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AI based Voltage Control in Distribution System

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Abstract:
The project is intended to propose a strategy for controlling the voltage in the power generation distribution system. The control strategy, acts on the tap changer for loaded condition of the distribution system and adaptively develops the voltage outline of power consumption under various load conditions using fuzzy logic.

***Keywords* :** *Radial distribution system, Voltage regulation, Adaptive Tap Control (ATC), Fuzzy logic, intelligent systems*

I. INTRODUCTION

In electrical power system, there is a continual exploration to have good quality in the power delivered to distribution system. The power is delivered to the consumers from the distribution system. So, voltage regulation plays a vital role in the distribution substation to maintain a suitable voltage level in order to maintain the power quality at the customer terminals. In particular, fuzzy controllers are advantageous in solving non linear problems and analyzing uncertain information.

Normally the distribution systems are configured radially for effective co-ordination of their protective systems [18]. The suitable voltage level of a radial distribution system considered adequate is 0.93p.u. to 1.05 p.u. above or below which the supply is turned off or the system is considered to be in the non operating state. Generally, voltage regulation in distribution substation is carried out by controlling the turns ratio of the OLTC transformer. Other similar techniques, such as those presented in [2] – [6] and in [10] – [18], have also achieved promising results. The OLTC transformer is mounted on the main distribution transformer which is operated using a voltage regulator relay. Previously, the relay switching was done manually on monitoring the load conditions [6]. Later, the tap operation schedules were programmed for 24 hours using historical operating conditions of the system [16]. The need for a real time control, where the tap operations are made simultaneously as soon as the load variation is sensed, motivated the search for an intelligent tool. The main objectives outlined here are, 1. To obtain better voltage for the power system and to maintain the voltage levels nearer to the base value (1 p.u.) under heavy load conditions. 2. To justify the figure of tapping conditions during light load situations. These objectives can be achieved by adaptively controlling the tap action of the transformer situated in the substation using fuzzy logic. This adaptive control based on fuzzy logic can be named adaptive tap control (ATC).

II. ADAPTIVE TAP CONTROL(ATC)

In this method, voltage regulation is done using the voltage control of the relay. The relay controls the tap using the voltage and the load curve. Operational decisions about tap changing depend on the monitoring of two input variables the load active power and system average voltage variation. The active power is selected as one of the input value since the distribution power systems have compensation of the VAR components in the load center. Due to this the substation reactive power can be neglected and the apparent power is nearer to active power.

In the proposed system rules are framed for the fuzzy logic system. The inputs are monitored using the fuzzy system to control the voltage of the relay.

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In order to explain this method, Fig.1 gives the sketch of the embedded fuzzy system to control the relay using voltage. This system receives two inputs to increase or lower the voltage for the LTC. [5].

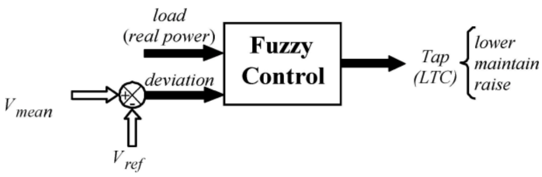

Fig.1 Sketch of Fuzzy System

The limits for the base values of the active power are represented as [0.5, 1.5]. The parameter value is taken as 1. The average value of the power reading is considered as the base value. This can be noticed from fig. 2. There are two fuzzy membership functions to represent the model of load. During the minimum load conditions, tap change can be done. During the heavy load conditions, voltage is regulated. The difference between the base value and the average value is calculated as deviation. There are four membership fuzzy functions to map the input parameter for all the voltage levels as shown in Fig. 3. The four membership functions are Downward Deviation (DD), upward deviation (UD), Large Negative, and Large Positive. The variations in the working range of the fuzzy control is restricted in some points like cross of DD and Large Negative and also the cross of UD and Large Positive. These are the lower and upper limits of this range. In this, the variations marked by DD and UD indicate the enough voltage ranges. The output voltage is divided into three membership functions such as high, low and normal. The high and low terms are used to represent the variations in the tapping voltage levels, and the normal level indicates that the tap position is in the required voltage level. These are shown in Fig.4.

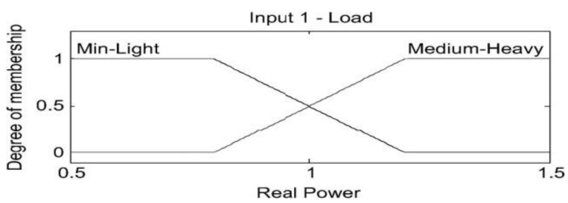

Fig.2 Load Real Power

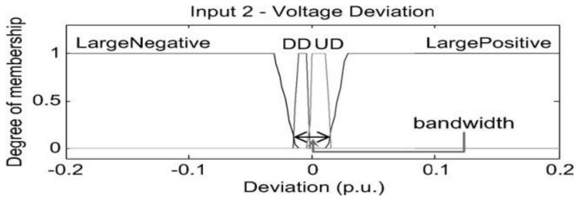

Fig.3 Voltage Deviation

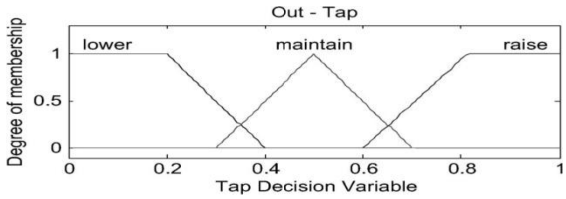

Fig.4 output Voltage Tap

TABLE I
FUZZY RULE BASE

1. IF	deviation	is Large Negative	and load	is minimum
	THEN	Tap (or Voltage) is high		
2. IF	deviation	is Large Negative	and load	is heavy
	THEN	Tap (or Voltage) is high		
3. IF	deviation	is UD	and load	is minimum
	THEN	Tap (or Voltage) is normal		
4. IF	deviation	is UD	and load	is heavy
	THEN	Tap (or Voltage) is normal		
5. IF	deviation	is DD	and load	is minimum
	THEN	Tap (or Voltage) is normal		
6. IF	deviation	is DD	and load	is heavy
	THEN	Tap (or Voltage) is high		
7. IF	deviation	is Large Positive	and load	is minimum
	THEN	Tap (or Voltage) is low		
8. IF	deviation	is Large Positive	and load	is heavy
	THEN	Tap (or Voltage) is low		

The proposed system uses IF-THEN conditional rule base system. Whenever the load is minimum,

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the rules 3 and 5 are in control for doing tap changes. Similarly, whenever the load is heavy, rule 6 says that the voltage is kept at a high level. , The rest of the rules are used when voltage level is in the normal range.

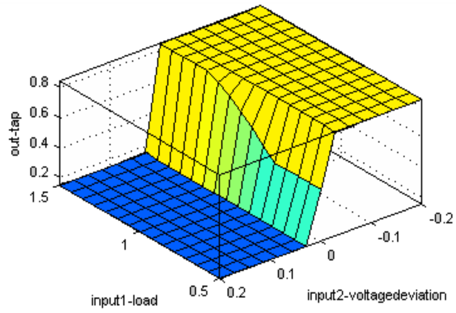

Fig.5 Fuzzy Relationship Surface

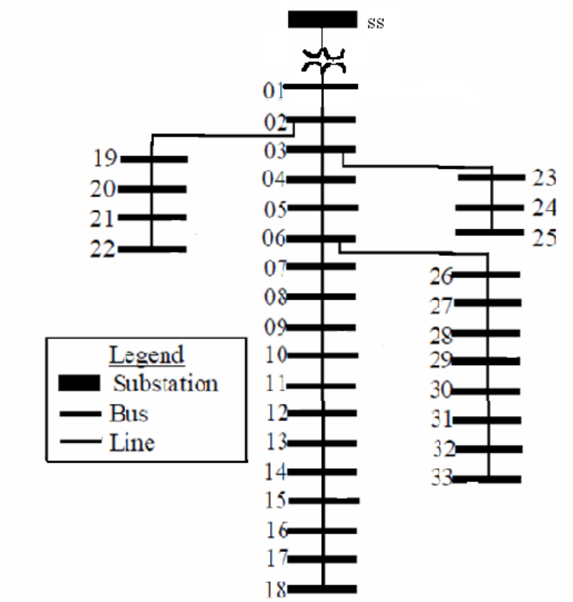

Fig. 6 IEEE 33 Bus Radial Distribution System

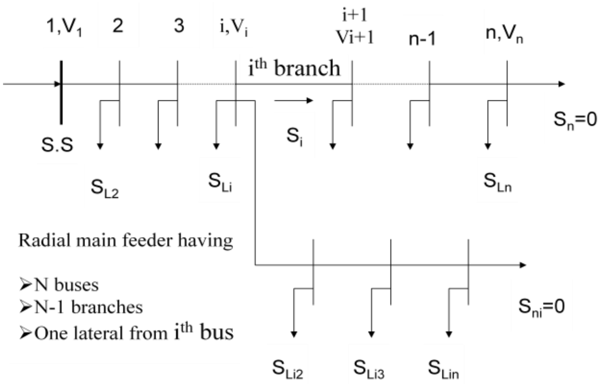

Fig. 7 Formulation of typical system

In the ATC fuzzy logic system, maximum minimum inference is used for fuzzification. Here the trapezoidal fuzzifier are used for the inputs because it is insisted that any input value should not make the system to operate with the maximum voltage level. The output uses triangular fuzzifier for the membership function 'maintain' because, one particular value of input surely has the maximum possibility for maintaining the tap position. The crisp non fuzzy output value tap* is obtained by the centroid of area defuzzification (the centroid of area method), which is provided by

$$tap^* = \frac{\sum tapi\,.\mu(tapi)}{\mu(tapi)} \quad i=1,2...N \qquad (1)$$

Where tap_i is the discrete value of the universe of discourse related to the output variable sampled at N points, and $\mu(tap_i)$ is the respective degree of membership, which is formed by taking the union of all the contributions of fuzzy rules whose consequent propositions are nonzero. This method is used mainly to reduce the complexity of problem solving. Also, the membership functions are made symmetrical in order to use the centroid method of defuzzification. The fuzzy controller for ATC strategy is thus successfully designed using MATLAB and simulated on applying to a radial distribution system.

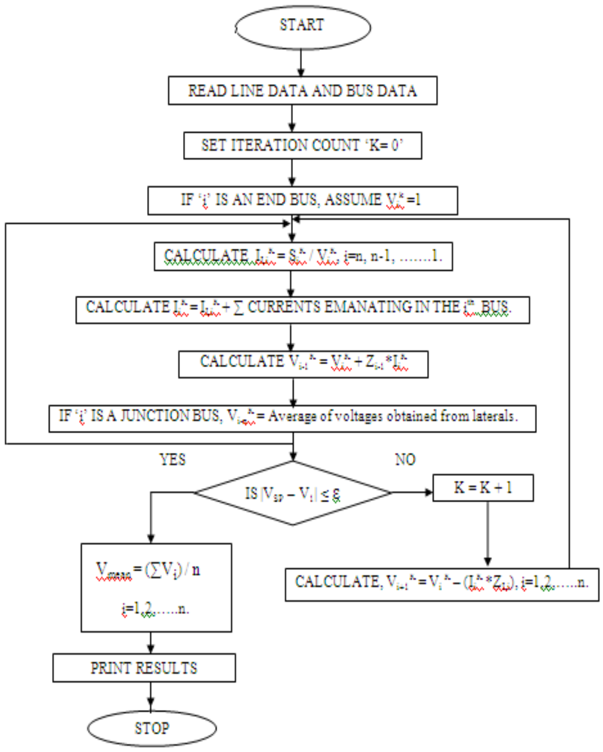

Fig. 8 Flow Chart of Iterative Load flow

III. SIMULATION OF ATC STRATEGY

The arrangement of the radial supply system is shown in fig. 6. The system is initially subject to a simple load flow diagram each time to obtain the average voltage of the system for each value of active and reactive power supplied. The outcomes are presented to the fuzzy control system which does the corresponding calculations to generate choices on tap changes. The mathematical model of the radial distribution system is formulated using a typical model as shown in fig. 7. Where, i is the bus number, Vi bus voltage, Ii load current, I_{li} line current, Si complex power (= P + jQ), Z_{li} line impedance (= R + jX). The distribution system load flow is performed using forward / backward sweep method which is explained in the flowchart in fig. 8.Here, the system is simulated for four hours between discrete intervals of ten minutes. It doesn't have any restriction that each and every ten minutes alone the load varies and the tap changes. Whenever load variation is sensed, the tap is adaptively controlled and voltage is regulated using the fuzzy controller. The flow chart of the ATC strategy is given in fig. 9. The voltages obtained due to the change of position of tap are send to the load flow and thus an improved voltage profile is obtained each time.

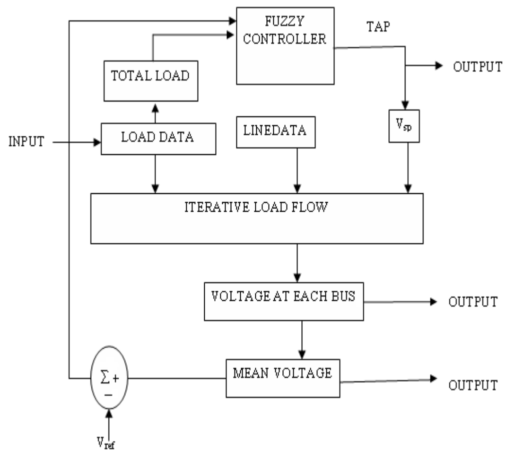

Fig. 9 Implementation of ATC

IV. ANALYSIS OF SIMULATION RESULTS

The simulated results in fig. 10 show the voltage variation of the system for mean load condition. The solid curve shows that, the voltage levels at each bus have been considerably increased after implementing the ATC strategy. Thus the quality of power delivered to the most distant customer is also increased by implementing ATC.

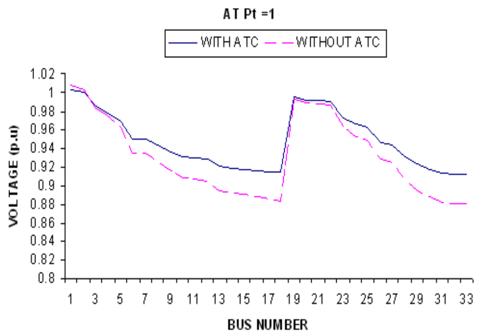

Fig. 10 Outputs of Mean Load Condition.

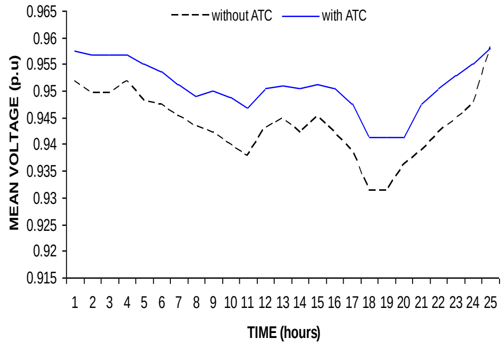

Fig. 11 Outputs of Varying Load Conditions

The simulation results in fig. 11 show the variation in system mean voltage subject to load variations. The results reveal that, the ATC strategy acts as a real time controller and takes instant tap decisions for varying load conditions which automates voltage regulation adaptively.

V. CONCLUSION

It is better to highlight the performance of the intelligent control strategy in terms of the ideas defined at the beginning. The tap action of the on load tap changing transformer situated in the distribution substation has been adaptively controlled using a fuzzy logic controller. Voltage profile of the distribution system has been improved under heavy load conditions and maintained within specified voltage bands under light load conditions. Thus the application of this fuzzy strategy to the simulated data of the radial distribution system, has given very satisfactory results and promising improvements in voltage regulation. The control strategy is very advantageous because of the ease of

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implementation of fuzzy logic controller in existing systems. As well as programming becomes easy and cost effective.

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