Fuzzy Logic based Reactive Power Control System in Radial Feeder

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Abstract- **This paper deals with the reactive power control system in radial feeder using fuzzy logic controller. The voltage declines gradually with increment of length in radial feeder. The addition of inductive load like motor causes the serious effect in later end of feeder. It is desirable to maintain the voltage in appropriate level. Power factor of the system is proportional with voltage of the system. Therefore the improvement of power factor in the system results in sound voltage level. This paper presents the simulation design of reactive power control system using fuzzy logic. The dynamic switching of capacitor bank maintains the power factor as desirable. The variation of operating capacitor bank is guided by variation of load. The proposed model enhances the dynamic performance of capacitor bank and maintains the power factor near to unity with variable consumer load.**

Keywords— reactive power, fuzzy logic controller, power factor, radial feeder

I. INTRODUCTION

The decentralization and rural electrification basically follows radial feeder as transmission and distribution network. The electrical energy sources like micro hydro power, solar energy, wind energy power plant etc. , mainly incorporate radial feeder system. The increment in feeder length consequently decreases the line voltage of the system. Increase in the reactive power demand simultaneously reduces the power factor of the system. Power factor resembles the voltage level, reactive power demand and supply. The variable consumer load has variable reactive power demand, thus it is necessary to supply required volt ampere reactive (VAR) to prevent from predominant effect of load on power system.

Several classical techniques are available for dynamic VAR compensation. Dynamic VAR compensation uses rapid switching technique to connect and isolate capacitive reactance as demanded by dynamic load [1]. To operate the VAR compensator in sound mode, one has to avoid the phase control for radial feeder. The possibility of high voltage at later end never occurs for isolated small power generation system. Therefore capacitor bank is usually implemented as reactive power compensator. An attempt to operate in phase control would result in generation of very large amplitude resonant current, leading to overheating of capacitor bank & thyristor valve and harmonic distortion in ac system [2].

Fuzzy logic has been applied in wide range for control of machines and electrical equipment. The new upcoming technology for control system is fuzzy logic control system. The realistic environment, system based uncertainty and imprecision make the promotion of this control system. The great virtue of fuzzy logic is solution of multi value logic. Fuzzy logic is an innovative approach for dynamic VAR compensation i.e. switching of capacitor bank. Fuzzy logic acts as the decision maker for switching of capacitor bank. The main reason of using fuzzy logic controller is to give raise non-linear control and look after the dynamic response in power system. The combination of fuzzy logic controller in switching capacitor bank would provide dynamic switching, reliability and better performance.

II. SYSTEM DESCRIPTION

Fig.1. shows the block diagram of fuzzy logic based reactive power control system in radial feeder. It consists of source as generator, fuzzy logic controller, capacitor banks and loads. Generator generates both active and reactive power. This power gets transmitted to load through transmission line. As the reactive or induce load get increased in the system, voltage tends to decline. To overcome, capacitor bank is connected parallel to load to fulfill the required reactive power.

The analysis of power factor data and maximum volt ampere (VA) demand is use for the application of appropriate rule base in fuzzy logic. The system consists the power factor measurement block to measure power factor. The operation of fuzzy logic controller (FLC) is determined by state of power factor and kVA demand of consumer load. FLC calculate the required value of capacitor bank as per the load. This value of capacitor bank has to be converts in to digital signal for smart switching. Digital signal accumulate the breaker to operate. As the load change, FLC command to change the value of capacitance. But value of capacitance can only be change by step switching not by phase control.

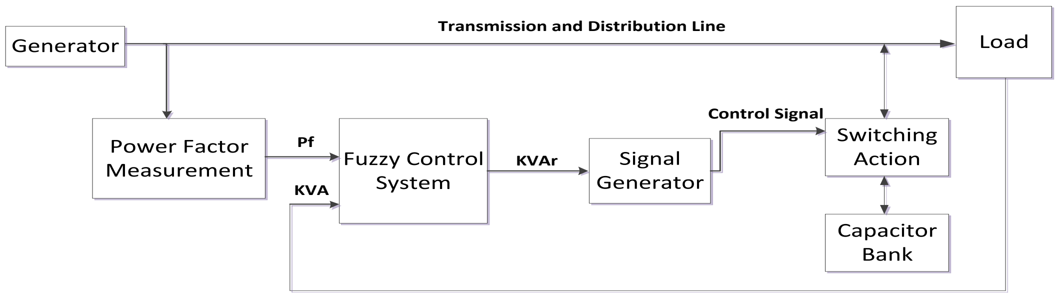

Fig. 1. System description of FLC based compensation system

III. FUZZY LOGIC CONTROLLER (FLC)

The fuzzy system is constructed from input fuzzy sets, fuzzy rules and output fuzzy sets, based on prior knowledge base of the system [3]. Fuzzy logic controller consists of four major parts as fuzzification, fuzzy rule base, fuzzy inference mechanism and defuzzification. Fuzzification converts the input variable into fuzzy variable by providing the membership degree to each variable. The process of providing the membership degree is called membership value assignment. The rule base uses linguistic variable as its antecedents and consequent. Fuzzy rule is define by the expression IF A AND B THEN C. The multiple input functions A and B are called antecedent and output C is called consequent. The fuzzy inference mechanism evaluates fuzzy information to activate and apply control rules [4]. The fuzzy results generated cannot used such to the application, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing called defuzzification [5]. Some of commonly used methods of defuzzification are centre of gravity, weighted average method, mean-max method etc. The design philosophy of fuzzy logic controller depends upon its application and experience of design engineer/expert. The design proceeds with fuzzification, rule base design and defuzzification.

A. *Fuzzification*

As computer only understands binary value, similarly fuzzy logic controller only understands the degree value between 0 and 1. The process of conversion of input variable to fuzzy variable (between 0 and 1) is called fuzzification. The degree value submission to crisp variables depends upon necessity of design and designer.

Fuzzy logic based reactive power control system in radial feeder consist power factor and kVA demand of load as input. The membership function design of power factor data is carried with fuzzy c-mean method, whereas membership function design for kVA load demand is carried out without omitting system loss and load calculation.

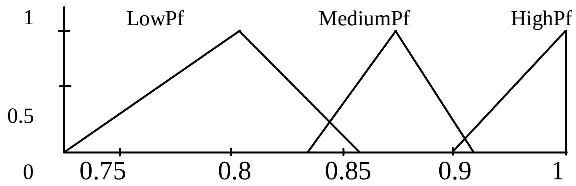

Fig. 2. Membership function for input power factor

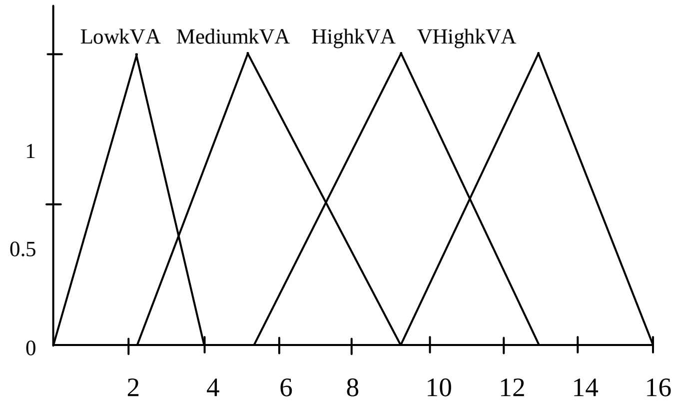

Fig. 3. Membership function for input kVA

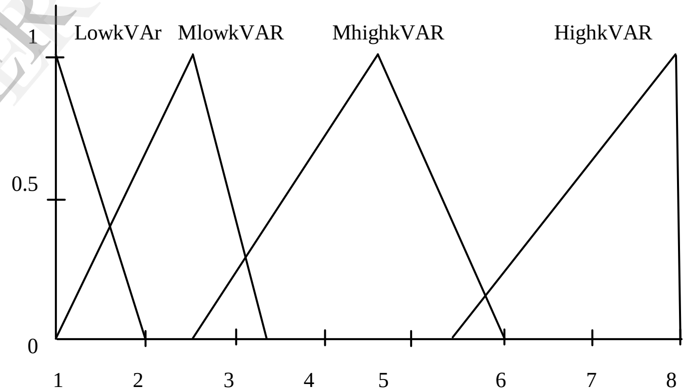

Fig. 4. Membership function for output kVAR

B. *Rule base design*

The action of FLC is guided by design of rule base. Rule base is design as per necessity and also depend upon the design of control engineer. Table I shows fuzzy rule set for VAR compensation. For example in rule first, when power factor (pf) is low and kVA demand of load is low, medium low VAR rating of capacitor bank should be connect. Similarly all the rules give required value of VAR for compensation except ninth rule.

TABLE I. Fuzzy rules set

kVA \ PF	Low	Medium	High
Low	Medium low	Low	None
Medium	Medium high	Medium low	Low
High	Medium high	Medium high	Medium low
Very high	High	High	Medium high

C. Defuzzification

The conversion of fuzzy variable into crisp variable is defuzzification. It is an anti-process of fuzzification, where crisp value is converted into fuzzy variable. Fuzzy variable is not understandable thus, have to convert. The centre of gravity method has been used to find the output of fuzzy rules.

Let us assume the condition to operate fuzzy logic controller. The power factor is 0.862 and kVA demand of load is 8 kVA. During this condition fuzzy logic controller works on following manner:

•The antecedent membership degree for power factor is 0.65 at medium power factor triangle.

•The antecedent membership degree for kVA demand of load is 0.35 and 0.635 at medium kVA and high kVA triangles respectively.

•These antecedent membership degree fire rule 6 and 7

Rule 6# IF power factor is medium AND kVA demand of load is medium THEN kVAR is MlowkVAR

Rule 7#IF power factor is medium AND kVA demand is high kVA THEN kVAR is MhighkVAr

Figure.5. shows the whole fuzzy logic operation:

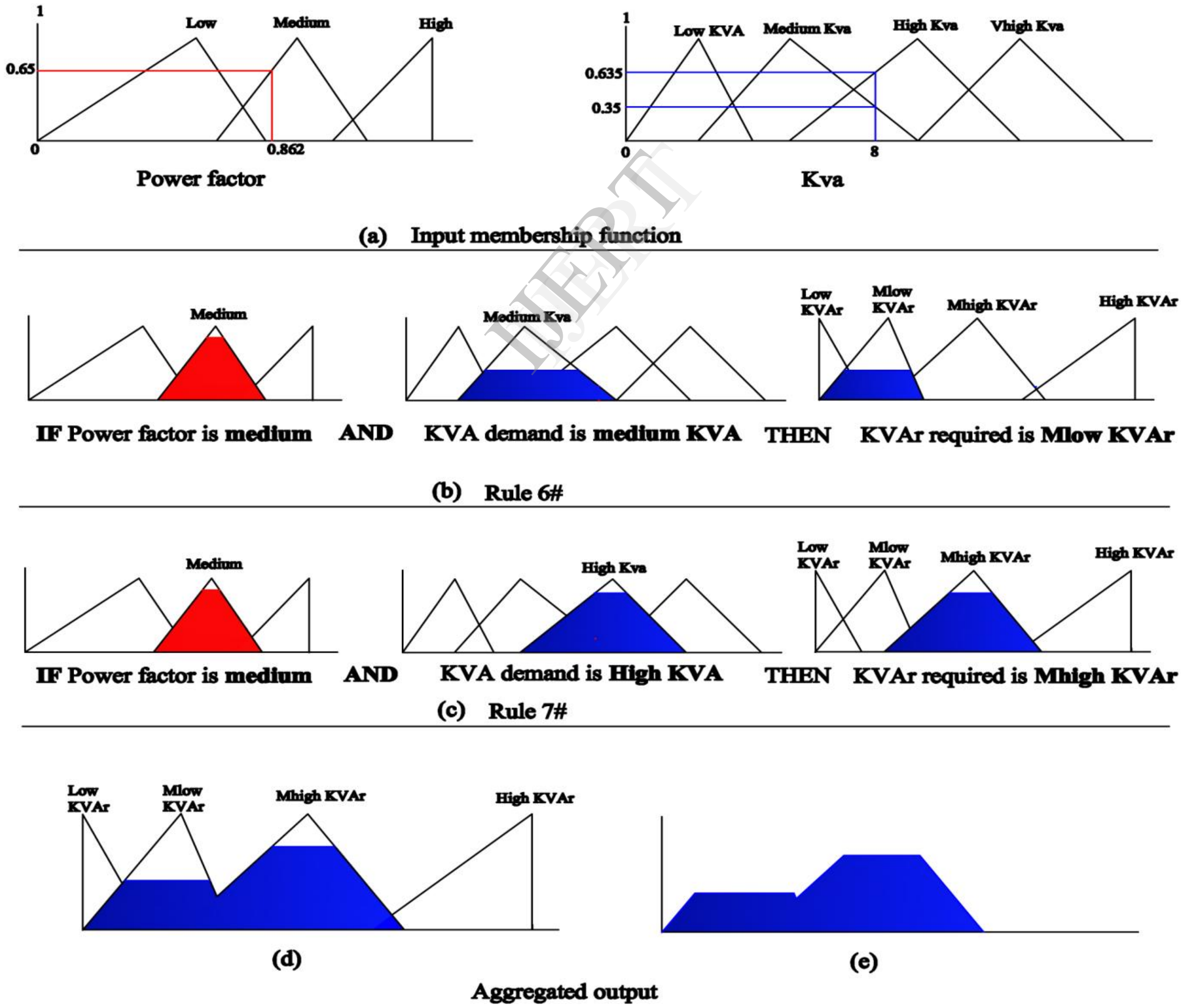

Fig. 5. Fuzzy logic operation for VAR compensation

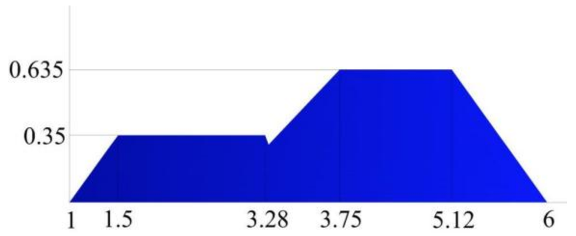

Fig. 6. Defuzzification

Crispaction

$$= \frac{(0+1.5+3.28)*0.35+(3.75+5.12+6)*0.635}{3*0.35+3*0.635}$$

=3.76 kVAR

IV. SIMULATION AND MODELING

V. SIMULATION RESULT

The power factor of the system improves due to FLC with suitable rating capacitor bank. The dynamic performance of FLC on switching action compensate required volt ampere reactive (VAR) Table.II. shows the comparison between power factor of uncompensated and compensated system. The experimental investigation on performance of different loads is quite good. The power factor of system tends to near unity.

TABLE II. Improved power factor from simulation

Load (kVA)	Pf before capacitor bank connection	Pf after capacitor bank connection
4	0.8575	0.9963
8.5	0.8138	0.9988
13	0.74	0.9699
(4+8.5)	0.8321	0.9874

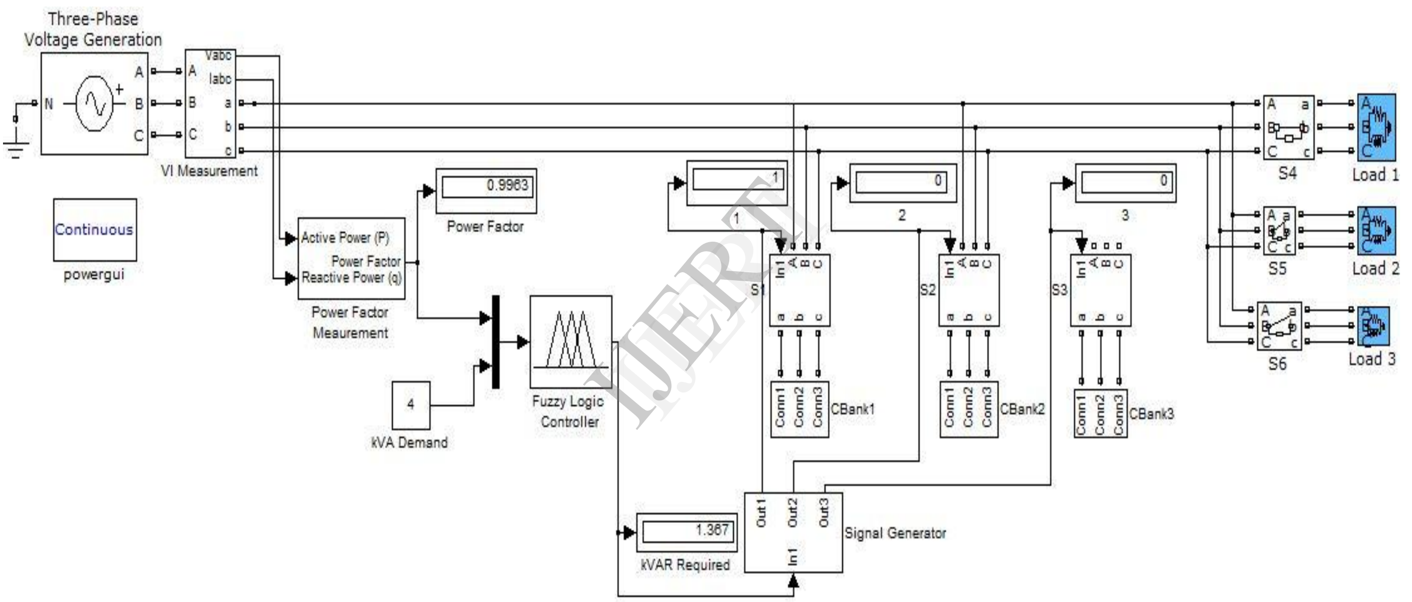

Fig. 6. MATLAB Simulink model

Fig.6. shows the MATLAB simulation model of radial feeder using fuzzy logic controller. The parameters included while designing the system are three phase voltage generator, fuzzy logic controller, signal generator, capacitor banks, switches and loads. Fuzzy logic controller estimates the required value of kVAR. Based on the required kVAR, signal generator switches the appropriate capacitor bank. The ON and OFF condition of the capacitor is represented by 1 and 0 in the display. The dynamic switching of the capacitor solely depends upon the signal from the fuzzy logic controller. Fuzzy logic controller includes 11 rule base systems. For low kVAR required, capacitor bank 1 is switched, for medium kVAR demand capacitor bank 2 is switched alone or simultaneously with capacitor bank 1. Capacitor bank 3 is switched on only for high kVAR demand.

VI. CONCLUSION

This paper presents volt ampere reactive (VAR) compensation technique using fuzzy logic controller (FLC) on the basis of simulation using standard software MATLAB. Four different kVA rating loads are taken for investigation action. The system is developed without compensator and with compensator controlled by FLC. All the values of FLC components and capacitor bank rating have been calculated manually as well as in MATLAB.

The FLC based system shows dynamic performance and verifies the manual calculation. Thus, the FLC embedded with power system gives near unity power factor in variable load.

VII. ACKNOWLEDGMENT

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