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# Analysis on the Effect of Magnetic Energy Storage on the Stability Parameters of a Wind Generator Connected System

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***Abstract: The usage of superconducting storage medium for the improvement of system stability is studied in this paper. A Superconducting Magnetic Energy Storage coil (SMES) is used along with the wind energy connected system. The grid connectivity is maintained with the help of converter unit, controlled using fuzzy logic. The system model is simulated on MATLAB/SIMULINK environment and the variations of parameters of the generators are studied.***
***Keywords: fuzzy logic, grid, MATLAB, SIMULINK, SMIB system, stability, superconducting magnetic energy storage (SMES), wind energy.***

## I. INTRODUCTION

The balance between power production and the usage is of utmost importance considering the stability of the system. With the emergence of new cities, factories etc. new load centers are evolving which demands more power , even outside the capabilities of the existing system. This should be done keeping cost as a constraint so as to establish a sustainable system. Operating the existing system in its maximum limit always attracts stability issues. The stability of a system may be defined as its ability to respond to the power demands for which it was designed[1]. The trends of stability studies varies with time but is a field which always attracts the attention of researchers because of the complexities it offer. The papers focusing on the stability problem came out from the early 1900s.[2,3,4].

Wind power is lately emerged as a trusted source as it offers various possibilities ranging from lower running costs to reduced pollution. Wind power plants are more close to nature. But the integration of them to grid is a complex process. Introduction of wind generating stations aggravate the stability issues which are already present in the system. The analysis of transients on systems with wind power plants and their stability problems is thus having profound significance on the total grid performance.

Wind systems always prefer having stored energy mechanisms that allows the storage of surplus energy during normal hours so that it can be utilized in peak load hours. This may help in reducing the stress on the grid thereby improving other parameters like power transfer capability, system stability, system frequency etc. As a result of this the burden of additional loads on the generator is removed and therefore the complete power system remains intact.

Superconducting Magnetic Energy Storage (SMES) systems make use of a coil to store the energy that it receives. Since this is an inductive coil, the presence of magnetic field paves the medium for storing energy. The coil is to be kept in a cryogenic medium so as to keep the temperature at its critical temperature level or below it. The primary advantage of having an SMES system comes from the fact that they can transfer power from and to the system within fraction of seconds. The only time lag may be due to the delay in operation of the converter unit. SMES units also allows the transfer of enormous amount of power. Also the energy can be stored without any time limits. Since at superconducting temperature the resistance of the material is almost zero , the power transfer happens without any losses. First SMES device in a grid is used at Bonneville Power Plant located at Tacoma Washington substation for transmission stabilization and low frequency oscillation damping[5]. Since then intense research is undergoing in this field to improve the performance of SMES unit and to diversify its application.

Fuzzy logic controllers offer accuracy and flexibility than the traditionally operated devices. In this paper the main control signal for the optimization is obtained with wind generator speed as the input. The paper [6] also proposes a similar technique for the stability improvement of wind power connected system ,with deviation in induction generator power as the input to fuzzy systems. The rotor speed deviation of the induction generator is considered as the input for the control system. The SMES is connected to the grid with the help of a dc–dc chopper unit and a voltage source converter. The control of converter is with the help of pulse width modulation (PWM) technique and the chopper by the fuzzy logic controller. The proper coordination of the control system is to be maintained for successful operation of the system.

## II. MODELSYSTEM

The proposed model is based on the single line diagram of the system given in fig.1[6].

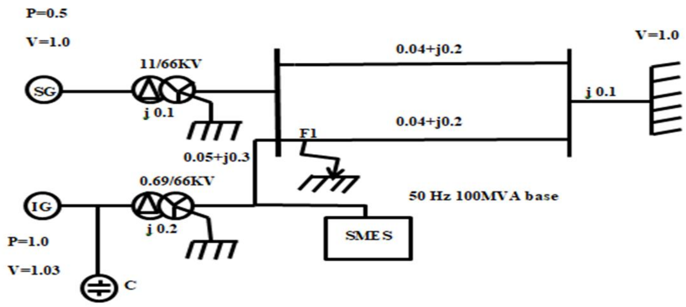


Fig.1 Power system model

The system has a single machine infinite bus-bar (SMIB) system with an induction generator(IG) .

For the effective control of power balancing in the system ,the SMES unit is connected to the grid at the terminal where wind generator is connected to the grid. Excitation system and speed governor is made use of in simulation. The parameter values used in the simulation are shown in table 1.

TABLE I

Generator Parameters

| Synchronous Generator(SG) | | Induction Generator(IG) | |
|---|---|---|---|
| MVA | 100 | MVA | 50 |
| ra(pu) | 0.003 | $R_1$(pu) | 0.01 |
| Xa(pu) | 0.13 | $X_1$(pu) | 0.18 |
| Xd(pu) | 1.2 | Xmu(pu) | 10.0 |
| Xq(pu) | 0.7 | $R_2$(pu) | 0.015 |
| Xd'(pu) | 0.3 | $X_2$(pu) | 0.12 |
| Xq'(pu) | 0.22 | H(sec) | 1.5 |
| Xd" (pu) | 0.22 | | |
| Xq" (pu) | 0.25 | | |
| Tdo'(sec) | 5.0 | | |
| Tdo" (sec) | 0.04 | | |
| Tqo" (sec) | 0.05 | | |
| H(sec) | 2.5 | | |

## III. WIND GENERATOR

The modeling of wind turbine is a complex process involving number of parameters, which are largely electrical as well as mechanical. Since we are studying the electrical parameters the scope of this paper is restricted to the electrical simulation of the wind generator and its analysis . For this study simple model of the design of wind generator is assumed where various other factors like blade of the wind turbine, the shaft design etc. are neglected .

Here torque developed in the wind turbine is calculated using the following formula;

$$T=0.5* \Pi R^3 * V\omega^2 * \rho * Cp (\lambda,\beta)/\lambda \qquad (1)$$

Where T is the turbine torque (in newton meters), $R$ is the radius of the blade (in meters), $V\omega$ is the wind velocity (in meters per second), $\rho$ is the air density (in kilograms per cubic meter), β is the blade pitch angle (in degrees) and $Cp$ , the power coefficient. $\lambda$ is the tip speed ratio (the ratio of the linear speed of the blade tip to the speed of the wind).

The mechanical characteristics is represented using the following 2 equations:

$$\lambda = v/\omega_B \quad (2)$$

$$Cp = 1/2 * (\lambda - 0.022\beta^2 - 5.6) * e^{-.17\lambda} \quad (3)$$

Where v represents the velocity of the wind (in kilometers per hour) and $\omega_B$ is the angular velocity of the blade (in mechanical radians per second).

The parameters of the system modeled with the above considerations are provided in the simulation of the system using MATLAB/SIMULINK.

## IV. SMES MODEL

The proposed SMES unit consists of a coil which is superconducting (represented as an inductor) of .24 H. A dc- link capacitor is used in between the converter and chopper unit. SMES is connected to the grid with the help of a 66 KV/.77 KV Wye/Delta transformer , a two quadrant dc-dc chopper ,a PWM rectifier /inverter of 50 MVA .

The energy stored in an inductor is given by the formula

$$E = \frac{1}{2} L I^2 \quad (4)$$

where E is the stored energy in the coil ,L depicts the inductance of the coil and I is the inverter current.

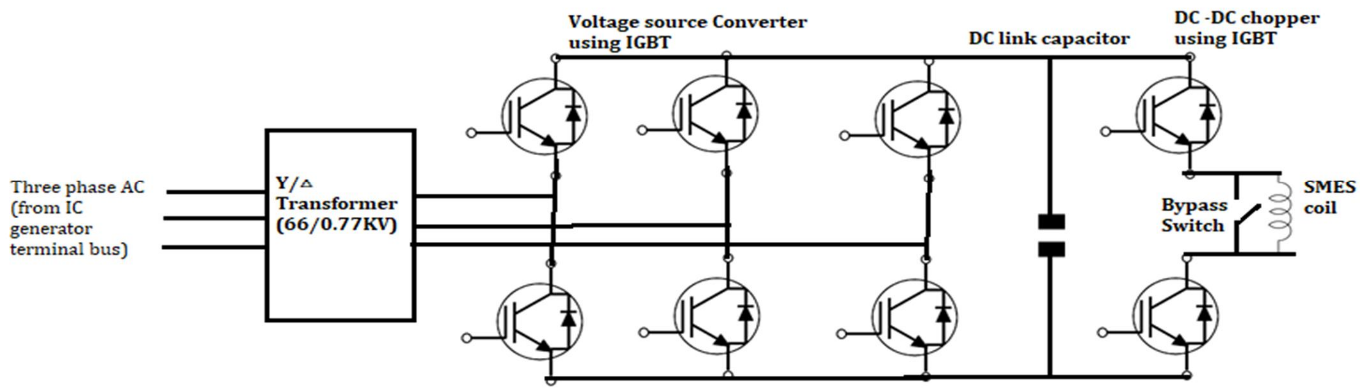


Fig.2 SMES system configuration

The dc-link capacitor is used to maintain the initial voltage at a constant value. The current in the inductor then rises to the rated value,$I_o$ and is maintained constant at this level by reducing the voltage level approximately to zero. Then the unit is ready to be connected to the grid. The current in the SMES network is given by the equation[8]

$$I = \frac{1}{L} \int_{to}^{t} V d\tau + I_o \quad (5)$$

Where $I_O$ is the initial current of the inductor and V the voltage across the SMES unit .

The output power of the SMES unit is a unique function of the voltage on the dc side of the converter unit. The transmission of power depends on the value of voltage in the system. The power is transmitted to the grid from the SMES unit if the value of V is negative and vice versa. The storage of energy in the coil is given by the formula

$$W = W_0 + \int_{to}^{t} P \, d\tau \quad (6)$$

Here $P$ represents the real power transferred by the SMES network. $W_O$ is the stored energy in the inductor because of the initial current flow along the inductor.

The power conditioning unit consists of the converter unit and the chopper [9]. The converter unit is a Voltage Source Converter made of IGBTs. The pulse signals for the converter unit is obtained with the help of PWM generator. The PWM pulse generation is by comparing the voltage signal of the wind turbine with a triangular waveform which is having a frequency of 1150Hz.

The duty cycle of the chopper circuit is adjusted to control the charging and discharging of the superconducting coil. The controller operates with the help of fuzzy logic to include improved accuracy and reliability. The power transfer is programmed in such a way that when the duty cycle is less than 0.5, the coil gives the power to the system and vice versa. The output signal from the fuzzy logic controller is compared with a continuous sequence and the duty cycle of the system is duly produced. The frequency of saw-tooth carrier wave I for comparison is fixed as 450 Hz.

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## V. DESIGN OF CONTROLLER FOR THE SMES UNIT

The greatest advantage of fuzzy logic is that it doesn't require any precise, numerical information. Fuzzy can produce crisp output from a set of approximate inputs. Fuzzy concept gives membership functions to each input and output. The output is obtained with the help of these membership functions with various defuzzification methods [10].

For the design of the fuzzy logic controller the fluctuation of the Induction generator speed, and its derivative are used as the inputs and the chopper duty cycle is selected as the output. The membership functions used for the input and output parameters are triangular in shape and are given in fig.2. Here same membership function is used as the membership function of both inputs and the output.

The control rules for the fuzzy operation is obtained by combining the practical system performance and by using trial and error method [11]. The developed rules for the proposed system is given in table 2.

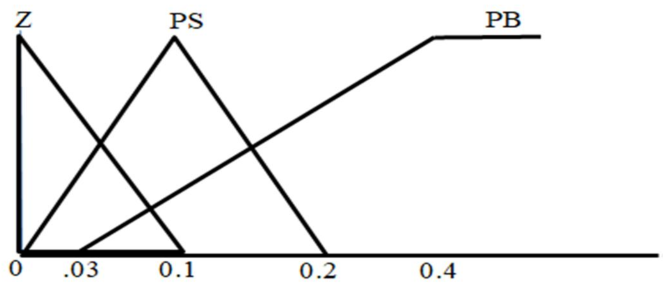


Fig.3 fuzzy membership function for inputs and output

TABLE.II
Fuzzy Rule Set

| INPUTS | | OUTPUT |
|---|---|---|
| $\triangle\omega$ | $\frac{d}{dt}\triangle\omega$ | |
| Z | Z | VERY SMALL |
| | PS | MEDIUM |
| | PB | BIG |
| PS | Z | VERY SMALL |
| | PS | MEDIUM |
| | PB | BIG |
| PB | Z | VERY SMALL |
| | PS | MEDIUM |
| | PB | BIG |

The fuzzy logic controller is developed with Mamdani's method as the inference mechanism. The production of crisp output from the fuzzy system is obtained with the help of centroid method of defuzzification. The output obtained with fuzzy is compared with the repeating sequence to obtain the duty cycle.

## VI. SIMULATION RESULTS

For simulation purpose the wind speed is assumed to be constant at 11.8 m/s. A balanced 3LG fault (3 phase to ground) is supposed to happen at 0.1 s. The circuit breaker on the faulted line is opened at a time of 0.2s and is closed again at 1.0s. One assumption that we use is that the circuit breaker is supposed to clear the faulted line before the reclosing period. The fault is assumed to be taken at one of the transmission lines as shown in the power system model. The time for simulation is taken as 10.0s and the time step is taken as .00001 s

The various responses obtained in the SIMULINK environment is shown below. The output obtained for the real power of the Induction generator (IG) is given in fig. 3.Here we can clearly see that with our proposed SMES system, the network can settle at its initial power value without much time lag.

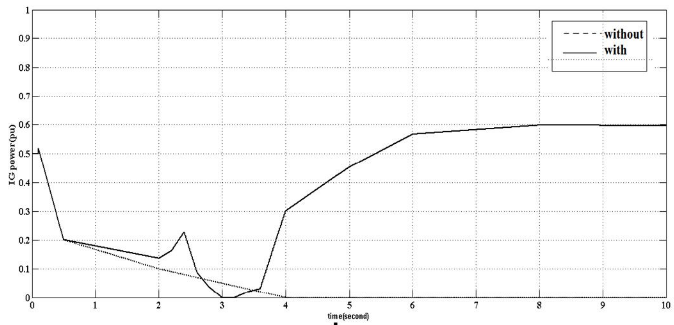


Fig.4 Response of IG real power

Likewise the case of the IG real power, SMES unit will helps to improve the IG terminal voltage ,rotor speed and also the synchronous generator load angle. They are illustrated in figures 4,5,6.

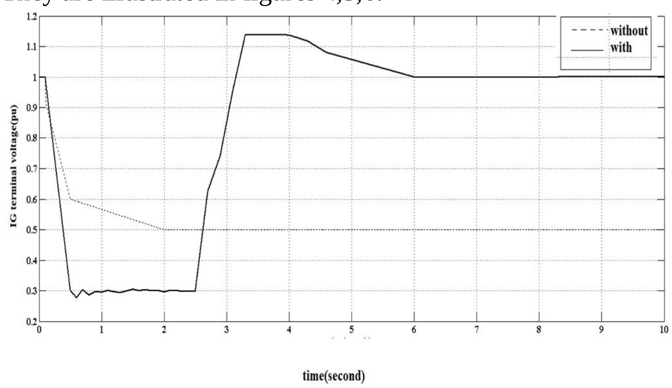


Fig.5 Response of terminal voltage of Induction Generator

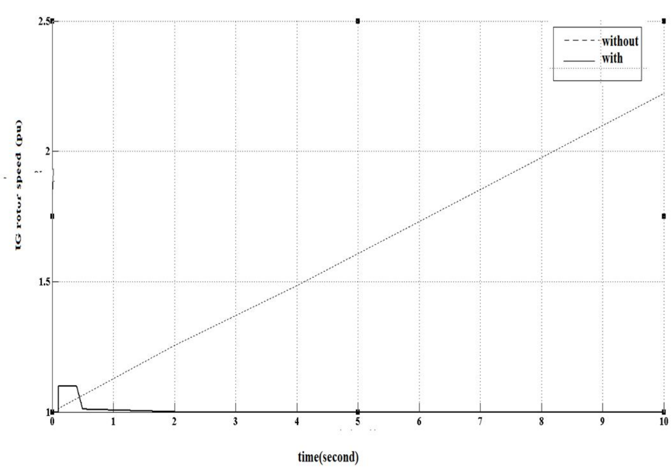


Fig.6 Response of rotor speed of Induction Generator

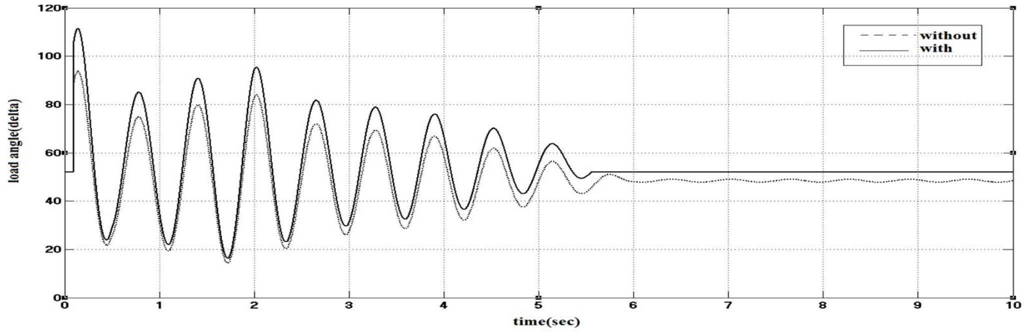


Fig.7 Response of SG load angle

Figure 7 shows the amount of real power absorbed and supplied by the SMES unit when the fault is occurred and cleared.

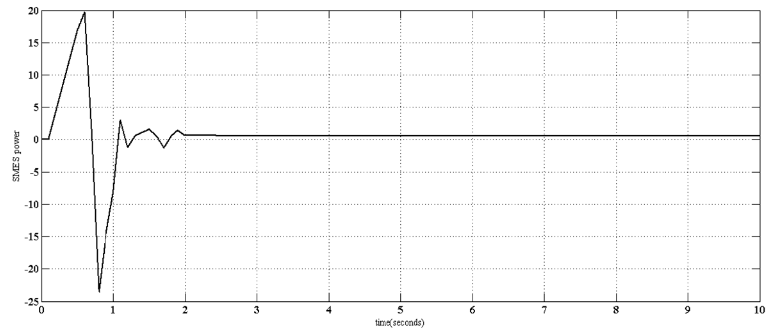


Fig.8 Real power waveform at the SMES terminal

## VII. CONCLUSION

This paper has proposed a SMES unit controlled by fuzzy logic controller which uses parameters from a wind turbine as the input with a control system developed in fuzzy logic. The analysis of the simulation results reveals that the usage of this controller will help to reduce the stability problem in a wind connected system. The basic reason for the superior performance of the SMES unit comes from the fact that it is capable of absorbing and delivering real and reactive power from and to the system respectively. Because the system is not having any moving mechanical parts the loss of power from the usage of SMES is also very less. Overall it will help to improve the performance of the system particularly when systems such as solar units ,wind power units etc. are connected to the grid.

## REFERENCES

[1] F. H. Glough, "Stability of Large Power Systems", IEEE Journal, Vol. 65, No. 367, July 1927.
[2] C.L. Fortescue, "Transmission Stability Analytical Discussion of Some factors Entering into the Problem", Pacific Coast Convention of AIEE Seatle, Washington, September 15 -19, 1925, pp. 951-961.
[3] J. G. Holm, "Stability study of ac power transmission systems", Proceedings of AIEE Summer Convention, Chicago, June 22 – 26, 1942, pp. 893 – 905.
[4] First report of Power System Stability, Committee Report on AIEE Committees on Power Transmission and Distribution, Electrical Machinery, Power Generation and protective devices, November 2, 1936, pp. 262 – 282.
[5] H. J. Boenig and J. F. Hauer, "Commissioning tests of the Bonneville power administration 30 MJ superconducting magnetic energy storage unit," IEEE Trans. Power App. Syst., vol. PAS-104, no. 2, pp. 302–309, Feb. 1985.
[6] M.H. Ali, Park Minwon ,Yu In-Keun ,T.Murata, J.Tamura, " Improvement of Wind-Generator Stability by Fuzzy-Logic-Controlled SMES", IEEE transactions on power systems, Vol.45 ,No.3,May/June 2009, pp.1045-1051
[7] P. M. Anderson and A. Bose, "Stability simulation of wind turbine systems," *IEEE Trans. Power App. Syst.*, vol. PAS-102, no. 12, pp. 3791–3795, Dec. 1983
[8] M H Ali, T Murata, J Tamura, "a fuzzy logic-controlled superconducting magnetic energy storage for transient stability augmentation", IEEE transactions on control systems technology, vol. 15, no. 1, January 2007,pp.144-150
[9] C.Rehtanz, "Systemic use of multifunctional SMES in electric power systems", IEEE transactions on power systems, Vol.14,No.4,November 1999, pp.1422-1428
[10] P.K.Dash, A.C. Liew, "Anticipatory fuzzy control of power systems," IEEE transactions on generation, transmission distribution, Vol.142 ,No.2,March 1995, pp.211-218
[11] T.Hiyama, Y. Ueki, H. Andou, "Integrated fuzzy logic generator controller for stability enhancement," IEEE transactions on power systems, Vol.12,No.4,December 1997, pp.400-404