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Improvement of Voltage Stability in VSC-HVDC System with Wind Generator using FUZZY-PI Controller

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Abstract

In power systems, various types of converters have different control strategies. and they play a significant role in altering, transmitting, and refining the performance of high-voltage .In this paper, the application of Fuzzy-PI controller is proposed for mainly two systems i.e. Permanent magnet synchronous generator (PMSG) and induction generator IG to improve the voltage stability of VSC-HVDC with the wind farm consisting Induction Generator with fixed speed and PMSG with variable speed which uses Fuzzy-PI Controller to Achieve Excellent Voltage stability of the system during Faulty condition to make system stable. Now to evaluate the capabilities of the Fuzzy-PI controller system, simulations and analysis are performed in MATLAB consisting of two wind farms which are connected to an infinite BUS.

Keywords: Voltage Stability, VSC-HVDC, Fuzzy-PI controller

1. Introduction

With the advent of enhanced stability boundaries in power system by means of VSC-HVDC has made this technology an important choice among network owners when there is a necessity to rise the transmission capacity of the network.[1] The ability to quickly control active and reactive power, autonomous of each other, permits VSC-HVDC to increase transient stability, escalation of damping of electromechanical oscillations, and improve voltage stability. Furthermore, when connected in synchronous systems, VSC-HVDC provides great flexibility in controlling the power flow in the network. Voltage failure generally occurs after a huge disturbance in extremely stressed power systems, resulting in increased reactive power and thus leading to a voltage drop. The constraints of providing reactive power in power systems, as well as the control of mechanisms that attempt to reestablish the magnitude of voltage under operating conditions, often result in voltage instability Also the probability of commutation loss is very high and VSC can handle limited voltage and power levels.[2] Therefore VSC-HVDC performance analysis will be performed at various voltage levels and power levels to ensure the stability of voltage for given system.

In this paper voltage stability improvement of system is investigated which consists of two wind farm system. The wind farm consists of an induction generator wind turbine with a fixed speed and a permanent magnet synchronous generator with a adjustable speed [4]. And for the PMSG converter with DC link protection controller, a control scheme was developed to support the fixed-speed wind turbine in the event of a fault to stabilize the system.

In wind farm, Wind Turbines with fix speed and with Induction Generators are generally introduced because of their preferences of machine-driven effortlessness, low explicit mass, robust constructions and cost productivity. If adequate reactive power is not given then the induction generator will become unstable and need to be detached from the main grid system. [3] Moreover, under consistent state condition the reactive power utilization is uncontrolled, and consequently terminal voltage of the wind generator prompts huge change. There are few techniques considered to improve stability of VSC-HVDC with wind generator system.

2. Overview of VSC-HVDC system with wind generator system

2.1. Basic circuit diagram :

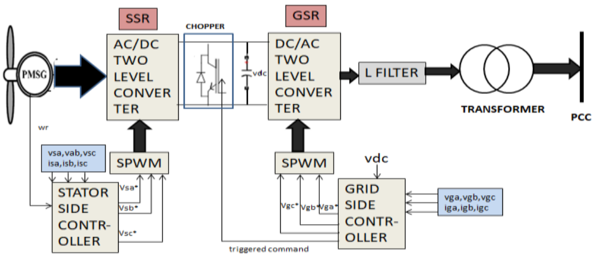

Figure 1. Basic circuit diagram of VSC-HVDC system

In wind farm 1 and wind farm 2 PMSG generator and induction generators are used respectively and by using wind turbine and generator wind farm converters varying wind and converted in to power. The generated AC is converted to require voltage which is used by transformer and that power is used to feed transmission line .when the fault is simulated on one of the transmission line of wind farm 2 at particular time so, when fault occurs the total load is transferred to wind farm. At a time of fault occurs on transmission line, at that time the reduction of voltage is very high and current is increase which may damage to connect load and device, so power must be stabilized as soon as possible .When faulty condition occur, at that time that particular of transmission line is disconnected through circuit breakers and other wind farm adjusts a speed of its generators to generate required power according to load. PMSG is variable speed generator so whenever fault occurs on transmission line of induction generator, at that time to supply load, PMSG varies its speed and there might be loading on generators to prevent overload condition and damage crow –bar is introduced [5]. Whenever overload condition occurs it creates a short circuit to overload voltage and at that time passive crowbar is used. But active crowbar uses a thyristor or GTO based on gate trigger signal. Active crowbar is activated to short circuit when overload occurs, and when overload finished then crowbar closed itself. [3]

The VSWT-PMSG structure is outfitted with consecutive electronic power converters and has robust low voltage conduction capacity during and after the structure system issue condition. This sort of generators is costly. Thus, both VSWT-PMSG and FSTW-IG acquainted merge present with reduce structure theory cost. The back to back VSC converter which contains stator side converter and matrix side converter are associated by DC circuit.[6]

A grid side converter assumes a significant part in ensuring that active power and reactive power is successfully transmitted to the network. Changes in parameters of grid system boundaries will genuinely influence the exhibition of the inverter control system, particularly in faulty conditions. Due to simple structure and great execution the conventional PI controller is generally utilized in the control of the converter of PMSG.[7] Based on this view, utilization of Fuzzy Logic Control (FLC) to grid side converter regulator is suggested in this paper to recover voltage stability of wind farm. Fuzzy logic control intends to change the addition limitations of the PI controller for any progressions in working circumstances. Consequently, great control system execution can be accomplished.

Control methods of VSC-HVDC system with wind generator :

There are various control strategies used in power system. For control in this VSC-HVDC system with wind generator work following methods are used: PI controller, FUZZY controller.

2.2.1. PI Controller

Proportional integral (PI) is a control loop mechanism typically used in control systems and other applications that need unceasing modulation control. The PI controller endlessly computes the error value as the variance between the obligatory set point and the measured process variable, and modifies it according to the proportional integral, and names the proportional controller.

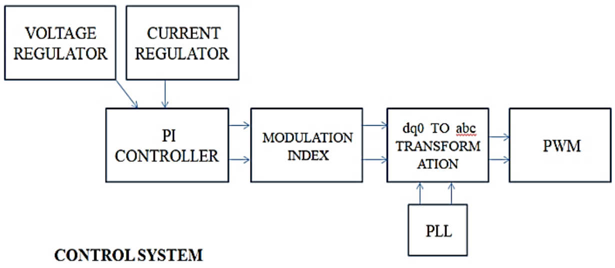

Figure 1. Control system of VSC-HVDC system

The PI controller will eliminate forced oscillation and steady-state errors. However, the introduction of integration mode will have a negative impact on the response speed and the complete stability of the system. Therefore, the PI controller will not escalate the response speed. It is foreseeable that the PI controller does not have to perfect the situation in which errors will occur in the future. This problem can be solved by introducing a differential mode, which can predict errors in the near future and thus reduce the time to respond to the controller. [8]

FUZZY Controller

Fuzzy logic is a derivative form of classic Boolean logic, and the soft language variables are implemented in a continuous truth value range defined between regular binary (i.e. [0, 1]). It can usually be considered as a subset of predictable set theory [9]. Fuzzy logic can process approximate information in a systematic manner. Therefore, it is suitable for governing nonlinear systems and modeling complex systems with inexact models or systems with ambiguity or ambiguity [10-11] .The purpose of fuzzy logic control is to simulate humanoid involvement and humanoid decision-making behavior.

Membership function:

The elements in fuzzy set can be defined by the mathematical function of membership function. The membership function (MF) expresses in what way each point of the input space maps to a membership value between 0 and 1.

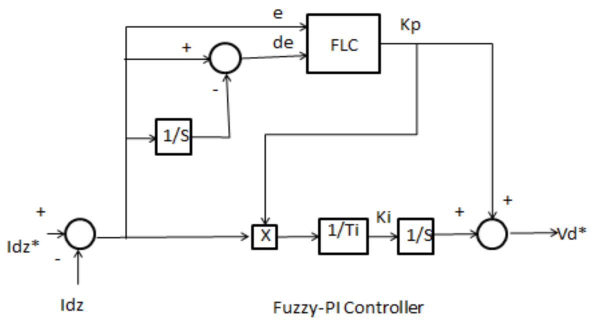

Figure 3. Fuzzy-PI controller

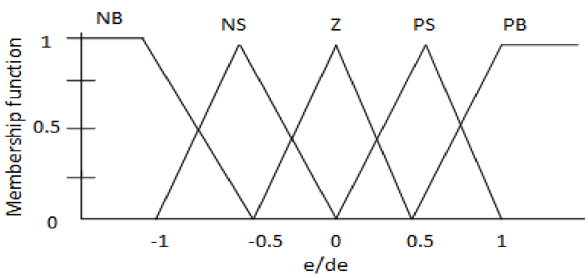

Figure 4. The membership function for input e/de

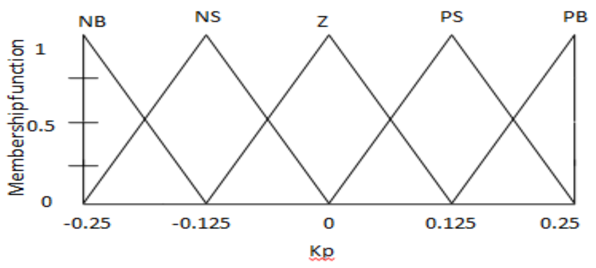

Figure 5. The membership function for output Kp

Table 1. Rule table for fuzzy controller

e/d **e**	**NB**	**NS**	**Z**	**PS**	**PB**
NB	NB	NB	NS	NS	Z
NS	NB	NS	NS	Z	PS
PB	Z	PS	PS	PB	PB
PS	NS	Z	PS	PS	PB
Z	NS	NS	PZ	PZ	PS

In this system a triangular membership function is used, which is utilized for input e/de and output Kp. The fuzzy subsets of factors employed for input are negative big (NB), negative small (NS), zero (Z), positive small (PS), and positive big (PB). Since the d-axis or q-axis current changes from - 1 to 1 pu, the scope of the input membership function is likewise established at this interval. In this paper the range of the membership function for output is from -0.25 to 0.025.

Power system model of VSC-HVDC with wind farm

Figure 6 shows the VSC-HVDC power system model with wind farm. In wind farm 1 and wind farm 2,PMSG generators and Induction generator are utilized, separately, and the wind speed is changed and converted in to electrical energy by utilizing wind speed is changed and changed over in to electrical energy by utilizing wind turbine and generator wind farm converters. The generated alternating current is changed over to the necessary voltage, which is utilized by the transformers, and this power is utilized to take care of the transmission line. The following are the system parameters used in this work, which are executed in the MATLAB software.

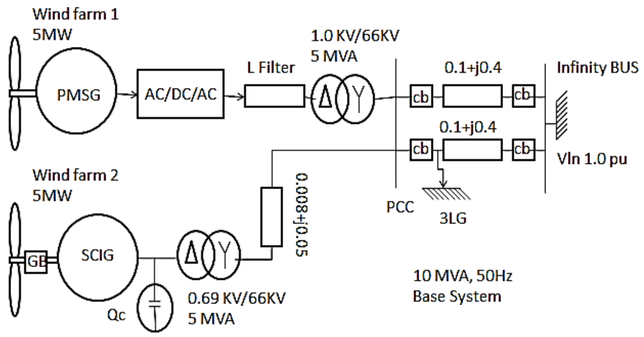

Figure 6. Power system model of the system

Table 1. System parameters

SYSTEM PARAMETERS	**RATINGS**
PMSG(PERMANENT MAGNET SYNCHRONOUS	575 V

GENERATOR)WIND TURBINE	50 Hz
WIND FARM:ASYNCHROUNUS GENERATOR	480 V,5 MVA,50 Hz
BUS 1,2,3	575 V ,480 V ,66 kV RESPECTIVELY
TRANSFORMER 1,2	5MVA, 575/66 kV, 50 Hz 5MVA,480/66kV,50 Hz
TRANSMISSION LINE 1,2	RL(R=0.1OHM,L=0.00127 H)
GRID(THREE PHASE SOURCE)	66 kV,50 Hz

3. Simulation and Results

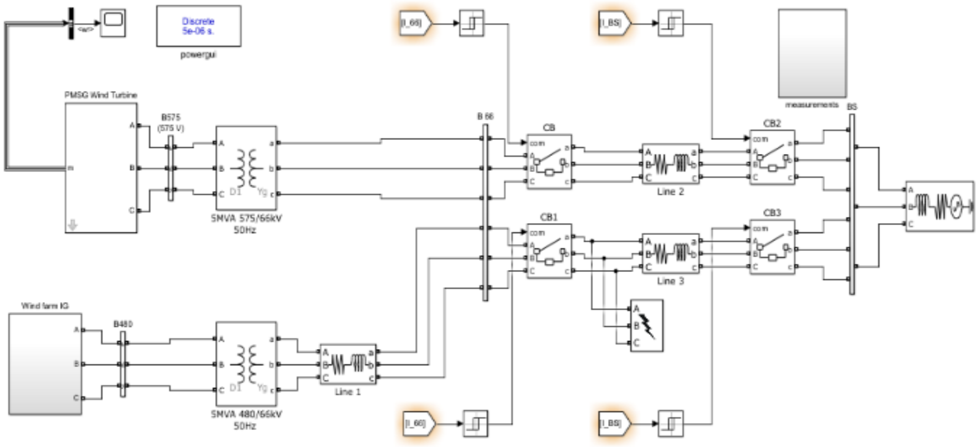

Figure 7: MATLAB simulation of VSC-HVDC with wind farm generator using fuzzy -pi controller

Figure 8 shows the MATLAB simulation of VSC-HVDC with wind farm generation with fuzzy-PI controller. In which wind farm 1 and wind farm 2(5MW) is connected to the infinite bus through power converters, filters with grid.

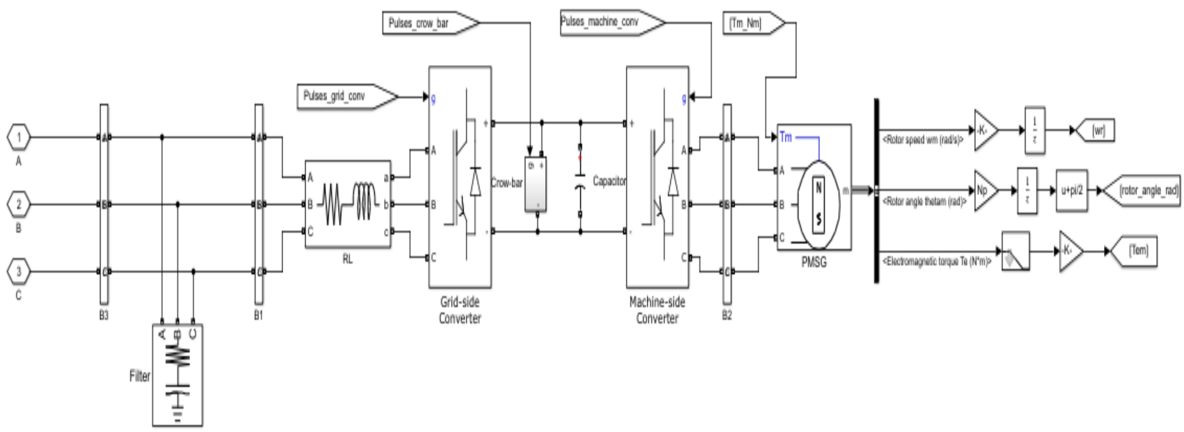

Figure 2. Control system of VSC-HVDC system

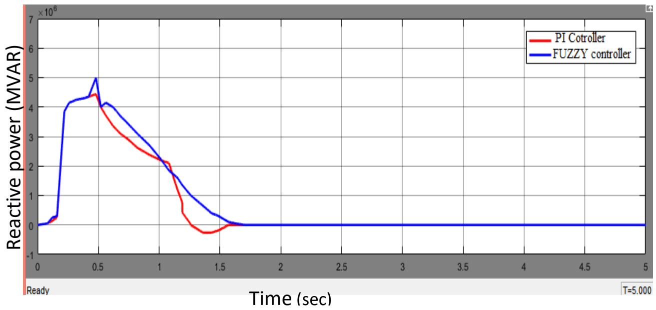

Figure 3. Waveform of reactive power at WF 1

Figure 9 shows wave form of reactive power at wind farm 1 of VSC-HVDC with wind farm generation with fuzzy-PI controller. In which red line shows the result of PI controller and blue lines shows the result of fuzzy controller. By comparing both, result of fuzzy logic controller is improved than the PI controller. The fault occurs at 0.1 sec and the faulted lines are opens at 0.2 sec and at 0.1 sec circuit breakers are re closed.

Figure 9 and 10 shows the waveform of reactive power at WF1 & WF2, in which WF1 at grid side converter provides reactive power during the fault because of that the terminal voltage is stabilized as shown in figure 13. Same as figure 11 and 12 shows the active power response of WF1&WF2.

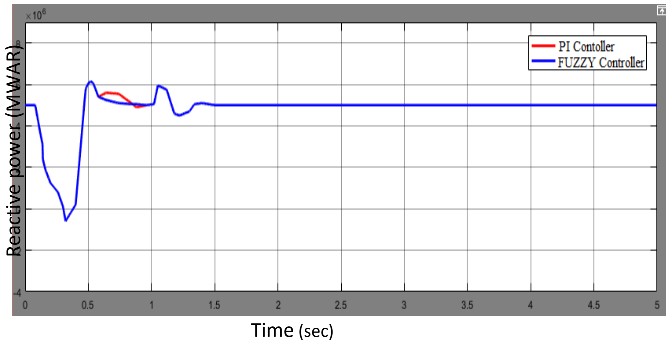

Figure 4. Wave form of reactive power at WF2

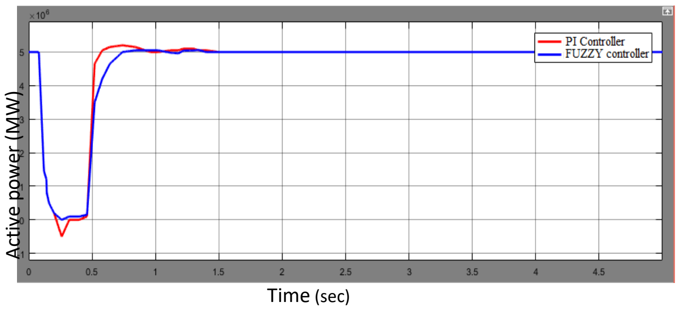

Figure 5: Waveform of active power at WF1

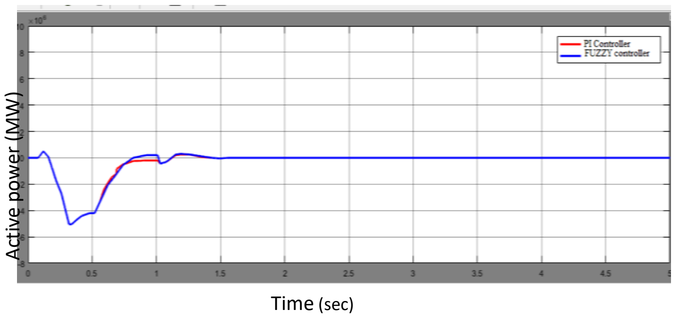

Figure 6: Waveform of active power at WF2

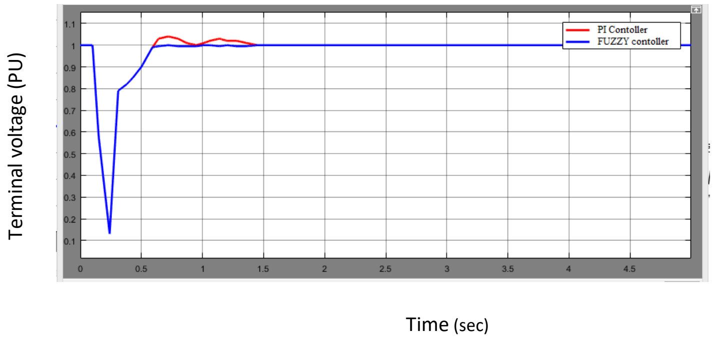

Figure 7: Terminal voltage at PCC point

4. Conclusion

When active power is positive and reactive power is negative, the value of current decreases nearly to zero, hence voltage is stabilized. With the variations in real and reactive power, voltage and current also vary, resulting into the voltage stability in HVDC system

Fuzzy-PI controller is projected in the grid side converter controllers of wind generator to increase its voltage stability as well as the performance of the neighboring wind farm composed of Fixed Speed Wind Generators.

The results express that the projected Fuzzy-PI controller is very active in refining the voltage stability of inclusive system during fault conditions. By creating the under voltage condition the applied voltage drop is almost 90 % of rated voltage 2.5 sec and at that time the behavior of active and reactive power changes according to that condition. After that voltage is stabilized

References

[1] O. J. Eyenubo and P. Oshevire, "Improvement Of Power System Quality Using VSC-Based Hvdc Transmission," Nigerian Journal of Technology, p. 8.

[2] J. Khazaei, P. Idowu, A. Asrari, A. Shafaye, and L. Piyasinghe, "Review on HVDC control of weak AC grids," Electric Power Systems Research, vol. 162, pp. 194–206, Sep. 2018.

[3] S. M. Muyeen, R. Takahashi, T. Murata, and J. Tamura, "Low voltage ride through capability enhancement of fixed speed wind generator," IEEE Bucharest PowerTech, Bucharest, Romania, Jun. 2009, pp. 1–6.

[4] J. Khazaei, P. Idowu, A. Asrari, A. Shafaye, and L. Piyasinghe, "REVIEW OF HVDC CONTROL IN WEAK AC GRIDS," Electric Power Systems Research, Sep. 2018.

[5] H. F. Latorre and M. Ghandhari, "Improvement of Voltage Stability by Using VSC-HVDC," South Korea, 2009

[6] M. A. Hannan et al., "Advanced Control Strategies of VSC Based HVDC Transmission System: Issues and Potential Recommendations," IEEE Access, vol. 6, 2018 pp. 78352–78369.

[7] Marwan Rosyadi, Rion Takahashi, Junji Tamura Japan S. M. Muyeen. "Fuzzy-Pi Controller Design For Pm Wind Generator to Improve Fault Ride Through Of Wind Farm"IEEE-2018

[8] R. Doherty, E. Denny, M. O'Malley, "System Operation With A Significant Wind Power Penetration", IEEE 2017

[9] K.S. Salman, A.L.J. Teo, "Windmill Modeling Consideration And Factors Influencing The Stability Of A Grid-Connected Wind Power-Based Embedded Generator", IEEE Trans,May 2003

[10] M. Imhof, A. Fuchs, G. Andersson, and M. Morari, "Voltage Stability Control Using Vsc-Hvdc Links And Model Predictive Control," IEEE-2014