The Improvement of Power System Stability With Excitation Current And The Prime Mover of Generator By Using Fuzzy Logic Controller

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Abstrak

Dalam suatu sistem tenaga listrik yang terdiri dari beberapa pembangkit, stabilitas tenaga listrik dalam menyalurkan energi listrik menjadi masalah yang harus diperhatikan. Pada sistem yang saling terkoneksi adanya gangguan pada sistem baik itu pada saluran transmisi, pembangkit, atau beban akan menyebabkan pembangkit lain ikut merasakan adanya gangguan tersebut. Untuk gangguan yang tidak terlalu besar biasanya sistem dapat mengatasi gangguan tersebut dan tidak akan mempengaruhi stabilitas sistem secara keseluruhan. Namun untuk gangguan yang skalanya cukup besar dan terjadi pada jangka waktu yang cukup lama dapat mengakibatkan sistem menjadi tidak stabil dan akan mengakibatkan terganggunya pasokan energi listrik ke beban. Untuk kondisi yang terburuk dapat mengakibatkan terjadinya black out.

Tulisan ini membahas tentang perbaikan stabilitas sistem tenaga listrik dengan cara pengendalian eksitasi dan penggerak utama yang dikoordinasikan dengan pengendali logika fuzzy pada pembangkit serempak. Dengan penggabungan dari tiga metode diatas diharapkan sistem akan cepat mencapai stabilitasnya kembali.

Dengan mengatur besarnya eksitasi dan daya mekanis dari penggerak utama pembangkit yang dikendalikan dengan logika fuzzy pada saat gangguan terjadi akan membuat daerah akselerasi menjadi berkurang dan menambah luas daerah deselerasi sehingga sistem dapat stabil dengan cepat.

Kata Kunci: *Stabilitas, Arus penguat, Penggerak utama dan Logika fuzzy*

Abstract

In electric power systems that consist of some generators, electric power stability in supplies side becomes the most important problems, which must be paid attention. In the interconnection system, if there are some troubles in transmission, generator or load will cause another generators feel the existence of instability condition. For instability condition which not too serious, system can overcome the fault and will not influence stability of system as a whole. However, for in big scale of fault and happened in a long duration can be effected system becoming unstable and will result hampered of electrics energy supply to the load. For the worst condition could be black out condition.

This article studies about improvement of the stability of the system by using excitation current and the prime mover of generators, which is coordinated fuzzy logic control in synchronize generator. By using annexation from three methods above, the condition of stability of the power system can attain the stability. The transient stability needed control in order that system with good stability can return to normal condition. Faulted electric power system often caused by failure in controlling the transient stability. It is because in transient stability forms critical condition for electrical power system.

By controlling the level of excitation current and mechanical energy from the prime mover of generators which controlled by fuzzy logic when the fault is happened, will make acceleration area become decreasing and deceleration area become increasing with the result that system can be stable quickly. It visible that from result of simulation obtained if using generator oscillation of fuzzy logic control, transient period becoming shorter and amplitude of oscillation wave is smaller compare by using without fuzzy logic. Likewise, this method is able too to overcome transient condition at starting period of a generator.

Keywords: *Stability, Excitation current, Prime mover and Fuzzy logic.*

1. Introduction

Power system electric have very dynamic load variation where each second will fluctuate, but with that change, electric supply must be keep continue with appropriate electric quantities. When at the certain time electric load fluctuate very extreme which is not anticipated by the system, that change called electric power system fault. That fault makes unbalance condition between electric supply and electric demand. Faulted generator will change into transient condition. If the system cannot tolerate the fault then generator will lost their synchronization with the system. So to avoid lost of synchronization between generator and system, when fault occur, system claimed to be able to overcome fault so that generator can continue to supply electric load. It is very important problem to maintain reliability of electric power system which is stability of its power system. System with good stability can return to normal condition after certain period of fault.

In power system stability divided in to 3 category [5]:

Steady-state stability
Dynamic stability
Transient stability

2. Transient Stability

Transient stability is an ability of power system to reach a new balance point which is not always at the same point before fault happened after certain time of big fault.

Analysis of transient stability conducted at the first second (first swing), because system stability very determined from early condition. The objective is how the characteristic of generator and load at the fault condition. Do they still can maintain synchronization between rotor and stator magnetic speed and back to normal condition.

To make easier in analyze the phenomena of transient stability we use a method called equal area criterion. With this graphic system can be determined whether it will become stable or unstable after fault happened.

3. Equal Area Criterion

To analyze equal area criterion we need 2 equations which are swing equation and load angle equation. Both of the equation used to analyze equal area criterion method.

The first equation is load angle equation which is define as the difference of angle phases of voltage between generating bus and load bus [3]. Faulted system will made load angle different from original angle phases when system is healthy. At the fault load angle will increase and keep continue increase and it will decrease if fault clear. At stable system, if fault clear then load angle will return at condition before fault occur after passing one or several oscillation around the normal load angle [4]. Load angle equation is :

$$P_e = \frac{|E_1||E_2|}{|X_{12}|}\sin(\delta - \varphi) \qquad (3.1)$$

$$P_e = P_{max}.\sin(\delta - \varphi) \qquad (3.2)$$

From swing equation which representing elementary principle movement of rotor generator we can get equation [1]:

$$\frac{2H}{w_s}\frac{d^2 d}{dt^2} = P_a \text{ pu} \qquad (3.3)$$

$$\frac{d^2\delta}{dt^2} = P_a \cdot \frac{\omega_s}{2H}$$

If we integral both sides we can obtain :

$$\int d\left(\frac{d\delta}{dt}\right)^2 = \frac{\omega_s}{H}\cdot\int P_a \; d\delta$$

$$\frac{d\delta}{dt} = \left(\frac{\omega_s}{H}\cdot\int_{\delta_0}^{\delta} P_a \; d\delta\right)^{1/2}$$

When generator work in synchronize condition $\frac{d\delta}{dt} = 0$ so that Pa which came from integral result equal to zero. Pa or accelerating power is reduction of mechanical power and electrical power of system, so that equation above became:

$$\int_{\delta_0}^{\delta}(P_m - P_e)\,d\delta = 0$$

When fault happen at δ_0 and clear at δ_c, and δ_c value between δ_0 and δ so the equation become:[1]

$$\int_{\delta_0}^{\delta_c}(P_m - P_e)\,d\delta + \int_{\delta_c}^{\delta}(P_m - P_e)\,d\delta = 0 \text{ or}$$

$$\int_{\delta_0}^{\delta_c}(P_m - P_e)\,d\delta = \int_{\delta_c}^{\delta}(P_e - P_m)\,d\delta \qquad (3.4)$$

From equation (3.4) it can be showed electric power graph as function of load angle which is shown under this :

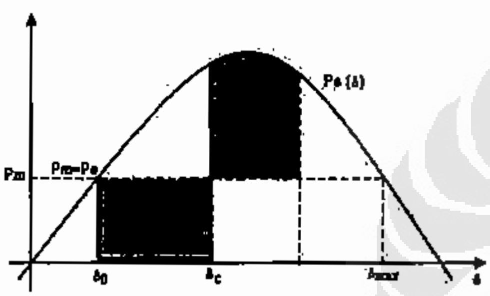

Figure 1.
Electric power as function of load angle

4. Governing Control of Generator

When fault occur in power system hence area of acceleration in equal area criterion have to be minimized so that area of deceleration that formed after fault clear can equalize area of acceleration. Fist effort to minimize area of acceleration is controlling mechanical power of generator.

Controlling mechanical power done by giving input controller fuzzy logic at system controller rotor of generator. As widely know before rotor controller often used PID. Before signal came into PID signal enter fuzzy logic controller first and the output from fuzzy logic controller become input for PID controller. [4]

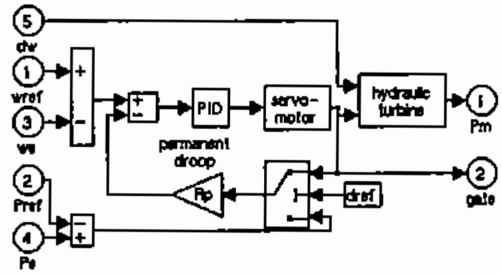

Figure 2.
PID controller in rotor generator

Characteristic of rotor rotation controller is slow response of machine rotation. This caused by tardy response of mechanical operation governor such as opening and closing of hydraulic valve at generator.

If it describe at equal area criterion, operation of mechanical power by controlling rotor rotation can be described as following :

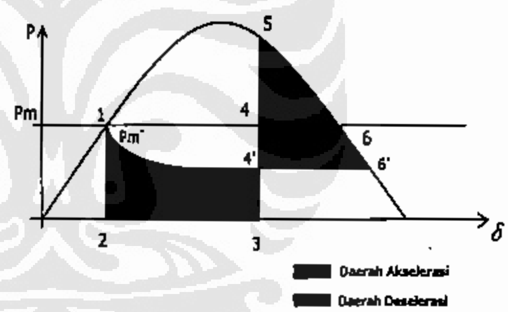

Figure 3.
Equal area criterion after Pm was controlled

By controlling speed of rotor with input of fuzzy logic controller will make degradation of mechanical power. It can be seen at graph influence from decreasing mechanical power of generator will make area acceleration decreasing and of course area deceleration will increase. Area acceleration change from 1-2-3-4 to 1-2-3-4'. While area deceleration will change from 4-5-6- to 4'-5-6'. But with only using this method not yet earned system return to stability better and faster.

5. Control Excitation of Generator

Function of excitation in generator is to arrange level of voltage in generator. By arranging the level excitation of generator then output power of generator can also be arranged. Voltage regulation can also arrange some output for example:

Voltage terminal
Power factor
Reactive current

Diagram block controller of excitation at simulink for simulation in matlab describe as follow :[4]

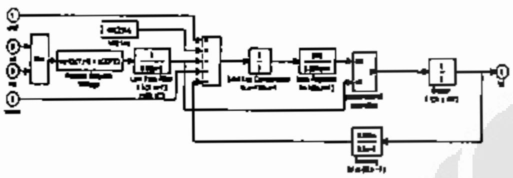

Figure 3.
Excitation controller

Same condition as mechanical power controller, input of excitation controller is the result of output fuzzy logic controller.
To make system return to stabilized after losing its stability not enough only using one method to repair power system stability. It required more method which operated with cooperated so that stability system can stabilize faster. It means that area of deceleration will increase. With excitation controller method will add electric power during fault happen in system. Equal area criterion shall be as follows :

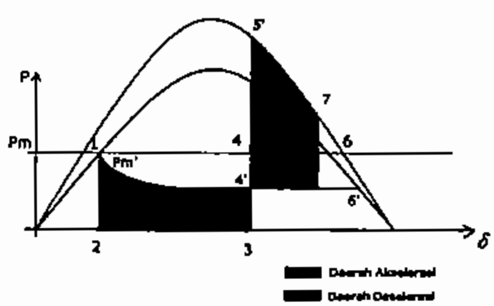

Figure 4.
Equal area criterion after excitation was controlled

Like seen at figure 4 after excitation was controlled with input of fuzzy logic controller area deceleration will increase from 4'-5-6' become 4'-5'-7. Where point 7 is point where area deceleration will be equal to area acceleration. And in this point system will swing back and return to stabilize. By controlling excitation it can be seen also level of deviation of load angle become smaller so that system will swing faster to return to normal condition.

6. Swing Back of Load Angle

To make system return into stable condition faster, area of deceleration after system swing back must become smaller and area acceleration must become wider. It will cause load angle deviation at the time of oscillation can be minimized and system will be damped faster and finally will return to synchronize situation.

This matter solved by returning mechanical power at first situation. After that reducing excitation which already rising before load angle swing back. Equal area criterion become :

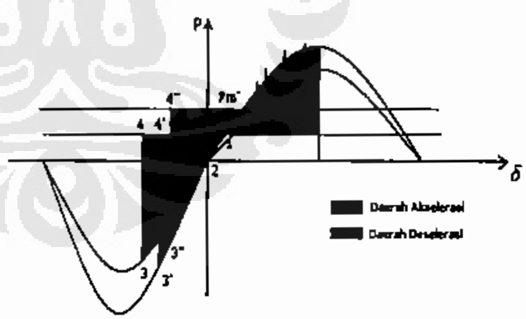

Figure 6.
Equal area criterion when load angle swing back

From figure above can be seen that load angle swing back usually formed by area 1-2-3-4. At the time when excitation was reducing area will increase from 1-2-3-4 become 1-2-3'-4'. The effect of increasing area acceleration will reduce load angle deviation. After that mechanical power will return into normal condition so that area acceleration will increase become 1'-2-3''-4'' and will reduce again load angle deviation. By reducing load angle deviation system was expected back to stable condition quickly.

7. Fuzzy Logic Controller

In general fuzzy logic controller used to increase power system stability is as follows : [6]

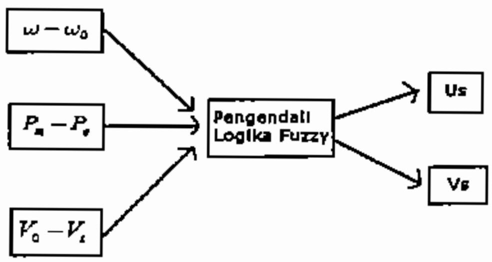

Figure 7.
Fuzzy logic controller

From figure 7 there are three input which used by fuzzy logic controller:

Rotor speed deviation
Difference from mechanical power and electrical power
Voltage deviation form generator

With output which consist of two signals which are signal Vs and Us. Signal Vs become input of excitation controller of generator and Us become input for mechanical power controller of generator.

Fuzzification for three input at fuzzy controller are as follows : [6]

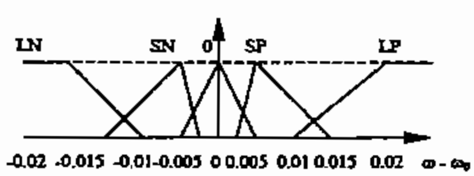

Figure 8.
Fuzzification for w - w_0

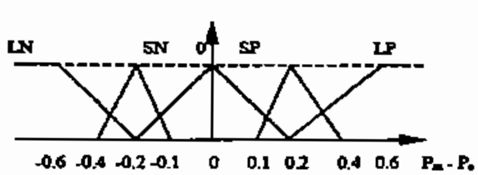

Figure 9.
Fuzzification for P_m - P_e

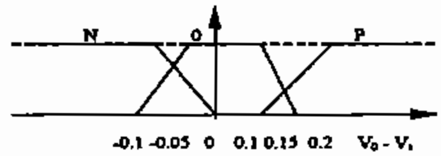

Figure 10.
Fuzzification for V_0 - V_t

Defuzzification for Vs and Us are:

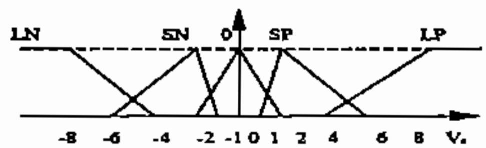

Figure11
Defuzzifikasi for Vs

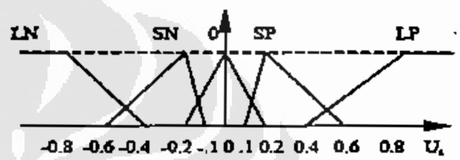

Figure 12.
Defuzzifikasi for Us

Rule in fuzzy logic controller is:[6]

Table 1.
Rule fuzzy logic controller for Us when V_0 - V_t not P

dw/dP	LN	SN	0	SP	LP
LN	SN	SN	SN	0	SP
SN	SN	SN	0	0	SP
0	SN	0	0	0	SP
SP	SN	0	0	SP	SP
LP	SN	0	SP	SP	SP

Table 2.
Rule fuzzy logic controller for Vs when V_0 - V_t not P

dw/dP	LN	SN	0	SP	LP
LN	LN	LN	LN	LN	SN
SN	SN	SN	0	0	0
0	SN	0	0	0	SP
SP	LP	LP	LP	LP	LP
LP	LP	LP	LP	LP	LP

When V_0 - V_t value P then Us always value LN and Vs always value LP.

8. Simulation Result

Simulation for repair power system stability with controlling mechanical power and excitation use MATLAB v 6.5 and using simulink with time iterate of variable order steps 15s. With step time equal to 0.001s for simulation using fuzzy logic controller coordination and 0.01 for not use fuzzy logic controller.

System modeled in the form of a generator connected to infinite bus through power transformator to increase voltage from 13.8 kV to 230 kV.

Generator only modeled as active source, and impedance in generator, in transformator, and in transmission line formed as inductive reactance which its values as according to condition of generally happen in life.
The result obtained form simulation as follows :

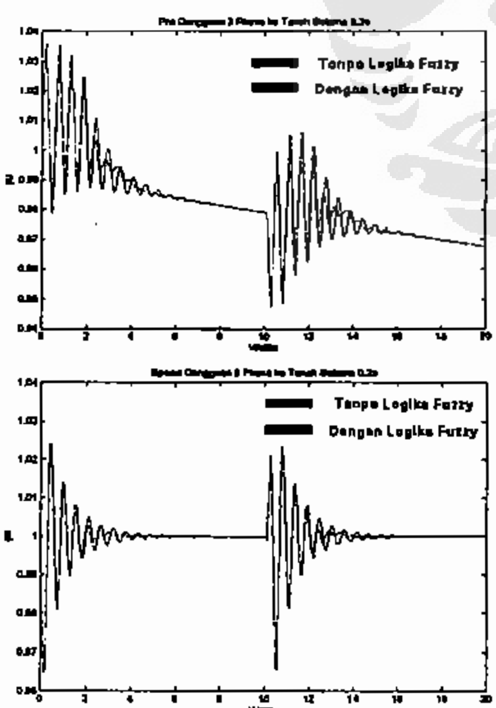

Figure 13.
Simulation result with MATLAB

At simulation program above fault duration is 0.2s and type of fault is 3 phase to ground fault. In fig 13 representing mechanical power to time (above) and rotor speed to time (below). Fault happen at 10s after generator reach stable condition. As seen at fig 13 result with fuzzy logic controller during transient condition system become stable quickly and amplitude of transient wave become smaller compare if system don't use fuzzy logic controller. With this method system returns to stable condition faster. So this controller worked during fault time until fault clear. After more observation this method also good to overcoming the problem when generator start to operated. It shown in the fig below :

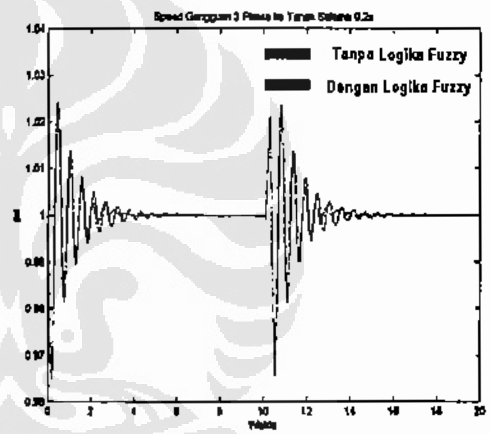

Figure 14.
Simulation result to start generator

9. Conclusion

To make system stabilize faster after fault happened in system is to reduce area of acceleration and increase area of deceleration when system still in faulted condition. One from many method to make system stable after fault happened is adding excitation and mechanical power control that widely use with fuzzy logic controller. After area of deceleration equalize area acceleration than system will swing back. To make system stable fast then load angle deviation must be small. That condition done by reducing area of deceleration and increasing area of acceleration.

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