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Controller Design Approach for Stability Enhancement in Wind Generation systems

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ABSTRACT: This paper presents a performance analysis of controller configurations in Wind energy conversion system (WECS), thus by maintaining the stability of the system. System stability is associated with power system faults in a network such as tripping of transmission lines, Three phase Faults and short circuits. To overcome this problems, effective control techniques have been incorporated in the appropriate area to enhance the operation of the system. Simulation results demonstrate that proposed Fuzzy configuration is better than that of PI configuration in order to stabilize the Self excited wind generator.

KEYWORDS: Wind energy conversion system(WECS), Self excited wind generator, Stability, Transmission Lines,Intelligent Controller.

I. INTRODUCTION

Generation of Electricity through wind received remarkable attention all over the world. Induction Generators are most widely used in Wind energy conversion systems, since they are reliable, robust and cost effective, also it has disadvantages like stability problems[1][3], unsatisfactory voltage and frequency regulation with variation in load. so its essential to analyse the transient stability of wind power stations.

This paper proposes PI-PI and Fuzzy-Fuzzy configuration for the stabilization of grid-connected wind generators. The control scheme is based on the PWM Voltage source converter and a two quadrant dc-dc chopper with IGBT switches.The power flow in and out of the storage coil is determined by the fuzzy controller in response to the undesirable transient faults in the system.The charge and discharge of energy storage coil are determined by the chopper duty cycle, which is controlled by the fuzzy logic. The electrical load is continuously varying by nature so there is need to maintain the stability of the system.In the literature many papers have been developed to control the SEIG using PWM converters. It has been a tendency to operate ac/dc converters with pulse width modulated switching patterns to improve the input and output performance of the converter, the majority of them is concerned with voltage regulation[5]. The difficulty in controlling the converters is mainly due to non-linearity, to overcome the nonlinearity the simplest way is to use conventional controllers. In this paper Intelligent fuzzy controller[7] is implemented ,which is compared and analysed with PI-PI configuration yields the better results than the former.

II. MODEL SYSTEM

The model system, as shown in fig.1,has been used for simulation work.

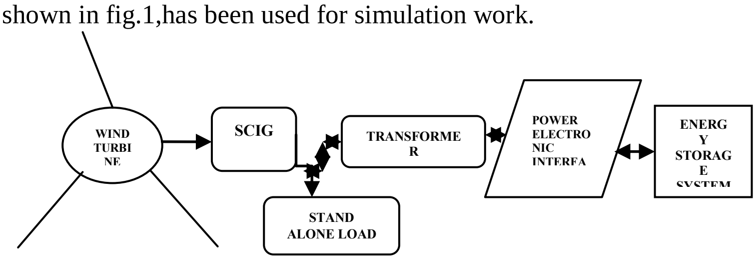

Figure 1 system model

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It consists of one squirrel cage induction generator which delivers power to a bus through transmission line. Capacitance value is chosen such that the power factor of the wind power station becomes unity, when it is generating the rated power. The Induction generator parameters are shown in Table I

TABLE 1
GENERATOR PARAMETERS

MVA	50
R1[pu]	0.01
X1[pu]	0.18
Xmu[pu]	10
R2[pu]	0.015
X2[pu]	0.12
H[sec]	1.5

III. MODELLING OF POWER ELECTRONIC INTERFACE

The power electronic interface comprises of three phase voltage source inverter and type-D chopper[8].

A.MODELLING OF VOLTAGE SOURCE CONVERTER AND TYPE-D DC-DC CHOPPER

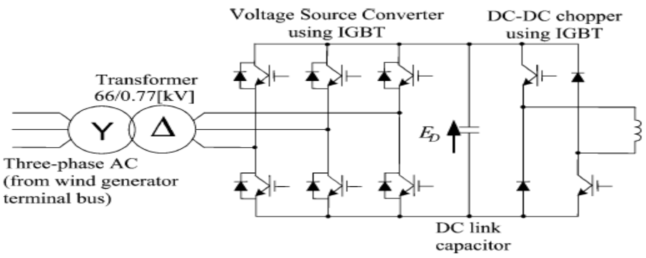

Figure 2 VSC-Chopper setup

A three-phase converter has three load-phase terminals.

The current supplied by the dc bus to the inverter switches is referred as dc link current and the magnitude of dc link current often changes in step (and some times its direction also changes) as the inverter switches are turned on and off.

The step change in instantaneous dc link current occurs even if the ac load at the inverter output is drawing steady power. However, average magnitude of the dc link current remains positive if net power-flow is from dc bus to ac load. [1]

The net power-flow direction reverses if the ac load connected to the inverter is regenerating. Under regeneration, the mean magnitude of dc link current is negative **.** The dc link capacitor should be put very close to the switches so that it provides a low impedance path to the high frequency component of the switch currents[2]

The voltage source converter gets its input voltage 0.77kv from the step down transformer. It acts as a bidirectional converter feeding two quadrant chopper through DC link capacitor,the voltage across the capacitor is maintained constant. If there is any fault in the line,the power returns in the reverse manner.

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The voltage equation is given by

$$V_d = \frac{3\sqrt{6}}{\pi} V_{rms} \cos\alpha - 6fLI_d \qquad (15)$$

Where,

Vd-voltage across the capacitor

f-frequency

L-Self inductance

Id-current

α-triggering angle

The two quadrant chopper is shown in fig.6

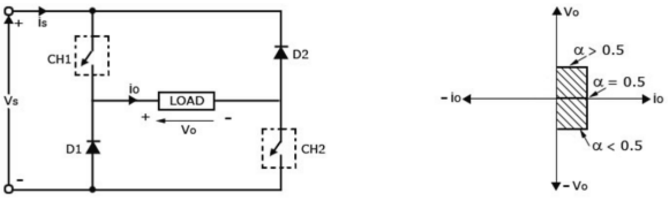

Figure 3 Type-D chopper and its quadrant operation

The circuit diagram of the type D chopper is shown in the above figure. When the two choppers are on the output voltage v_0 will be equal to V_s . When $v_0 = -V_s$ the two choppers will be off but both the diodes D1 and D2 will start conducting. V_0 the average output voltage will be positive when the choppers turn-on the time T_{on} will be more than the turn off time T_{off} its shown in the wave form below. As the diodes and choppers conduct current only in one direction the direction of load current will be always positive.[2]

The power flows from source to load as the average values of both v_0 and i_0 is positive. From the wave form it is seen that the average value of V_0 is positive thus the forth quadrant operation of type D chopper is obtained.[3]

From the wave forms the Average value of output voltage is given by

$$V0 = (V_s T_{on} - V_s T_{off})/T$$

$$= V_s.(T_{on} - T_{off})/T \qquad (16)$$

B.ENERGY STORAGE SYSTEM

The energy storage system consists of SMES device. A SMES device is a dc current device that stores energy in the magnetic field. The dc current flowing through a superconducting wire in a large magnet creates the magnetic field. Generally it consists of the superconducting coil, the cryogenic system, and the Power Conversion/Conditioning System (PCS) with control and protection functions

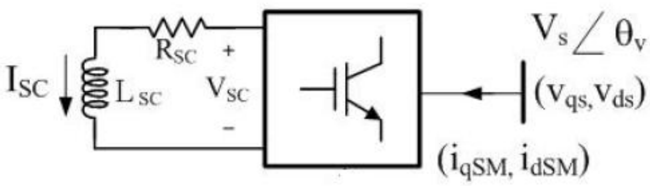

Figure 4 Schematic of energy storage coil

The equations of the real power flowing through the coil is given by

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$$P_{sm} = V_{ds}I_{dsm} + V_{qs}I_{qsm} = m1|Vs||Isc|\cos\alpha C \quad (17)$$

The energy stored in the coil is given by[4][7]

$$E = \left(\frac{1}{2}\right)(LsmIsm^2)$$

$$P = \frac{dE}{dt} = LsmIsm\left(\frac{dism}{dt}\right) \quad (18)$$

$$= VsmIsm \quad (19)$$

$$Vs = \sqrt{(V_{qs}^2 + V_{ds}^2)} \quad (20)$$

Where

P_{sm}-Power in the coil.

V_{ds}, V_{qs}-d-q axis voltage.

L_{sm}-Inductance of the coil

I_{sm}-current flows through the coil

I_{sc}-Short circuit current

α_C-angle between the voltages

m_1-duty cycle

IV. PROPOSED SYSTEM

A.PI-PI CONFIGURATION

In this configuration the PI controllers are used to control the firing pulses for voltage source converters as well as the duty cycle of type-D chopper as shown in figure.7

The PI controller is tuned by the traditional Ziegler-nichols method. After tuning, the values of proportional, integral gains were obtained. Effective rigorous tuning methods yields optimum values. [4]

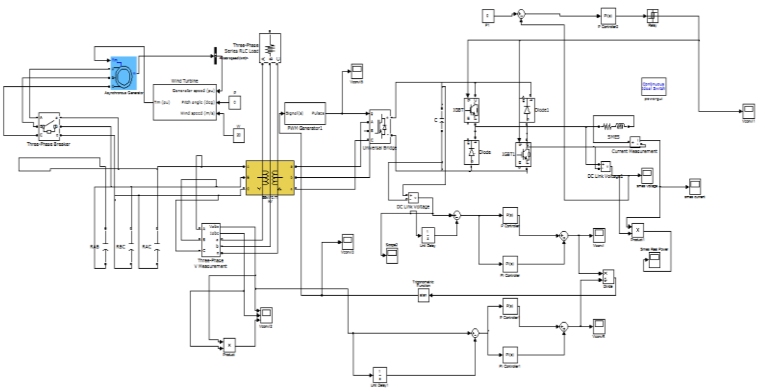

Figure 5 Simulink model for PI-PI configuration

When single phase open circuit fault is applied the energy stored in the coil maintains the voltage and power in B phase under fault time.[5]

The PI controller is a best conventional controller used in various fields. It does not have the offset associated with proportional control, yet it yields a much faster dynamic response than does integral action alone. Due to the presence

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of the integral mode the stability of the control loop is decreased.[6] Extreme caution should be used in applying this controller to process transfer functions containing I/s terms[6].

$$\mathrm{u}(t) = \mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau \qquad (21)$$

Where,

Kp-proportional gain
Ki-integral gain
E(t)-error
U(t)-controller output

The output voltages, current and power waveforms of the IG after applying single phase open circuit fault to B phase between 0.033 to 0.067 seconds are shown in fig.9

It can be clearly seen that, after the fault get cleared, the power and voltage doesn't regain to its original operating point. The power shoots through and settles down. This may cause unwanted disturbances in the load.[7]

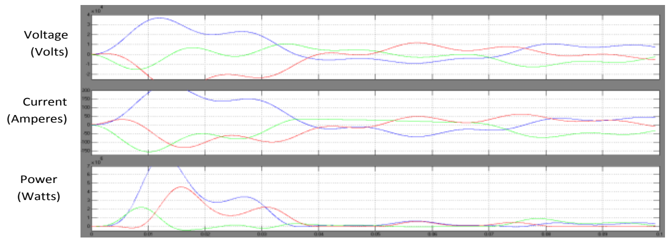

Figure 6 Output waveforms of PI-PI configuration

B.FUZZY-FUZZY CONFIGURATION

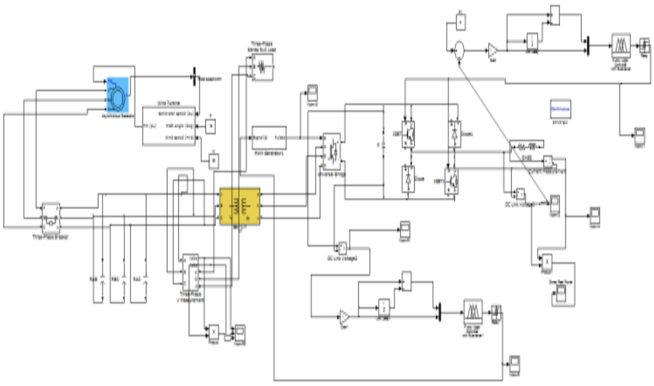

Figure 7 Simulink model of fuzzy-fuzzy configuration

Fuzzy rules

The rules included in fuzzy technique for chopper and voltage source converter is shown in table 1 and 2.

In fuzzy-fuzzy configuration the controller generates appropriate firing signals as well as duty ratio for chopper . [8]

The output voltages, current and power waveforms of the IG after applying single phase open circuit fault to B phase between 0.033 to 0.067 seconds are shown in fig.15

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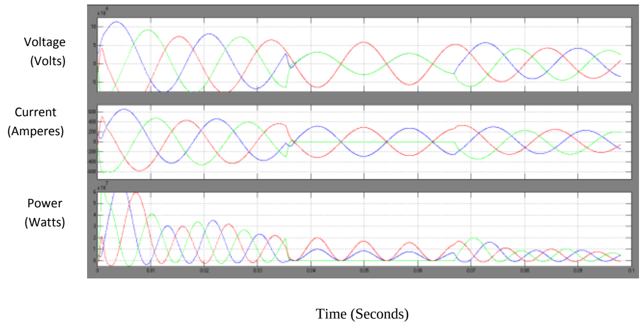

Figure 8 Output waveforms of Fuzzy-fuzzy configuration

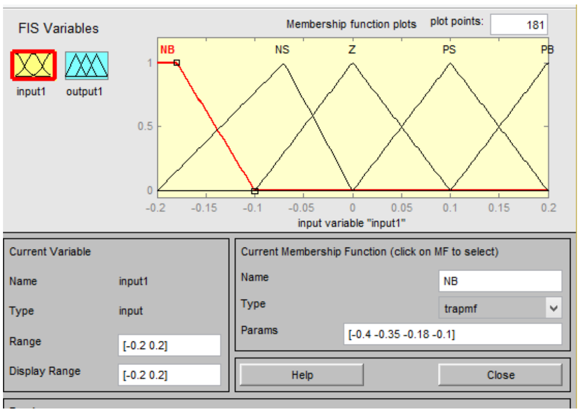

Figure 9 GUI Development of fuzzy rules

Table 2 Fuzzy rules for SMES control through chopper

Change in power across the coil	**Duty cycle**
NB	VERY SMALL
NS	SMALL
Z	MEDIUM
PS	BIG
PB	VERY BIG

Table 3 Fuzzy Rules for Voltage source converter

Change in power across the coil	**Duty cycle**
NB	VERY SMALL
NS	SMALL
Z	MEDIUM
PS	BIG
PB	VERY BIG

Fig.11 shows the curves of output voltages, currents and power of SCIG after opening circuit breaker at 0.0333 sec to 0.067 sec and Fuzzy controller maintains voltage and power. [9]

Compared to PI controller it has much improved performance and without distortions in O/P waveforms. After the faults get cleared at 0.067 sec immediately the voltage, current and Power gets settled without any deviations.[10] In the case of SMES with Fuzzy configuration, the power regaining is very much sooner and performance is healthier than the configuration having PI controller.

V. COMPARISON BASED ON SIMULATION RESULTS

I t can be inferred that, when fuzzy controller is incorporated either to control DC link voltage or to control the SMES voltage, the results depicts that output voltage and power has a quicker regaining compared to PI-PI configuration.[11]

Moreover, the Fuzzy-Fuzzy configuration yields better performance parameters than PI-PI configuration, so it is compared with it which is shown in table 3 with respect to output voltage.[12]

Table 4 Comparison of Controller parameters

Control configuration	Steadystate error	overshoot	Settling time(secs)
PI-PI	0.7	0.06	0.003
Fuzzy-fuzzy	-	-	0.0001

It shows that there is no steady state error, overshoot in Fuzzy-Fuzzy configuration[13]. Thus fuzzy Configuration along with SMES is invoked, then the output voltages and power were balanced sinusoidally and settles down to normal values in a very less time compared to PI-PI configuration. [14]

VI. CONCLUSION AND FUTURE WORK

Thus the proposed fuzzy logic controlled system has a better stability to fault conditions than the PI-PI configuration. Thus fuzzy Configuration along with SMES is invoked, then the output voltages and power were balanced and settles down to normal values in very less time compared to PI-PI configuration. The effective tuning of Fuzzy controller by adding more number of rules in order to stabilize the fixed speed WECS under various short circuit faults and This proposed model is to be interfaced with grid so that various stability problems can be analysed in future

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