy will be limited at that time of operation. A control strategy for a wind farm will play an important role at this situation to provide its capabilities in frequency regulation. The proposed paper presents control method for regulating the frequency of power generated from the wind farm using fuzzy controller algorithm in order to achieve optimal power deliverance to the grid without any disturbances. The key feature of this approach is that each wind turbine can react to grid disturbances in a different way, which depends on wind speed as seen by the wind turbine itself and by its dynamical conditions. The maximum power point tracking (MPPT) method for the wind farm using Fuzzy will deliver maximum electric power with high efficiency.***

Keywords— ***Maximum Power Point Tracking (MPPT), Fuzzy Logic controller(FLC), Fuzzy Logic Algorithm Rules, Primary Frequency Regulation.***

I. INTRODUCTION

The control of the power grid is of primary importance, especially now that renewable energy sources (RES) have widely spread. Large-scale wind farms (WFs) can contribute to variation in the generated active power in order to help the grid to recover from under- and over frequency conditions. Many control strategies have been proposed to achieve these results. In [9], a probabilistic approach of the aggregate inertial response of a WF is proposed for the estimation. The authors state that to provide the method for estimating the aggregate inertial response and considering constant wind speeds during transients is inadequate of WF, even though considering the same profile for each wind turbine. In [10], a centralized control approach is developed by traditional proportional integral (PI) controllers whose gains are varied in a fixed way during transients in Kinetic energy response. Wind turbines are set to a constant large value for a preset discharge time (3 s) in order to let the wind turbines deliver their support. The recovery times are different for each wind turbine but are arbitrarily set before the transient occurs. Moreover, should involve a significant trial and error phase and tuning of the gains of the PI controllers is critical. In [4] and [6], frequency support is achieved through the use of a high-pass filter (HPF). This is overcome one of the main problems of droop controllers, which require wind turbines to provide steady-state contribution to operate at derated conditions. The presence of a zero in the transfer function of the filter ensures that the filter itself does not give any contribution in steady-state operation.

In addition to this, to avoid a fast change for the output power of the wind turbines, the deactivation of the control is equally critical and suitable actions should be designed. The proposed control strategy exploits the model predictive control (MPC) approach [11], coupled with an estimation of the wind, for the definition of the contribution to frequency regulation of each wind generator. The main contribution is the combination of different techniques (i.e., KF and MPC) to estimate the variation in load and the actual operating conditions of each wind turbine and to define the optimal set point for each of them to effectively contribute to reduce frequency variation without hitting their operational limits.

The proposed method is designed with a control method for regulating the frequency of power generated from the wind farm using fuzzy controller with MPPT algorithm in order to achieve optimal power deliverance to the grid without any disturbances. The maximum power point tracking (MPPT) method for the wind farm using Fuzzy will deliver maximum electric power with high efficiency. In this paper, a Fuzzy based control logic approach is studied. The proposed control strategy exploits the Fuzzy control logic algorithm approach [11], coupled with an estimation of the wind, for the definition of the contribution to frequency regulation of each wind generator.

The main contribution of this paper is to estimate the variation in load and the actual operating conditions of each wind turbine and to define the optimal set point for each of them to effectively contribute to reduce frequency variation without hitting their operational limits. Moreover, the proposed approach has been tested in a software-in-the-loop framework [1].

This paper is structured as follows. In Section II, the implemented power system models are outlined. In Section III, the designed control strategy, based on Fuzzy logic control theory, is described. Fuzzy controller is disabled in normal operation conditions. But its task is to set the power reference for each wind turbine, overwriting the local reference, when a disturbance occurs. The fuzzy controller is estimating the external load variation, and output voltage is calculated by comparing the reference voltage and input voltage using fuzzy logic based rules. In Section IV, the design of fuzzy control rule based simulation. Finally, in Section V, the obtained results are discussed.

II. POWER SYSTEM MODEL

The power system model is implemented using Lab VIEW Power Factory environment. The model includes static and dynamic models of the components and the controllers.

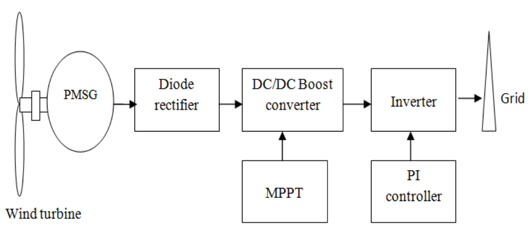

Fig 1: Power system model

This paper proposes the maximum power for wind energy conversion systems based on permanent magnet synchronous generators. Generator output is converted into dc by using diode bridge rectifier. Then the dc output voltage is given to voltage source inverter. Here using MPPT controller to extract the maximum power. By using three point comparison algorithms, maximum power corresponding to any wind velocity can be captured. But the time taken to reach MPP is long and a considerable amount of power loss takes place during the tracking phase. The output dc power is controlled by additional grid side inverter using PI controller technique.

The rotor aerodynamics are presented by the well-known static relations in equation (1)

$$p_w = c_p \frac{1}{2} \rho A v w^3 \qquad (1)$$

Where, P is the power extracted from the wind [W]

ρ is the air Grid density

c_p is the power coefficient

v_w is the wind speed upstream of the rotor [m/s] and

A is the area swept by the rotor [m^2] ($A=\pi R^2$, being R the radius of the blade [m]).

The amount of aerodynamic torque (τ_w) in Nm is given by the ratio between the power extracted from the wind (P_w), in W, and the turbine rotor speed (ω_w), in rad/s, as follows equation

$$\tau_w = \frac{p_w}{\omega_w} \qquad (2)$$

The general function defining the power coefficient (c_p)as a function of the tip-speed ratio and the blade pitch angle is defined as

$$c_p(\lambda, \vartheta) = c_1\left(c_2 \frac{1}{\beta} - c_3\vartheta - c_4\vartheta^x - c_5\right)e^{-c_6\frac{1}{\beta}} \qquad (3)$$

The parameter $\frac{1}{\beta}$ is defined by

$$\frac{1}{\beta} = \frac{1}{\lambda + 0.08\vartheta} - \frac{0.035}{1+\vartheta^3} \qquad (4)$$

Where ϑ is the pitch angle [°]

The tip-speed ratio λ is defined as

$$\lambda = \frac{\omega_w R}{v_w} \qquad (5)$$

Where ω_w is the angular velocity of rotor [rad/s], R is the rotor radius [m] and v_w is the wind speed upstream of the rotor [m/s].

When a wind turbine is operated at its optimum power coefficient (Cp)opt . This can be achieved by operating the turbine at Not all kinetic energy available from wind can be extracted by a wind turbine and hence power coefficient Cp is defined which is a function of tip-speed ratio λ, and pitch angle β is employed. Therefore, power captured from a wind turbine is given by (1). The typical turbine power characteristics and its MPPT curve described in (1)–(4) are shown in Fig. 2 The maximum power curve, the wind turbine generator initially operates at point A when the wind speed is v1 . If the wind speed changes from v1to v2 , then the turbine changes its power output from A to B. The wind generator cannot respond to this wind speed change quickly due to the inertia associated, thus retains the same electrical power (i.e., power at point A). As a result, the mechanical power input from the turbine to the generator is greater than its electrical power, causing the wind generator system to accelerate. This

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.09.05 Published on 05 (11) 2017

acceleration would lead mechanical power to follow the path from B to C (B → C) while generator power from A to C (A → C). Finally, the system becomes stable at point C. Stability of a wind turbine around its optimal 4 operating curve can be found. In this paper, the maximum power extraction from wind (Pw)opt is obtained using the indirect speed control technique.

$$Pa = ½Cp(\lambda, \beta)A\rho v3 \qquad (6)$$

λ: air density (Kg/m3)
A : swept area (m2)
CP: power coefficient of the wind turbine
V : wind speed (m/s)

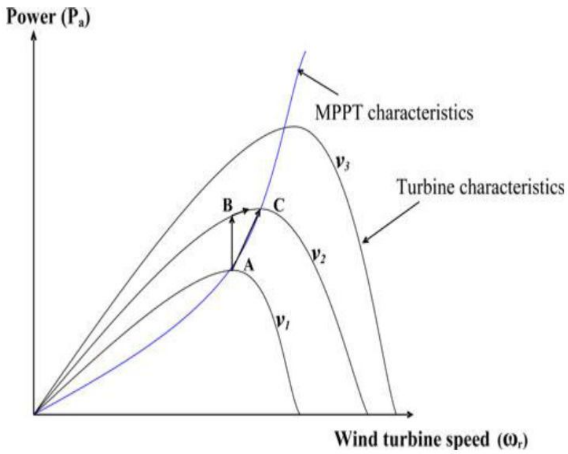

Fig 2: Wind turbine power characteristics with maximum power

MPPT controller sends the active power set point to the grid-side converter control according to a lookup table that maps the maximum power for every generator speed. Charge controllers are used in wind turbine systems to prevent the batteries from being overcharged. To implement a grid tie system, a charge controller is not necessary, as any excess electricity that don't use at any particular moment is sold directly back to the grid. However, for any battery setup, a charge controller is necessary as it prevents damage to the battery by monitoring the flow of electricity in and out.

If the system overcharges the battery it will damage them, the same is also true if you completely discharge all the charge held within the battery. Most charge controllers associated with Wind turbines have dump load capability associated with them. Most charge controllers are also equipped with maximum power tracking. The principle of it is to extract the maximum available power from the wind turbine by making them operate at the most efficient voltage.

III. CONTROL STRATEGY

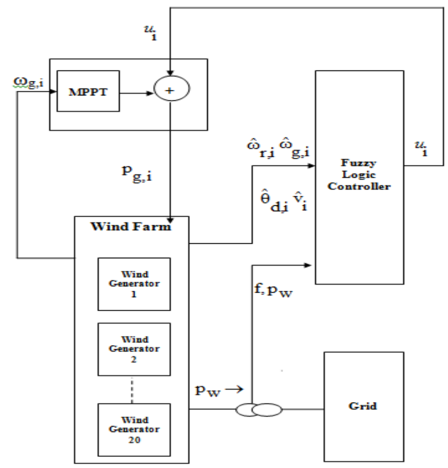

Fig 3: Proposed control model

The control structure proposed in this paper is depicted in Fig.3. It consists of a Fuzzy controller which receives the sampled measurements of the generators rotor angular speed, the pitch angle, the grid frequency variation, and the total power delivered to the grid by the whole WF.

The pitch angle control is independently determined by standard PI regulators which keep and under their nominal values. The WTs locally operate a conventional MPT regulation using a lookup table that defines the optimal power to be delivered to the grid for a given value of the measured rotor speed ω_i, i.e.$P_{g,i}=P^{*}_{g,i}(\omega_{i,g})$ The mission of the Fuzzy controller is to determine the variation from the MPPT signal in order to support the primary regulation when a significant frequency variation arises. The resulting control input for the WT is

$$P_{g,i}=P^{*}_{g,i}(\omega_{i,g})+u_i \qquad (7)$$

The additive control signal has to be computed by considering the wind conditions of each WT and guaranteeing the overall system stability. This is carried out through an Fuzzy control algorithm, which states the optimal tradeoff among the main control objective, which is the reduction of the frequency variation, and further specifications and/or system limitations. Where wind turbine characteristics are unknown, the controller algorithm brings the operating point towards by stepwise increases or decreases in the rotational speed of the wind turbine. This is known as the perturbation and observation method.

Generally, MPPT in this case is achieved using intelligent control methods. The most commonly used techniques are based on Fuzzy Logic controllers [8]. Block diagram of fuzzy logic controller is shown in Fig 4.

Corresponding Author: Ms.N.Kavithamani, RVS College of Engineering and Technology, Coimbatore, Tamilnadu, India.

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.09.05 Published on 05 (11) 2017

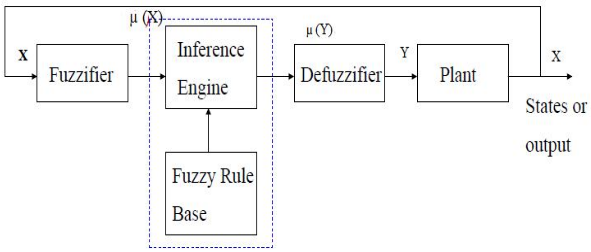

Fig 4: Block diagram of Fuzzy Logic controller

The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world. Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity. Wind speed error 'E' and error change rate 'EC' are used as fuzzy input and the modulation index 'm' as fuzzy output. The degree of truth of E is configured as 7 degrees, all defined as {VN,N,LN,Z, LP,P, VP}, and EC is configured as 3 degrees all defined as {N,Z,P} where VN,N, LN,Z,LP,P and VP represent very negative, negative, low negative, zero, low positive, positive and very positive respectively. In this paper 21 rules of fuzzy are proposed in this system. The control rules are listed in Table I.

Table I: The Control Rules

E ΔE	NB	NS	ZE	PS	PB
NB	NB	NS	NS	ZE	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PS	PB
PB	ZE	ZE	PS	PS	PB

The inputs to a MPPT fuzzy logic controller are usually an error E and a change of error ΔE as given equation respectively.

$$ref \; d \; E(n) = I - I$$

$$\Delta E(n) = E(n) - E(n-1)$$

This type of simple calculation is the first tool required for calculations of fuzzy logic operations. Rule evaluation is done by using an algorithm where loops compare the antecedent value depending on the rule being evaluated in a repeated fashion until all rules are evaluated.

IV. FUZZY CONTROL RULE

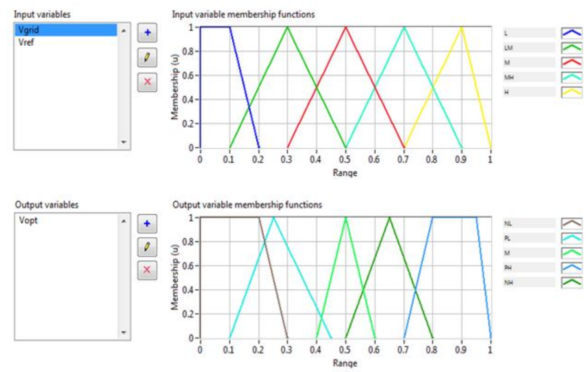

Fig 5: Fuzzy Design rule base variable

The fig. 5 shows the fuzzy design rule based variable. The rule base defines the relationship between grid voltage and reference voltage membership functions. The control rules are evaluated by the inference mechanisms. Shows the rule base of fuzzy logic controller the linguistic variables used are NL-Negative Low NM–Negative Medium NH – Negative High ZE- Zero PL- positive Low PM-positive medium PH - positive High.

The fig. 6 shows the Fuzzy control rule based system voltages The input variables of grid voltage and reference voltage of 20 sample points and its corresponding output voltage is simulated by fuzzy rule. If grid voltage is LM and reference voltage is M then output voltage is M. If grid voltage is LM and reference voltage MH then output voltage is MH.

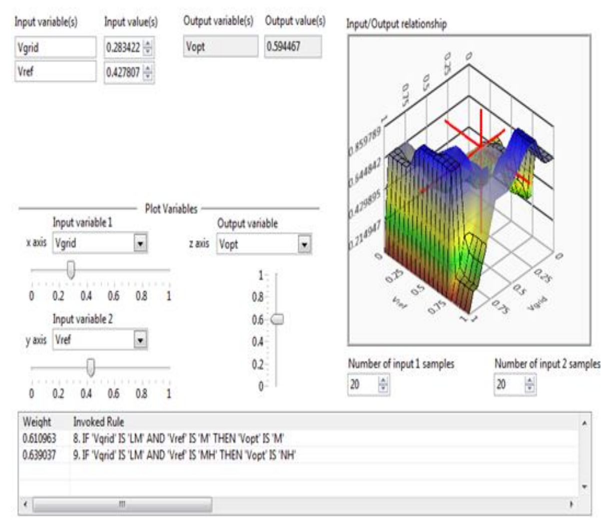

Fig 6: Fuzzy control rule based system voltage

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.09.05 Published on 05 (11) 2017

V. RESULTS

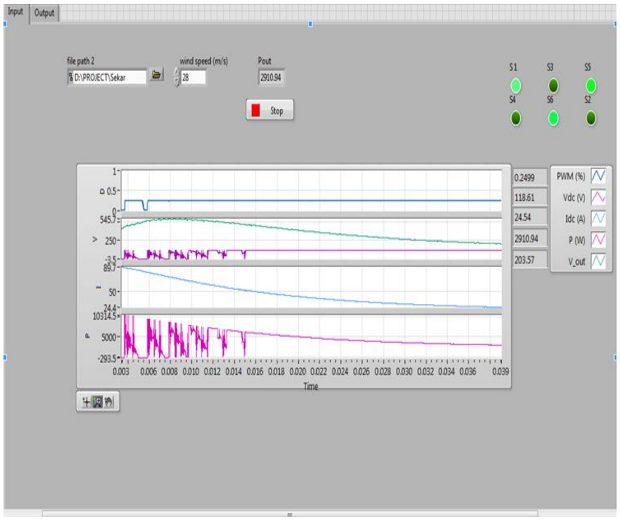

Fig 7: Simulation result of Current, Voltage, Power

The Fuzzy design is given in the file path. Based on fuzzy rules (IF-THEN) reference voltage and the grid voltage is compared and produced the output voltage. The Fig 7 shows the Simulation result of wind generator current, voltage, and power for corresponding wind speed of 28 m/s. The wind generator speed 28m/s is produced the corresponding voltage and current range is 118.61v and 24.54A. It is compared with MPC controller it improve the power range is 2910.94W Whole WF.

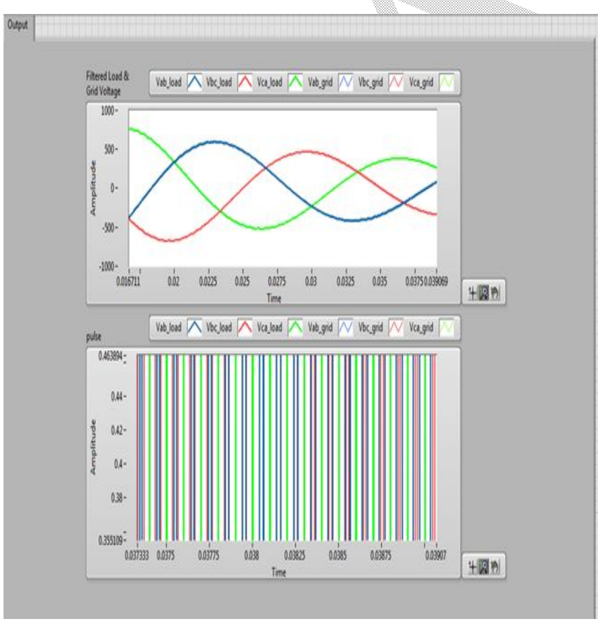

Fig 8: Simulation result of Frequency regulation

Finally, it is worth mentioning that by repeating the simulations with variations on parameters of 10% and 20%, the stability of the WTs is still kept. Fig. 8 reports the case of FLC-FS. When the over-load occurs, all speeds decrease, allowing the WF to deliver more power in about 10 s. After this phase, speeds increase toward the values determined by the MPT lookup table. Such acceleration is obtained by the lower power delivery which is occurring at the same time. Consider now the three emphasized WTs. When the over-load occurs, they have different angular speeds: the green one is the fastest, the red one is the medium, and the blue one is the slowest. This is obviously due to different wind conditions because of the use of the MPT control.

If compared with the blue lines, which depict the corresponding speeds in the case without frequency support, it is clear that the speed variations are similar for the fastest and medium cases and lower in the slowest case. The similarity between the two first WTs means that the MPC operates the expected coordination of the aeroturbines. In fact, the deceleration of the faster WTs is obtained with a higher power delivery, as shown in the FLC demands more power to the faster WTs, which have a larger kinetic energy reserve. For slower WTs, the deceleration is further limited since the rotor speed is too much close to the cut-in speed. This behavior is remarkable since it is due to the introduction of the constraint , $\omega_r^{cut\text{-}in} < \omega_{g,i} < \omega^{Nom}$ which is one of the key properties of the proposed FLC approach.

Finally, it is worth mentioning that by repeating the simulations with variations on parameters of 10% and 20%, the stability of the WTs is still kept.

VI. CONCULTION

The primary frequency is regulated by using control technique through Fuzzy logic controller algorithm. The wind speed of each wind turbine and dynamical characteristics of wind turbine are estimated by fuzzy logic controller. Optimality is achieved by minimizing a cost function subject to set of constraints which define a physically consistent operating area. The fuzzy controller is measure the variation of maximum signal power of each wind turbine in order to support the primary frequency regulation when a signification frequency variation arises. The maximum signal power has to be computed by considering the wind conditions of each wind turbine and guaranteeing the overall system stability. This is carried out through the Fuzzy logic algorithm, which states the optimal trade off among the main control objective, which is reduction of the frequency variation, further specifications and/or system limitation.

Corresponding Author: Ms.N.Kavithamani, RVS College of Engineering and Technology, Coimbatore, Tamilnadu, India.

ISSN 2348 – 9928
Doi:01.0401/ijaict.2015.09.05 Published on 05 (11) 2017

References

[1] Francesco Baccino, Francesco Conte, "An Optimal Based Control technique to Improve the Participation to Frequency regulation", IEEE Trans

[2] J. Lin, Y. Sun, Y. Song, W. Gao, and P. Sørensen, "Wind power fluctuation smoothing controller based on risk assessment of grid frequency deviation in an isolated system," IEEE Trans. Sustain. Energy, vol. 4, no. 2, pp. 379–392, Apr. 2013.

[3] C. Rahmann et al., "Justified fault-ride-through requirements for wind turbines in power systems," IEEE Trans. Power Syst., vol. 26, no. 3, pp. 1555–1563, Aug. 2011.

[4] G. Ramtharan, A. Arulampalam, J. Ekanayake, F. Hughes, and N. Jenkins, "Fault ride through of fully rated converter wind turbines with AC and DC transmission," IET Renew. Power Gener., vol. 3, no. 4, pp. 426–438, Dec. 2009.

[5] S. Grillo et al., "Transient support to frequency control from wind turbine with synchronous generator and full converter," in Proc. 45th Int. Univ. Power Eng. Conf. (UPEC), Sep. 2010, pp. 1–6.

[6] D. Xiang, L. Ran, P. Tavner, and S. Yang, "Control of a doubly fed induction generator in a wind turbine during grid fault ride-through," IEEE Trans. Energy Convers., vol. 21, no. 3, pp. 652–662, Sep. 2006.

[7] L. G. Meegahapola, T. Littler, and D. Flynn, "Decoupled-DFIG fault ride through strategy for enhanced stability performance during grid faults," IEEE Trans. Sustain. Energy, vol. 1, no. 3, pp. 152–162, Oct. 2010.

[8] Galdi V., Piccolo A. and Siano P., "Designing an adaptive fuzzy controller for Maximum wind energy extraction," IEEE Transactions on Energy Conversion, vol.

[9] L. Xie et al., "Wind integration in power systems: Operational challenges and possible solutions," Proc. IEEE, vol. 99, no. 1, pp. 214–232, Jan. 2011.

[10] L. Wu and D. G. Infield, "Towards an assessment of power system frequency support from wind plant—Modeling aggregate inertial response," IEEE Trans. Power Syst., vol. 28, no. 3, pp. 2283–2291, Aug. 2013.

[11] D. Mayne, J. Rawlings, C. Rao, and P. Scokaert, "Constrained model predictive control: Stability and optimality," Automatica, vol. 36, pp. 789–814,2000.