Fuzzy logic control (FLC) does not need complex mathematical models and results in much simpler and extremely robust control laws. FLC uses linguistic variables, that is just as numerical variables take numerical values, in fuzzy logic, linguistic variables take on linguistic values which are words (linguistic terms) with associate degrees of membership in the set. The general structure of FL is

IF x_1 THEN y_0

where x_1 is input and y_0 is output. It was previously mentioned that the " ε " parameter generally resulted in chattering effect. To avoid this side effect, we used FLC based on S and the variation of S. Figure1 shows the structure of fuzzy controller.

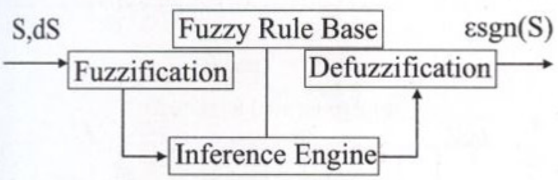

Fig. 1. Structure of fuzzy controller.

In the fuzzification module crisp values are converted into fuzzy sets and degrees of membership (Wang, 1997). A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 to 1. In this study, the triangular membership functions are used for all variables.

The fuzzy rule base is constructed by using several if-then statements and premises, and consequent of each statement are fuzzy propositions. Fuzzy propositions are made by using a linguistic variable, which is defined as

$X=\{x_N, L_x, \mu_x\}$

where x_N is a name of the variable, L_x is a set of linguistic values, H_x is a physical domain of the corresponding crisp values and μ_x is a semantic rule which gives a meaning of a linguistic value (membership function). In this study, the following fuzzy variables are used for the rule base.

S = {The switching variable, {NB (Negative big), ZO (Zero), PB (Positive big)} , H_s , μ_s }

dS = {The variation of switching variable, {NB (Negative big), ZO (Zero), PB (Positive big)}, H_{ds} , μ_{ds} }

ε sgn(s) = {The control variable, {NB (Negative big), NM (Negative medium), NS (Negative small), ZO (Zero), PS (Positive small), PM (Positive medium), PB (Positive big)} , H_ε , μ_ε }

In this work, the switching variable S and the variation of S (dS) represent the input variables and the control variable εsgn(s) represents the output variable. If the trajectory in the phase plane leaves from the switching surface with a large angle (dS is big) and S is large, then the control variable εsgn(s) will become large. However, if the trajectory leaves from the switching surface with a small angle, the trajectory will need a small control variable εsgn(s) to return to the switching surface. Finally, if the trajectory is on the switching surface, the control variable εsgn(s) will become zero. The states of the control variable εsgn(s) are shown in Table 1 according to the conditions of S and dS.

Table 1

The rule base.

εsgn(s)		dS		
		NB	ZO	PB
S	NB	NB	NB	NM
	ZO	ZO	ZO	PS
	PB	PB	PB	PB

In the module of the fuzzy inference, Mamdani's fuzzy inference method (Wang,1997) is used. The fuzzy control variables are transformed to the form of the crisp numbers by using the centroid method in the module of defuzzification.

In this study, we built the fuzzy system in the new control method using the graphical user interface tools provided by the Fuzzy Logic Toolbox in MATLAB.

The block diagram of the new control algorithm is shown in Figure 2.

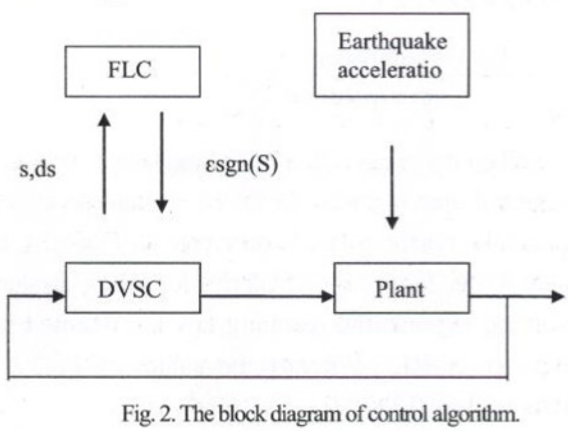

Fig. 2. The block diagram of control algorithm.