

# Design of Fuzzy Controller for Improvement of Transient Stability of Hybrid Energy Generation System

N. V. Rathi and H. S. Dalvi

**Abstract**—This paper deals with soft logic rather than hard logic. Matlab based hybrid model of wind solar and thermal energy generation is developed. Fuzzy logic based controller takes decision As how much non conventional power can be injecting to the conventional system during fault condition so that the rotor angle variation limits and transient stability of system is improved .Large interconnected power system events need careful co-ordination of logical events for complex or catastrophic situations such as huge power swings, Faults, Cascade tripping etc needs careful control and control law in such cases becomes vague or fuzzy. Hence human expert decision is required or expected from automated control. Intelligent decisions similar to humans can very well be handled by fuzzy controllers. Hence the proposed work will highlight the need of fuzzy based decisions as modernized approach to improve the transient stability of hybrid (Wind, Solar & Thermal) energy generation system.

**Index Terms**—Wind, solar, thermal, fuzzy controller, transient stability, matlab/simulink

## I. INTRODUCTION

Model simulates a sample power system consisting of hybrid energy (Wind, Solar) non conventional energy sources with conventional energy sources i.e. synchronous generator along with a transmission line and load and facility to create fault. Fuzzy controller limits the power angle during the fault condition by injecting the proper amount of non conventional power as per the variation of power angle of the system. Fuzzy controller gives the Fast and efficient control action. It introduces artificial intelligence, it enhances decision making capability of system hence it is better. Fuzzy logic is a new way of expressing probability. Fuzzy logic and probability are different ways of expressing uncertainty. While both fuzzy logic and probability theory can be used to represent subjective belief, fuzzy set theory uses the concept of fuzzy set membership (i.e. how much a variable is in a set), probability theory uses the concept of subjective probability

In engineering systems, fuzzy logic provides a convenient and user-friendly front-end to develop control programs, helping designers to concentrate on the functional objectives, not on the mathematics.

## II. WIND POWER BASED ON MATHEMATICAL EQUATION

Air has mass and it moves to form wind, it has kinetic

energy.kinetic energy (joules) =  $0.5 \times m \times V^2$ , where:  $m$  = mass (kg),  $V$  = velocity (meters/second) we're more interested in power which changes moment to moment than energy. Since energy = power  $\times$  time and density is a more convenient way to express the mass of flowing air, the kinetic energy equation can be converted into a flow equation

Power in the area swept by the wind turbine rotor:

$$P = 0.5 \times \rho \times A \times V^3$$

where:  $P$  = power in watts ,  $\rho$  = air density (about 1.225 kg/m<sup>3</sup> at sea level)  $A$  = rotor swept area, exposed to the wind (m<sup>2</sup>)  $V$  = wind speed in meters/sec.

This yields the power in a free flowing stream of wind. Of course, it is impossible to extract all the power from the wind because some flow must be maintained through the rotor So, we need to include some additional terms to get a practical equation for a wind turbine.

Wind Turbine Power:  $P = 0.5 \times \rho \times A \times C_p \times V^3 \times N_g \times N_b$

where:  $C_p$  = Coefficient of performance (0.59 is the maximum theoretically possible, 0.35 for a good design)  $N_g$  = generator efficiency (80% or possibly more for a permanent magnet generator or grid-connected induction generator)  $N_b$  = gearbox/bearings efficiency (depends, could be as high as 95% if good)

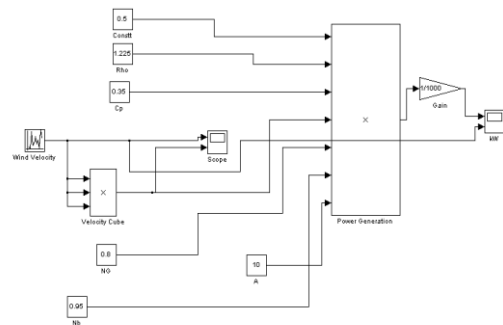


Fig. 1. Matlab based Wind power generation model.

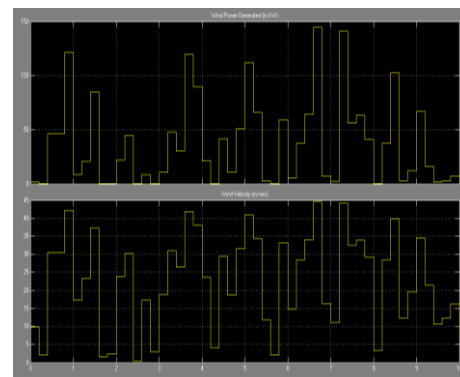


Fig. 2. Wind power generation and wind velocity.

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### III. SOLAR POWER BASED ON MATHEMATICAL EQUATION

The power incident on a PV module depends not only on the power contained in the sunlight, but also on the angle between the module and the sun. When the absorbing surface and the sunlight are perpendicular to each other, the power density on the surface is equal to that of the sunlight (in other words, the power density will always be at its maximum when the PV module is perpendicular to the sun). However, as the angle between the sun and a fixed surface is continually changing, the power density on a fixed PV module is less than that of the incident sunlight.

The amount of solar radiation incident on a tilted module surface is the component of the incident solar radiation which is perpendicular to the module surface. The Fig shows how to calculate the radiation incident on a titled surface ( $S_{module}$ ) given either the solar radiation measured on horizontal surface ( $S_{horiz}$ ) or the solar radiation measured perpendicular to the sun ( $S_{incident}$ ).

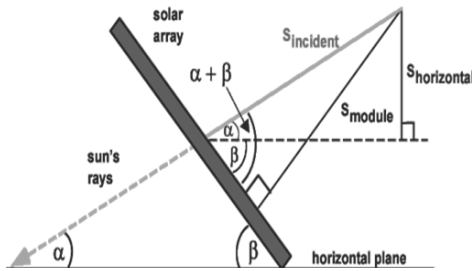


Fig. 3. Amount of solar energy converted to electrical power.

The equations relating  $S_{module}$ ,  $S_{horiz}$  and  $S_{incident}$  are:

$$S_{horiz} = S_{incident} \times \sin \alpha$$

$$S_{module} = S_{incident} \times \sin(\alpha + \beta)$$

where,  $\alpha$  is the elevation angle; and  $\beta$  is the tilt angle of the module measured from the horizontal.

The elevation angle is given as  $\alpha = 90 - \Phi + \delta$ ,  $\Phi$  is the latitude; and  $\delta$  is the declination angle.

$$\delta = 23.45^\circ \sin \left[ \frac{360}{365} (284 + d) \right]$$

where d is the day of the year.

From these equations a relationship between  $S_{module}$  and  $S_{horiz}$  can be determined as:

$$S_{module} = \frac{S_{horizontal} \sin(\alpha + \beta)}{\sin \alpha}$$

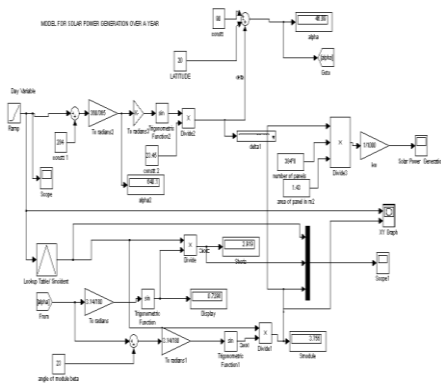


Fig. 4. Matlab based solar power generation model.

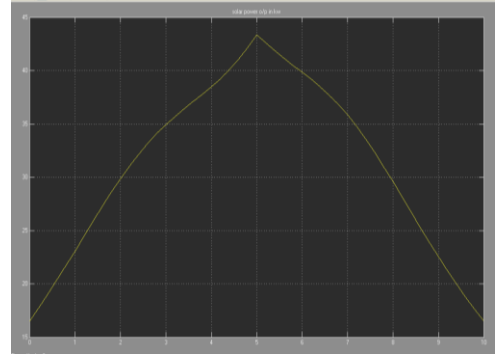


Fig. 5. Solar power output with variation of day time in hours.

### IV. POWER SYSTEM MODEL WITH SYNCHRONOUS GENERATOR

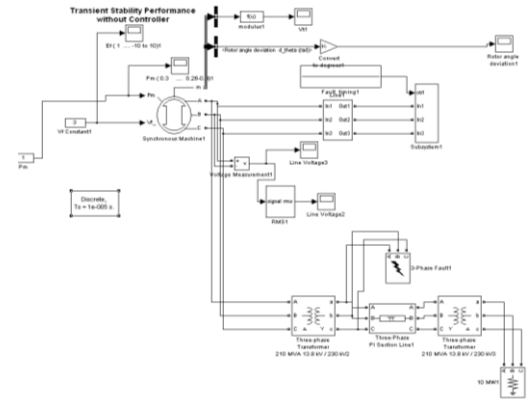


Fig. 6. Power system model of synchronous generator with 3-Ph. Fault.

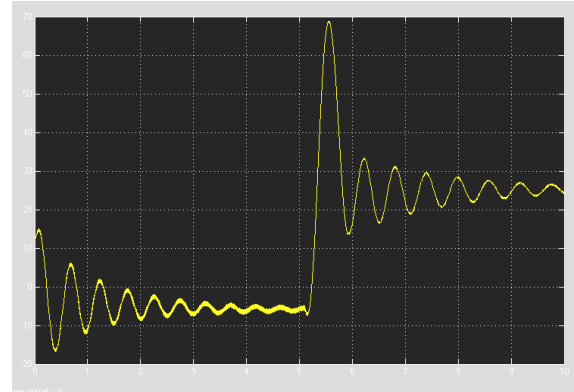


Fig. 7. Power angle variation with respect to time.

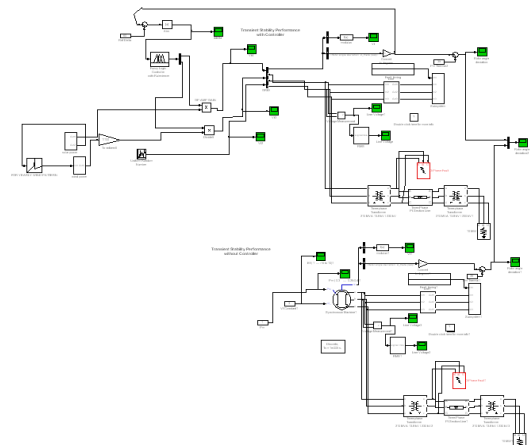


Fig. 8. Hybrid model of energy generation with fuzzy controller for transient stability improvement.

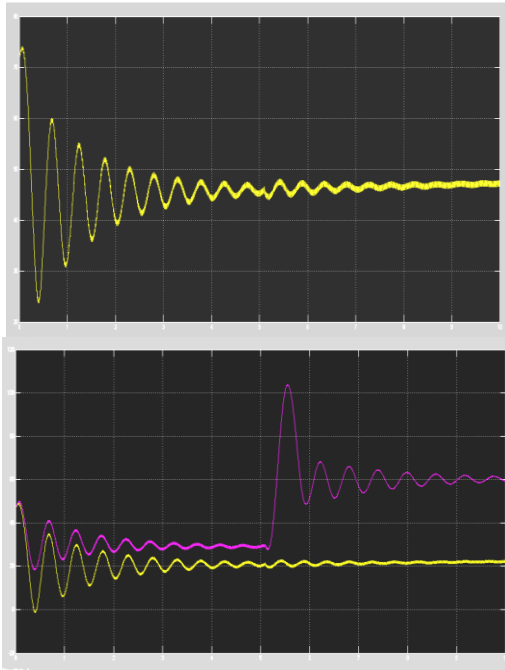


Fig. 9. Power angle variation with and without fuzzy controller for hybrid energy generation system.

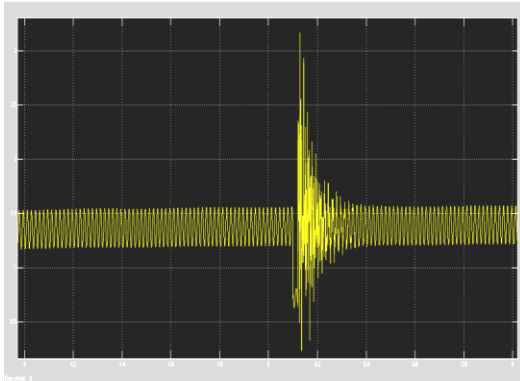


Fig. 10. Line voltage with respect to time.

## V. CONCLUSION

In above results Fig. 7 shows power angle variation during creating fault and clearing fault which show large

variation to limit that large variation fuzzy controller based decision to add non-conventional power to the system. Fig. 8 shows the hybrid power generation system with & without fuzzy controller. From Fig. 9 it is clear that using fuzzy controller the variation of power angle limited with the help of non-conventional energy sources. Hence the Transient stability is improved as the fuzzy rule based hence it can be modified very efficiently according to different situation.

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