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Hybrid Fuzzy Logic Controller for Improving Voltage Stability of Grid Connected SCIG Wind Turbine

Pankaj Bhakre[1],A.G.Thosar[2]
Assistant Professor, Dept. of EE, MSS college of Engineering & Technology Nagewadi Jalna, Maharashtra, India[1]
Professor, Dept. of EE, Govt. Engineering college Aurangabad, Maharashtra, India[2]
Corresponding Author: Pankaj Bhakre

Abstract: *Depleting in the fossil fuel and increasing the demand of renewable energy sources have forced researchers to study the concept nonconventional energy sources and explore the best potentials associated with it. Wind turbine and micro hydro turbine with induction generator are considered as alternative choice for fossil fuel depletion. Fixed speed wind turbine is common problem in wind power plants. In fact, being equipped with a squirrel-cage induction generator (SCIG), they tend to drain a relevant amount of reactive power from the grid, potentially causing voltage drops and voltage instability. Wind turbines with isolated mode and with grid connected mode induction generator are being used to generate electrical energy. Grid conneted induction generator found more application as it requires no external excitation. However wind turbine being equipped with SCIG draw large transient currents, sometimes more than machine rated current when it is connected to utility grid. This condition affects on power system when voltage fluctuations occurs thus the continuity of power generation suddenly decreases. Disturbance may be due to fault condition or due to utility grid. To improve SCIG transient stability, this paper investigates a new control strategy for pitch angle control based on proportional-integral (PI) controller and a fuzzy logic controller (FLC). This paper focuses mainly on comparative analysis of hybrid fuzzy logic controller and PI controller which helps to improve transient stability of grid connected SCIG wind turbine. 3 MW wind turbine model developed and simulation results are implemented here through MATLAB software.*

Keywords: *voltage stability, model of grid conneted induction generator, PI controller, Hybrid fuzzy logic controller*

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I. INTRODUCTION

Wind Power technology is one of the most emerging nonconventional source of energy which can be considered as alternative choice for conventional energy sources. Nowadays so many efforts are made to develop wind farms directly connected to grid. Induction generator consisting squirrel cage has become popular for generating power because of reliability, low cost and robustness for harsh environment.[1] These induction generators are generally connected at weak end of grid which usually draws maximum reactive currents during faults. Due to these disturbances the terminal voltage and electrical output power decreases. After the fault clearance, generator needs more reactive power for voltage recovery. This reactive power should be supplied by the network which in turn causes the voltage drop. Hence machine terminal voltage cannot be recovered. If this voltage is not recovered then generator will continue to accelerate rotor speed and reactive power consumption will increase which will decrease terminal voltage. If the rotor speed becomes greater than some critical speed then it may be disconnected from the grid hence whole system may collapse. Hence stability plays an important role in power systems [2]. Along this few challeges are to be penetrated into the power systems when SCIG is connected to grid.one of the important challenge is related to the wind speed which is variable every time.This speed variation affects on generated power of SCIG to fluctuate. Due to this voltage start flickering. This can cause instability in voltage[3]

Many authors and researchers discussed about the transient stability analysis and its mitigation technique. Power system transient stability is related to the ability to maintain synchronism when subjected to a severe disturbance, such as a three phase fault or short circuit on a bus. The resulting system response involves large excursions of the generator rotor angles and is governed by the nonlinear power–angle relationships. Transient stability assessment essentially determines whether the system can reach an acceptable steady-state operating point in post-fault operating stage. Amutha, N.; Kalyan Kumar B[4] discussed the stability of a post-fault power system can be determined by checking the fault-on trajectory at clearing time. If it lies inside the stability region of a desired stable equilibrium point of the post-fault system, then the system is stable. L.

Dusonchet, F. Massaro and E. Telaretti[5] discussed about the voltage stability behavior of a fixed speed wind turbine (FSWT) connected to the grid, after a short-circuit fault in the power network. Li Jianlin, Liang Liang, yangshuili, Hui Dong[6] describe about wind power fluctuations and its impact on grid. Mohsen Rahimi and Mustafa Parniani[7] have investigated the dynamic behavior of FSWT under wind speed fluctuations and systems disturbances. Olof Samuelsson and Sture Lindahl[8] briefly explain the on speed stability for induction generator also describes the phenomenon for speed stability and provide a tentative definition. H. Li B. Zhao, C. Yang H.W. Chen Z. Chen [9] discussed the transient models of the wind turbine generation system including the flexible drive train model based on the direct transient stability estimation method. A method of critical clearing time (CCT) calculation is developed for the transient stability estimation of the wind turbine generation system. Walmir Freitas, Andre Morelato, and Wilsun Xu[10] present the issue of short term voltage instability and improvement voltage instability by braking resistor. Daniel Trudnowski[11] mention about the problem of fixed-speed wind-generator based on transient stability studies. This problem of stability is evaluated by Wind Park modeling technique.Pankaj Bhakre and A.G.Thosar [12] discussed the different stability issues occurring in grid connected SCIG wind turbine.

There was analytic method to analyze the large disturbance stability of induction generator. Ahda Pionkoski Grilo, Alexandre de Assis Mota, Lia Toledo Moreira Mota [13] explained analytical method for analysis of large-disturbance stability of induction generators. In this literature the mechanical torque was assumed to be constant during the fault occurance. Few more research had been carried out to improve transient stability and found that the FACTS devices like STATCOM, dynamic voltage restorers DVR, braking resistor and plugging mode methods are suitable to improve stability of SCIG grid connected systems. Obando-Montano, A.F Carrillo, C. Cidras, J. Diaz-Dorado E [14] explained about STATCOM based transient stability improvement. FACTS devices improves rotor speed stability and voltage during fault disturbances. But FACTS devices are considered to be expensive. Ahmed Abu Hussein and Mohd. Hasan Ali [15] explained Comparison among Series Compensators for Fault Ride through Capability Enhancement of Wind Generator Systems. Amutha, N., Kalyan Kumar, B[16] explained the method for improving fault ride-through capability of wind generation system using DVR. Freitas, W,Morelato, A Xu, W [17] the solution obtained is applied to controlled external resistance which is connected to rotor winding and another one is used to control the rotor voltage. However this scheme is suitable for wound rotor only and not for SCIG WT. The BR decreases the rotor speed and absorbs electrical power during the grid fault, and thus improves transient stability. The method implemented using BR is already used for improvement of stability analysis of synchronous generator. However the SCIG is different from synchronous generator hence BR is less effective for stability improvement of SCIG. Another method used previously for stability analysis of grid connected SCIG was plugging mode method. Zamani, M.; Fathi, S, Riahy, G, Abedi, M, Abdolghani, N[18] explained in plugging mode that machine produces reverse electromechanical torque opposing the mechanical torque which wastes kinetic energy in terms of heat in rotor winding causing the rotor speed to be decreased. T.Maheswaran, M.Venkateswaran[19] explained transient stability improvement by plugging mode operation of grid connected squirrel cage induction generator. The intensive flow of current in plugging mode can cause damage to rotor and stator winding.. All the above mentioned methods which was used previously for transient stability analysis of SCIG needs additional equipments such as SVC, STATCOM, BR, DVR, UPFC. Due to this, these methods are foumd to be less efficient in economic point of view.

In previous work [20], author proposed the hybrid fuzzy logic controller based on propotional integral (PI) and fuzzy technique for normal as well as for fault condition for improving transient stability of grid connected SCIG wind turbine.Author has implemented $\mathbf{9 \times 3}$ FLC. The error and its derivative has nine and three fuzzy sets respectively. Simillarly $\boldsymbol{\beta}$ output has nine membership function.

In this research more foccus is given on improved and accurate results during fault condition.Hence to design fuzzy logic controller we have implemented matrix of $\mathbf{11 \times 3}$. The error and its derivative has 11 and three fuzzy sets respectively. Simillarly $\boldsymbol{\beta}$ output has eleven membership function.The paper is organised as follows. The second section describes the mathematical modelling of grid connected wind farm with SCIG; section third proposes improved hybrid fuzzy logic controller for both normal as well as fault condition; In section four, MATLAB simulation results are shown and discussed; last section gives conclusion

II. MODEL OF GRID CONNECETD SCIG WIND FARM

Figure 1 shows the SCIG wind farm coupled to grid at the point of common connection(PCC). Step wise mathematical modelling of SCIG is given below.

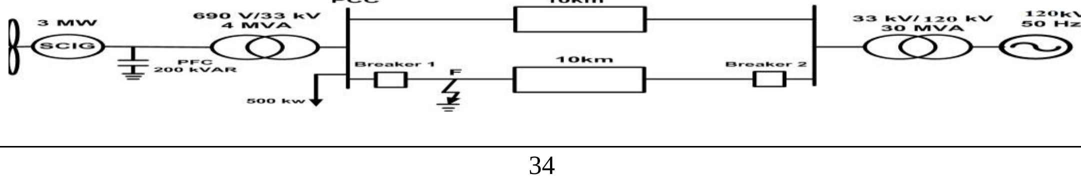

Fig 1: SCIG wind Farm coupled to grid at PCC

The wind turbine rotor trasnforms the absobed kinetic energyof air into mechanical power.The energy available in the rotor is

$$\boldsymbol{P_{wt} = \frac{1}{2}\rho\pi R^2 V^3} \quad (1)$$

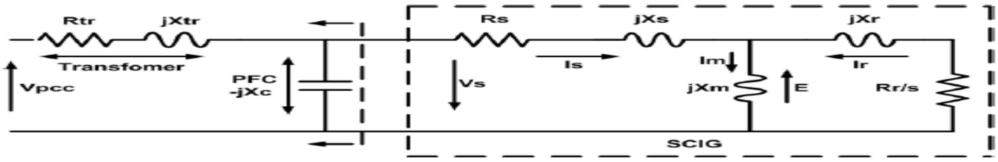

Fig 2: Equivalent circuit diagram of squirrel cage induction generator

Where $\boldsymbol{P_{wt}}$ is extracted power from the wind , $\boldsymbol{\rho}$ is the air density in $\boldsymbol{Kg/m^3}$, R is the blade radius in m and V is the wind speed.The mechanical power which is extracted from the wind depends on power coefficient $\boldsymbol{C_p}$ and it is given by

$$\boldsymbol{P_{mech} = C_p P_{wt} = \frac{1}{2} C_p \rho\pi R^2 V^3} \quad (2)$$

The power coefficient is a function of the turbine tip- speed ratio λ and the pitch angle β . The general expression is defined as

$$\mathrm{C_p} = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right) e^{-C_5/\lambda_i} + C_6\,\lambda \quad (3)$$

Where the value of λ_i is

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.008\beta} - \frac{0.035}{\beta + 1} \quad (4)$$

The coefficients $C_1\ to\ C_6$ can also be found in Ref [21].

Turbine mechanical power $P_{mec\,h}$ that can be extracted depends on power coefficient C_P or pitch angle β is given by

$$P_{mec\,h} = C_P(\lambda\,\beta)P_{wt} = \frac{1}{2} C_P(\lambda\,\beta)\,\rho\pi R^2 \left(\frac{R}{\lambda}\right)^3 \omega_R{}^3 = C_P(\lambda\,\beta)k\omega_R{}^3 \quad (5)$$

Where k = $\frac{1}{2}\rho\pi R^2\,(\frac{R}{\lambda})^3$ (6)

The mechanical torque is given by

$$T_m = \frac{P_{mec\,h}}{\omega_R} = \frac{C_P(\lambda\,\beta)P_{wt}}{\omega_R} \quad (7)$$

From fig 2 the static equivalent circuit diagram of SCIG, the voltage equivalent is given by

$$E = jI_m X_m = -I_r\ (R_{\frac{r}{s}+j} X_r) \quad (8)$$

$$I_m = I_s + I_r \quad (9)$$

$$V_s = E + I_s(R_s + jX_s) \quad (10)$$

$$P_{mec\,h} = 3I_r{}^2(R_r/s) \quad (11)$$

E is electromotive force, I_m is magnetizing current, I_s is stator current and I_r is rotor current

R_s & R_r are stator and rotor resistances; X_s & X_r are stator and rotor secondary leakage reactance's; X_m is magnetizing reactance ; $P_{mec\,h}$ is input mechanical power ; s is slip. All the rotor parameters are converted to equivalent stator parameter. By considering the voltage equivalent and small variation range of slip we can conclude that

$$V_r \cong \frac{I_r}{\mathrm{IsI}X_m} K_s \quad (12)$$

Where

$$K_s = \sqrt{M^2 + N^2} \quad (13)$$

M=-($s\ R_sX_r + s\ R_sX_m + X_sR_r + R_rX_m$) (14)

N=($R_s\ R_r - sX_s\ X_r - sX_m\ X_s - s\ X_r\ X_m$) (15)

Thus from the equation (3) and (9) we get

$$I_r = \sqrt{\frac{C_P(\lambda\,\beta\,)k\omega_R{}^{3\,2}}{3R_r}} \qquad (16)$$

Where s is slip ratio

$$s = \frac{\omega_s - \omega_R}{\omega_s} \qquad (17)$$

From the (10), (14) & (15) we get

$$V_s \cong K_r\sqrt{\frac{\omega_R{}^3}{\omega_s - \omega_R}} \qquad (18)$$

Where ω_s is synchronous speed K_r is defined as

$$K_r = \frac{k_s\sqrt{\omega_s k C_P(\lambda\,\beta\,)}}{\sqrt{3}R_r X_m}$$

(19)

From (18) we can have voltage behavior of SCIG against the ω_R. It is clear that when the rotor speed is varied, terminal voltage of SCIG decreases. Figure 3 shows that variation of terminal voltage due to change in rotor speedω_R.

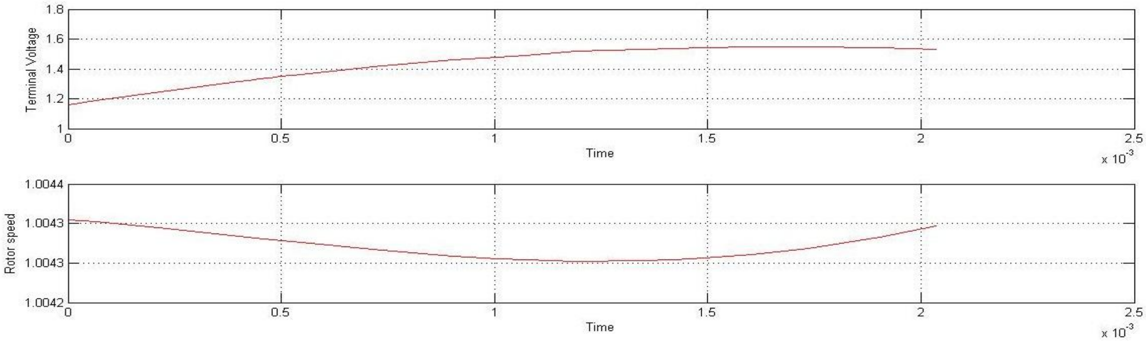

Fig 3: Variation of terminal voltage and rotor speed in SCIG

III. TRANSIENT STABILITY

Power system transient stability is related to the ability to maintain synchronism when subjected to a severe disturbance, such as a three phase fault or short circuit on a bus. The resulting system response involves large excursions of the generator rotor angles and is governed by the nonlinear power–angle relationships. Transient stability assessment essentially determines whether the system can reach an acceptable steady-state operating point in post-fault operating stage. Power system stability is ability of system, for given initial condition, to regain the state of operating equilibrium after being subjected to physical disturbance. A severe voltage sags due to fault causes increase in speed of turbine and generator rotor. In this case rotor may accelerate to high speed which later on becomes uncontrollable. This is the generator counterpart to induction motor stalling which is referred as voltage instability. Fixed speed induction generator like squirrel cage when connected to grid, it leads to stability issues. Fixed speed wind turbine is common problem in wind power plants. In fact, being equipped with a squirrel-cage induction generator (SCIG), they tend to drain a relevant amount of reactive power from the grid, potentially causing voltage drops and voltage instability. Wind power output is proportional to the cube of wind speed, which is time-varying in the real world. Thus, SCIG power fluctuations can lead to over-speed and network instability.

IV. IMPROVMENT TECHNIQUES FOR TRANSIENT STABILITY

So far little efforts have been taken by previous researchers to improve transient stability. In this paper new hybrid combination of traditional PI and fuzzy logic controller is applied for improvement of voltage stability.

I. Implementation of PI Controller

PI is the control loop feedback controller basically used in industrial control system. When grid connected SCIG wind turbine system undergoes fault condition then voltage at PCC goes down to some value. In such situation system become unstable. This recovery of voltage can be obtained by controlling wind turbine parameter like pitch angle through measured power and measured rotor speed. Figure 3 shows the controlling circuit of conventional PI controller.

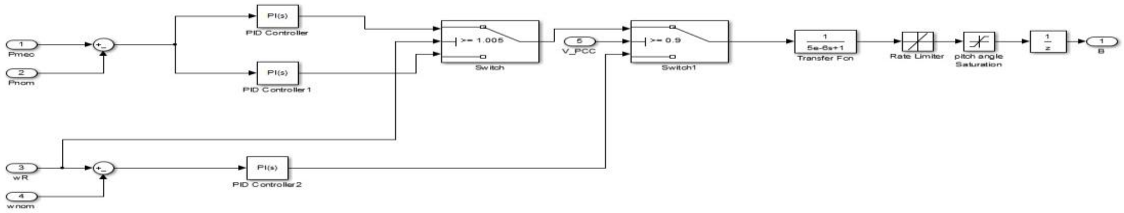

Fig 4: Control circuit of PI controller

Figure 4 shows that difference between measured power P_{mech} and reference power P_{nom} as error ε_1 and measured rotor speed ω_R and nominal speed ω_{nom} as error ε_2 goes through PI controller which regulates the output in accordance with the relative error $\varepsilon_1 = \frac{P_{mech} - P_{nom}}{P_{nom}}$ and $\varepsilon_2 = \frac{\omega_R - \omega_{nom}}{\omega_{nom}}$

II. Fuzzy Logic Controller

Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results are much more accurate. Fuzzy logic includes 0 and 1 as extreme cases of truth but also includes the various states of truth. As PI controller is used for lineralized model related to nominal frequency it cannot provide sufficient damping for any operating point caused by disturbances. This leads to voltage drops in system however large wind variation will bring remarkable change in output power. In this paper, to improve transient stability of grid connected SCIG wind turbine, fuzzy logic controller is designed. There are two basic reasons for using fuzzy logic controller.

1) The traditional methods found less efficient for acquiring complete stability
2) The most important things about FLC is that it provides the accurate and efficient result compare to PI & PID control methods

a) Block Diagram of FLC

The FLC process is composed of Fuzzification, membership function, rule base, fuzzy inference engine and Defuzzification in which input error is quanti-sized into eleven membership function and three fuzzy sets of its derivative.

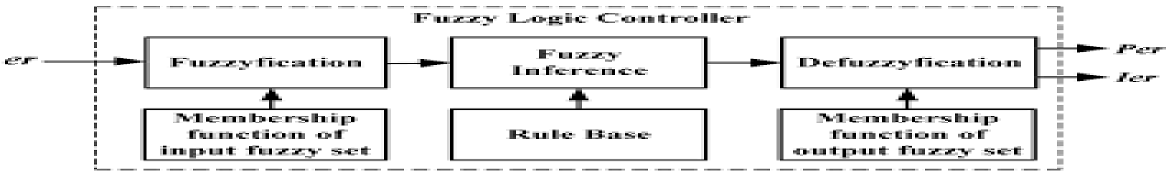

Fig 5: Block diagram of FLC

Input control variables to the FLC are power error signal ε_1 , speed error ε_2 and its rate of change shown in figure 5. If the value of pitch angle is increased or decreased then corresponding value of P_{mech} is estimated. Similarly with the variation of pitch angle, corresponding value of T_m can be estimated. Voltage instability can be maintained by controlling the blade angle through rotor speed ω_R related to overspeeding of SCIG as shown in FRT section of figure 8 . If the PCC voltage decreases below base voltage of generator pitch angle is changed accordingly so as to reduce rapid increment of rotor speed. The ε_2 can be evaluated by using relative difference between measured speed and reference speed of rotor $\varepsilon_2 = \frac{\omega_R - \omega_{nom}}{\omega_{nom}}$.

Due to this T_m can be controlled to increase the range of ω_R to ω_{crit} to maintain SCIG stability. If ε_1 and ε_2 are increases with last positive derivative then this indicates that variation of β is continued in same direction otherwise negative derivative causes decrease in ε_1 and ε_2 . Hence direction of search of β become reversed immediately. All variable are described by using fuzzy language.

b) Fuzzification

The term fuzzification means to fuzzify the data. This is done by converting the classical set to fuzzy set. For this process we need different fuzzifiers such as Triangular, Trapezoidal, Sigmoid and Gaussian. With the help of these fuzzifiers we assign some membership function to each and every input and convert it into fuzzy set. Each input and output variable used in controller design is expressed in fuzzy sets of linguistic variables. In this dissertation work, the input fuzzy sets are quantisized in to 11 membership function for rotor speed error. They are very large negative (VLN), large negative (LN), medium negative (MN), small negative (SN), negative (N), zero (ZO), positive (P), small positive (SP), medium positive (MP), large positive (LP), very large positive (VLP). In block diagram of FLC FRT scheme, the error $\varepsilon_2 = \frac{\omega_R - \omega_{nom}}{\omega_{nom}}$ and its derivative are fuzzified using Gaussian and generalized bell membership function respectively shown in figure 6.a. and 6.b. The selection of membership function mainly depends on nature of input and output .Gaussian and generalized bell membership function is chosen because behavior of input error shows the Gaussian nature. The output error is sent to FLC to generate suitable β which is characterized by triangular membership function shown in figure 7.

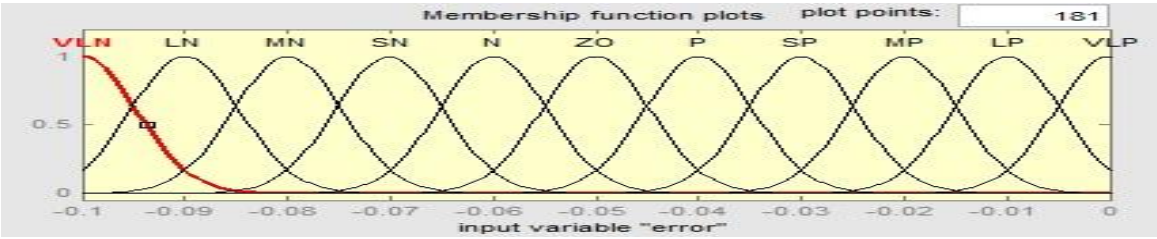

Fig 6a: Input fuzzy sets for error ε_2

The nature of Input fuzzy sets for derivative of rotor speed error ε_2 is represented using generalized bell membership function because of its specific nature. Obviously, the rotor speed error and its time derivative are all normalized, fuzzified, and expressed as fuzzy sets.

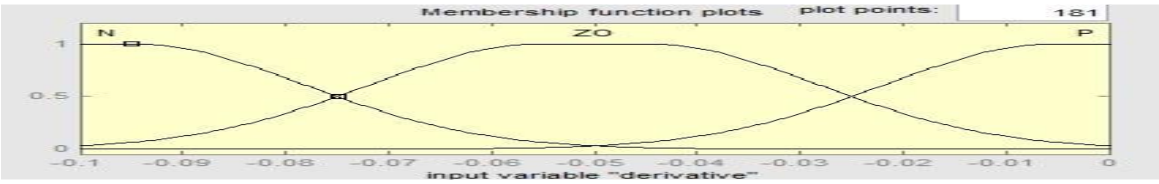

Fig 6b: Input fuzzy sets for derivative ε_2

c) Decision Making Logic

After defining the input fuzzy sets decision making logic is used to define rules called as fuzzy logic rules. The overall control strategy is based on set of IF-THEN rules. For example if (Error is VLN) and (Derivative is N) then (Pitch angle control is VLN). The set of rules are given in table 1.

Fuzzy logic controller technique implemented for improving voltage stability is based on certain fuzzy logic rules. The system is created for two inputs and one output. In this both inputs i.e rotor speed error and their derivatives are quantisized into 11 membership functions. According to expert knowledge based and by using fuzzy sets notation, 11×11matrix is designed for executing fuzzy logic rules.

Table 1: Fuzzy pitch angle rules

du/dt	Error									
	VLN	LN	MN	SN	N	ZO	P	SP	MP	LP	VLP
N	VLN	LN	MN	SN	N	N	ZO	P	SP	MN	LP
ZO	VLN	LN	MN	SN	N	ZO	P	SP	MP	LP	VLP
P	LN	MN	SN	N	ZO	P	P	SP	MP	LP	VLP

d) Defuzzification

In Defuzzification we need to transform output linguistic variables to crisp values for controlling the pitch angle. Finally the defuzzification is applied to fuzzy sets produced by decision making logic to convert fuzzy sets into numerical value by equation (21).

$$y(x) = \frac{\sum_j^N w_j \mu_j \text{ (x)}}{\sum_j^N \mu_j \text{ (x)}}. \tag{21}$$

Where y(x) is the output reference pitch angle, w_j is the weight corresponding to a given output fuzzy set, μ_j (x) is the degree of the fuzzy rule, and x is the input vector. This Defuzzification is carried out using triangular membership function which is quantisized in to eleven variables as output. Figure 6 shows the triangular membership function plot for output.

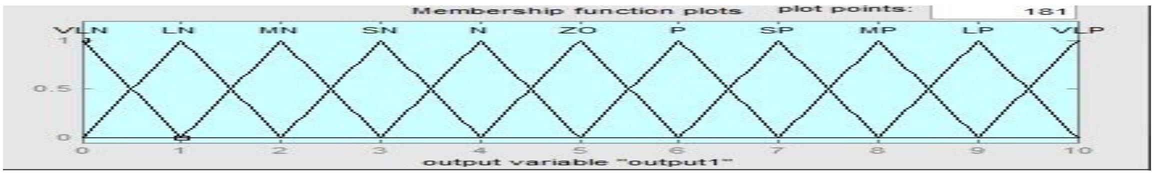

Fig 7: Output fuzzy sets for pitch angle control

V. HYBRID PITCH ANGLE CONTROLLER DESIGN

Improved hybrid fuzzy logic control design for pitch angle controller using fuzzy and PI technique for all operating region is presented here. The design topology for improved hybrid pitch angle controller is represented as

$$\beta_{Ref} = \frac{\Delta\beta}{\Delta P}(P_{mech} - P_{nom}) + \beta_0 \qquad (22)$$

Where β_0 is initial Pitch angle, P_{mech} and P_{nom} are measured and reference power $\Delta\beta$ and ΔP are small signal state of β and P_{mech} respectively.

Blade direction will depends on variation of wind which varies continuously in different direction. Thus to control the blade direction, hydraulic or electric pitch servo is implemented which is modeled by first order transfer function.

$$\beta = \frac{1}{1+T_\beta s}\beta_{Ref} \qquad (23)$$

Where s is the Laplace operator and T_β is the time constant of orientation system of the blades**.** Pitch actuation system is limited by its actuation speed hence it could not respond to the change in wind speed immediately. Thus pitch rate is included in order to get fast and realistic solution from the pitch angle control system. Pitch rate response is limited to $\pm 3(°/s)$ and regulation range of pitch angle is limited from 0° to 90°. For the purpose of improving the voltage stability and output power performance, new hybrid system for pitch angle controller is implemented based on both normal and fault condition utilizing both fuzzy and PI technique shown in figure 8.

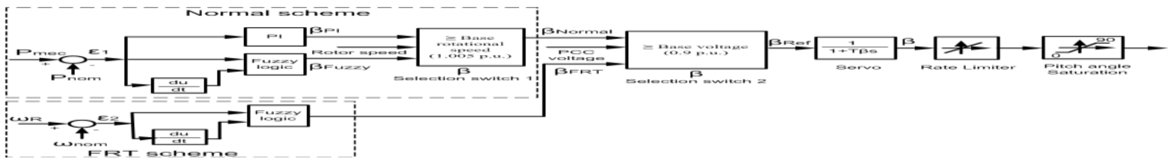

Fig 8: Hybrid pitch angle controller

When the short circuit fault occurs in the external grid, voltage at PCC and measured power reduces. The pitch angle control will detect this reduction of output power and voltage and it will try to increase the P_{mech} by keeping β_{Ref} close to zero. The β selection switch depends on rotor speed. If the rotor speed is higher than the base generator speed given by the manufacturer, β selection switch 1 will moves to β_{PI} input thus

$$\beta_{Ref} = \beta_{Normal} = \beta_{PI}$$

If the rotor speed is less than base generator speed given by manufacturer, β selection switch 1 will moves to β_{fuzzy} input thus

$$\beta_{Ref} = \beta_{Normal} = \beta_{fuzzy}$$

VI. SIMULATION RESULTS AND DISCUSSION

The mathematical modelling of SCIG is simulated in MATLAB. Figure 9 shows the MATLAB simulink model of grid connected squirrel cage induction generator wind turbine. The dynamic model of fixed speed SCIG wind turbine consisting of 3MW induction generator is connected to grid through 4 MVA transformers with point of common connection. The wind turbine is connected with subsystem block which consist of FLC and PI controller for pitch angle system. The inputs to subsystem block are measured power, reference power, measured rotor speed, reference rotor speed and voltage at PCC. The corresponding output is pitch angle which is used to control the mechanical torque.

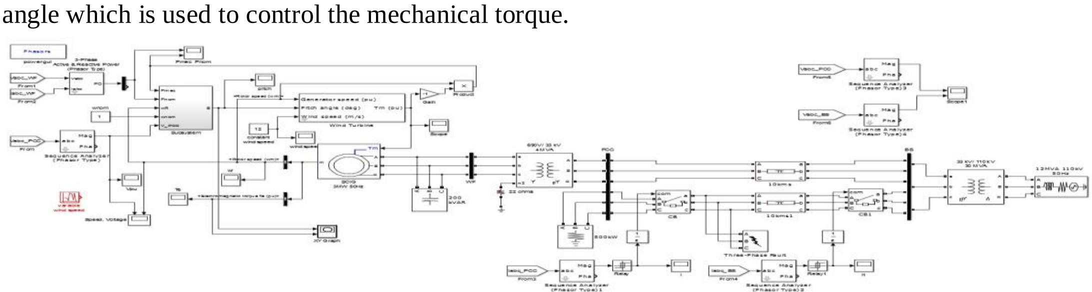

Fig 9: MATLAB model for implementing FLC and PI controller

The grid connected SCIG model of 3 MW wind turbine is implemented in MATLAB implementing both fuzzy logic controller and PI controller. Effect of transient stability on generator parameter and wind turbine parameter is well explained in [21].The main controlling parameter is found to be pitch angle β.

So pitch angle variation during different wind speed for both PI and FLC controller is observed in MATLAB shown in fig 10. Pitch angle variation for PI controller is always negligible so remain zero for any value of wind speed whereas fuzzy logic controller gives better and fast response for pitch angle variation.

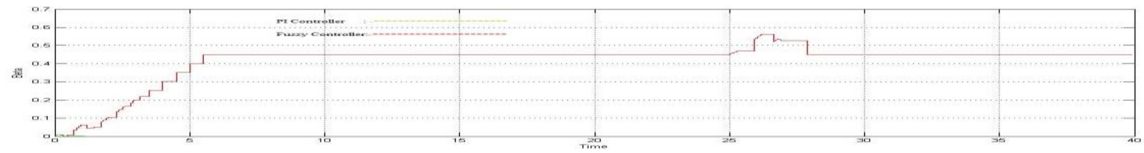

Fig 10: Pitch angle comparison between PI and FLC

From equation (7), the relationship between mechanical torque T_m and pitch angle β is given.
Mechanical torque is directly proportional to tip speed ratio and pitch angle. As tip speed ratio is negligible compared to pitch angle so it is not considered. As FLC helps to increase the pitch angle even in case of normal as well as fault condition. Hence mechanical torque can be well maintained during fault condition using fuzzy logic controller. Fig 11 shows the comparison of torque variation between FLC and PI controller.

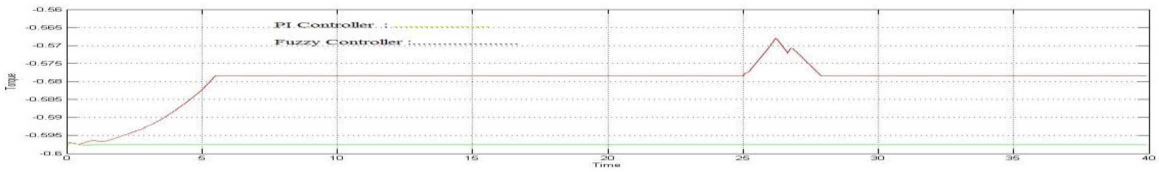

Fig 11: Torque comparison between PI and FLC

Now improvement in transient stability of grid connected SCIG wind turbine through FLC is discussed here. Improved voltage at PCC due fuzzy logic controller is discussed and comparison analysis between PI controller and FLC is shown in fig.12.

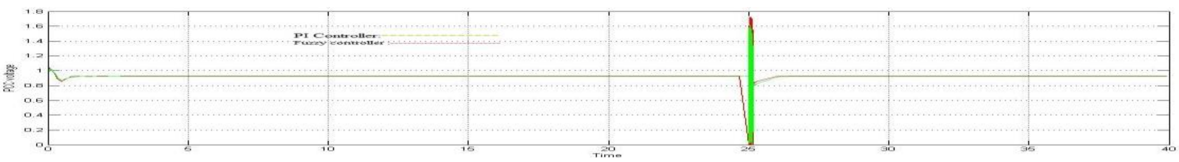

Fig12: Voltage comparison at PCC

VII. CONCLUSION

Integration of large number of wind farms into grid power system have been increasing significantly since the last decade. The Fixed Speed Wind Turbines with Squirrel Cage Induction Generators (FSWT-SCIGs) are most widely used in wind farms due to their advantages of mechanical simplicity, robust construction, low specific mass and smaller outer diameter, and lower cost. However, the FSWT-SCIG directly connected to the grid does not have any low voltage ride-trough (LVRT) capability when a short circuit occurs in the grid system. Moreover, under steady state condition the reactive power consumption cannot be controlled and hence terminal voltage of the wind generator leads to large fluctuation which is a serious disadvantage of the SCIG wind turbine.

From the mathematical modeling and MATLAB simulation results, it is observed that the parameters like voltage, current, rotor speed and its angle are affected mostly. As the other parameter like torque and power depends on voltage and current so these factors also reduced and get affected drastically.
In this work main focus is given on controlling technique of transient's stability of grid connected SCIG wind turbine. In this section, we compare the pitch angle control performance of the hybrid fuzzy logic controller versus the conventional PI controller. In this work, the performance of the proposed control system was evaluated with MATLAB/Simulink for a 3-MW SCIG-based wind turbine.
It was found that,

- Pitch angle increment in PI controller is almost zero whereas hybrid fuzzy logic controller gives 40-45% increment in pitch angle
- Torque varies linearly with pitch angle. Hybrid fuzzy logic controller gives smooth variation in torque.

- Comparison between PI and Fuzzy logic controller for Voltage stability is shown in figure 4.5.4. The difference of increment in voltage at point of common connection is almost 35% based on hybrid fuzzy logic controller compared to conventional PI controller.

Therefore, this controller configuration might be an effective solution to considerable increase future SCIG WT performance, in terms of simplicity, reliability, low weight and low maintenance cost.

REFERENCES

[1]. Anamika Kumari, Dr. A. G. Thosar, S. S. Mopari ,“ A Review on Various Approaches for Determination of Excitation Capacitance of a Three Phase Self Excited Induction Generator” IJMER vol 4 issue 5 may 2015

[2]. Kamel RM, Chaouachi A, Nagasaka K., “Wind power smoothing using fuzzy logic pitch controller and energy capacitor system for improvement micro-grid performance in island mode.”, Energy 2010;35:2119e29.

[3]. Chowdhury MA, Hosseinzadeh N, Shen WX, “Smoothing wind power fluctuations by fuzzy logic pitch angle controller.” ,Renew Energy February 2012; 38(1):224e33.

[4]. Amutha, N, Kalyan Kumar, B., “Improving fault ride-through capability of wind generation system using DVR”, Int. J. Electr. Power Energy Syst. 2013, 46, 326–333.

[5]. L. Dusonchet, F. Massaro and E. Telaretti, “Transient stability simulation of a fixed speed wind turbine by Matlab/Simulink,” IEEE conference on Clean Electrical Power, 21-23 May 2007

[6]. Li Jianlin, Liang Liang, yangshuili, Hui Dong, “Study on Energy storage system smoothing wind power fluctuations,” 2010 International Conference on Power System Technology

[7]. Mohsen Rahimi, Mostafa Parniani, “Dynamic behavior and transient stability analysis of fixed speed wind turbines”,Renewable Energy journal homepage: www.elsevier.com/locate/renene

[8]. Samuelsson and Sture Lindahl ,“ On speed Stability, ” IEEE Transactions On Power Systems, Vol. 20, No. 2, May 2005

[9]. Li, H Zhao, B.,Yang, C, Chen, H, Chen, Z. “Analysis and estimation of transient stability for a grid-connected wind turbine with induction generator.”, Renewable Energy 2011, 36, 1469–1476.

[10]. Walmir Freitas, Andre Morelato, And Wilsun Xu, “Improvement Of Induction Generator Stability By Braking Resistor”, IEEE Transactions On Power Systems, Vol. 19, No. 2, MAY 2004 1247

[11]. Daniel Trudnowski, “Fixed-Speed Wind-Generator and Wind-Park Modeling for Transient Stability Studies”, IEEE Transactions On Power Systems, Vol. 19, No. 4, NOVEMBER 2004 1911

[12]. Pankaj Bhakre, A.G.Thosar, “ Transient stability analysis of grid connected SCIG wind Turbine”, IJAREEIE vol 5 isssue 5 may 2016

[13]. Ahda Pionkoski Grilo, Alexandre de Assis Mota, Lia Toledo Moreira Mota,,” An Analytical Method for Analysis of Large-Disturbance Stability of Induction Generators” IEEE Transactions On Power Systems, Vol. 22, No. 4, November 2007

[14]. Obando-Montano, A.F Carrillo, C. Cidras, J. Diaz-Dorado, E. “A STATCOM with Super capacitors for Low-Voltage Ride-Through in Fixed-Speed Wind Turbines.”, Energies 2014, 7, 5922–5952.

[15]. Ahmed Abu Hussein and Mohd. Hasan Ali, “ Comparison among Series Compensators for Fault Ride through Capability Enhancement of Wind Generator Systems”, International Journal of Renewable Energy Research author header Vol.4, No.3, 2014

[16]. Freitas, W.; Morelato, A.; Xu, W,“Improvement of induction generator stability using braking resistors.”, Power Syst. IEEE Trans. 2004, 19, 1247–1249

[17]. Mohammad Hassan Zamani, Seyyed Hamid Fathi, G. H. Riahy, MehrdadAbedi, and Nazanin Abdolghani, “Improving transient stability of grid connected squirrel cage induction generators by plugging mode operation,” IEEE Trans. Energy conversion, vol. 27, no. 3, pp. 707_714, Sep. 2012.

[18]. T.Maheswaran1, M.Venkateswaran2,”Transient stability Improvement by Plugging mode operation of grid connected squirrel cage induction generator”, International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 79-84 (2013) Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

[19]. Minh Quan Duong , Francesco Grimaccia , Sonia Leva , Marco Mussetta and Kim Hung Le, “Improving Transient Stability in a Grid-Connected Squirrel-Cage Induction Generator Wind Turbine System Using a Fuzzy Logic Controller”,Energies 2015, 8, 6328-6349; doi:10.3390/en8076328

[20]. Minh Quan Duong , Francesco Grimaccia , Sonia Leva , Marco Mussetta ,Emanuele Ogliari ,” Pitch angle control using hybrid controller for all operating regions of SCIG wind turbine system”, journal homepage: www.elsevier.com/locate/renene

Pankaj Bhakre. “Hybrid Fuzzy Logic Controller for Improving Voltage Stability of Grid Connected SCIG Wind Turbine.” International Journal of Engineering Research and Development, vol. 13, no. 10, 2017, pp. 33–41.