Voltage Regulation in Distribution Networks using Fuzzy Logic Controller- A Case Study

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***Abstract*—The Fuzzy Logic controller based – automatic voltage control relay can provide effective voltage control of the network similar to that provided by conventional voltage control relay. It has been observed that fuzzy logic based control has simple and fast controlling, simplify design complexity and reduce the hardware costs etc. The structure of the proposed Fuzzy Logic based-AVC relay is presented and the results that show its performance into distribution network are also presented and discussed. Voltage control is necessary for electrical power system for both at distribution and transmission levels. In consideration of the complexity of voltage and reactive power control, fuzzy logic control theory is considered to apply in the control. Fuzzy control is a new control method based on fuzzy mathematics, which qualifies the variable through fuzzy set theory, expresses people's experience in fuzzy conditional statement and generates control strategy using fuzzy reasoning.**

I. INTRODUCTION

Today voltage control is necessary for electrical power system for both at distribution and transmission levels. At any point, where a change of voltage level is required, transformers must be applied. Such transformers are usually built with fixed turn-ratios, or sometimes they are equipped with tap terminals for turn-ratio control (OLTC). The operation of tap changers may be twofold: off load tap changer, or on load tap changer. A number of factors that can influence the optimum tap position are primary voltage level, load level, power factor, distributed generation and circulating current. The increasing connection of distributed generation in a distribution network may lead to unacceptable voltage rise. Hence there is a big need to control voltage in distribution networks with distributed generation.

II. PRINCIPAL OF AUTOMATIC VOLTAGE CONTROL RELAY

Figure shows the various basic blocks of automatic voltage control relay

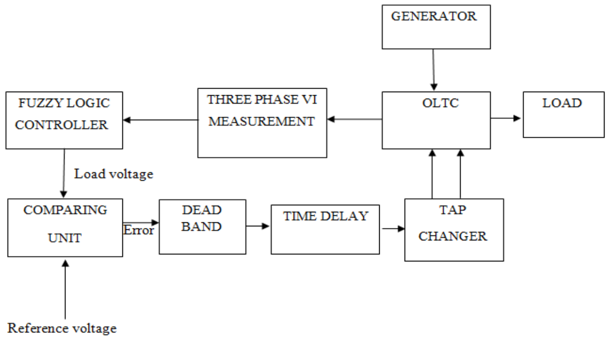

Fig. 1. Block disgram of AVC relay

A. *Three-Phase V-I Measurement:*

The Three-Phase V-I Measurement is used to measure three-phase voltages and currents in a circuit. When connected in series with three-phase elements, it returns the three phase-to-ground or phase-to-phase voltages and the three line currents. Output voltages and currents in per unit (pu) values or in volts and amperes. The phasor magnitudes displayed in the Power guide stay in peak or RMS values even if the output signals are converted to pu.

B. *Fuzzy logic controller:*

Fuzzy logic controller takes the input from measuring element. It take active power and from that it's generate load voltage by using if- then rule and that output is compared with reference voltage and it will generate error. In consideration of the complexity of voltage and reactive power control, fuzzy logic control theory is considered to apply in the control. Fuzzy control is a new control method based on fuzzy mathematics, which qualifies the variable through fuzzy set theory, expresses people's experience in fuzzy conditional statement and generates control strategy using fuzzy reasoning.

C. *Comparing unit:*

It is an adjustable dead-band relay element which gives the voltage error ΔV.

$$\Delta V = Vm - VR$$

Vm is the measuring voltage after negative reactance compensator voltage VR is the reference voltage in pu.

D. Dead Band:

The Dead band generates zero output within a specified region, called its dead zone. The lower and upper limits of the dead zone are specified as the Start of dead band and End of dead band parameters. The block output depends on the input and dead band:

If the input is within the dead zone (greater than the lower limit and less than the upper limit), the output is zero.

If the input is greater than or equal to the upper limit, the output is the input minus the upper limit.

If the input is less than or equal to the lower limit, the output is the input minus the lower limit.

E. Time Delay:

The Transport Delay block delays the input by a specified amount of time. It can be used to simulate a time delay. At the start of the simulation, the block outputs the Initial output parameter until the simulation time exceeds the Time delay parameter, when the block begins generating the delayed input. The Time delay parameter must be nonnegative. The block stores input points and simulation times during a simulation in a buffer whose initial size is defined by the Initial buffer size parameter. If the number of points exceeds the buffer size, the block allocates additional memory and Simulink software displays a message after the simulation that indicates the total buffer size needed. Because allocating memory slows down the simulation, define this parameter value carefully if simulation speed is an issue. For long time delays, this block might use a large amount of memory, particularly for dimensionalised input.

F. Tap Changer:

A tap changing mechanism is usually built as a step-by step “go-no-go” instrument. When signals connected to up and down with inputs change from 0 to 1 the OLTC moves tap one step upward or downward.

G. On - load Tap Changer Transformer:

OLTC consist of two fixed windings and a third tap winding (regulation winding) connected in series with either winding 1or winding 2. A +30° or - 30° phase shift is introduced when winding 1 or winding 2 are connected in delta. In automatic mode voltage regulator on and the signal applied at the Vm inputs is monitored and the voltage regulator asked for tap change. The three-phase two-winding transformer or autotransformer uses an on-load tap changer (OLTC) for regulating voltage on a transmission or distribution system. Controlling voltage on a transmission system will affect primarily flow of reactive power, which, in turn, will affect the power transfer limits. Although the regulating transformer does not provide as much flexibility and speed as power-electronics based FACTS, it can be considered as a basic power flow controller.

H. Three-Phase Parallel RLC Load:

The Three-Phase Parallel RLC Load implements a three-phase balanced load as a parallel combination of RLC elements. At the specified frequency, the load exhibits constant impedance. The active and reactive powers absorbed by the load are proportional to the square of the applied voltage.

III. METHODS FOR AUTOMATIC VOLTAGE CONTROL RELAY

When automatic load-tap-changing transformers operating in parallel are located remotely from each other, interconnecting control wires are impractical and a modification of the line-drop compensator setting is necessary to obtain satisfactory operation. This type of control is sometimes referred to as the "reduced" or "reversed" reactance method. This method serves to distinguish between circulating current and load current and does this by virtue of a difference in power factor between these currents. A compensator which employs normal resistance and reverse reactance results in a characteristic such that high power-factor currents cause the transformer to increase the voltage and low power-factor currents cause it to decrease. Thus, it is possible to set compensators so that load currents will cause a boosting operation and circulating currents will cause a slight bucking operation of transformers with no intervening impedance.

These are the two methods from which we can control the AVC Relay:

A) Negative Reactance Compensation

B) Line drop compensation

A. Negative reactance *compensation:*

Negative reactance compensation combined with positive resistance compensation is a simple scheme for limiting circulating currents and maintaining constant voltage at the load center. Essentially this scheme consists of reversing the connections of the reactance element of the line drop compensator so that the low power-factor circulating current between units will produce an effect on the voltage control relays of the two machines such as to cause the units to run closer together

B. Line-Drop Compensation:

The aim of line-drop compensation is to keep the voltage constant, not at the local bus bar on the transformer secondary, but at some remote load center. Normal practice is to sense the load current (local to the transformer) and from this to simulate the voltage drop in the line to the remote load center. Modern voltage-control relays include line-drop compensation as standard.

IV. FUZZY LOGIC CONTROLLER

MATLAB’s Fuzzy Logic Toolbox and Simpower system are used to simulate and design the Fuzzy logic based automatic voltage control relay.

Figure 2 Shows the schematic diagram of fuzzy logic based AVC relay. This relay consists 4-input and 1-output, which is low voltage side of OLTC transformer voltage (V), Phase angle of the current through the OLTC transformer.

Fuzzy control is a new control method based on fuzzy mathematics, which qualifies the variable through fuzzy set theory, expresses people’s experience in fuzzy conditional statement and generates control strategy using fuzzy reasoning.

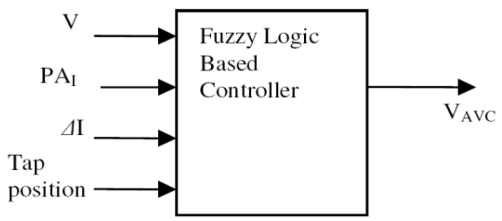

Fig. 2. Fuzzy Logic Based AVC Relay

A Fuzzy Logic Controller (FLC) is a kind of a state variable controller governed by a family of rules and a fuzzy inference mechanism. The FLC algorithm can be implemented using heuristic strategies, defined by linguistically described statements. The fuzzy logic control algorithm reflects the mechanism of control implemented by people, without using any formalized knowledge about the controlled object in the form of mathematical models, and without an analytical description of the control algorithm. The main FLC processes are fuzzification, rules definition, inference mechanism and defuzzification. Fuzzification is the process of transferring the crisp input variables to corresponding fuzzy variables.

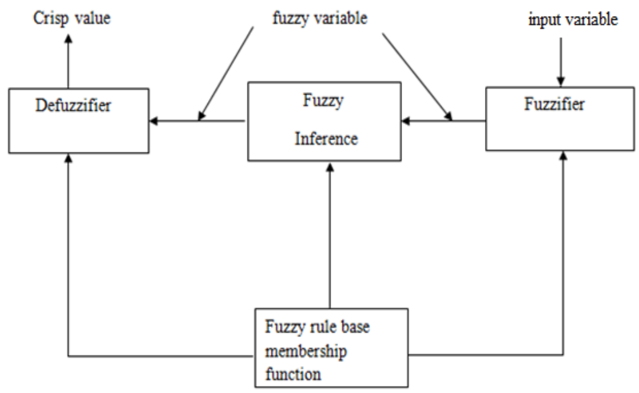

Fig. 3. Structure of fuzzy logic controller

A. *Some advantages of FLC are:*

- The word “data” is plural, not singular.
- Fuzzy logic can be built on top of the experience of experts or can be implemented with other techniques.
- Fuzzy logic can resolve conflicting objectives.
- Fuzzy logic is tolerant of imprecise data and can handle ambiguity.
- Fuzzy logic is flexible and is relatively easy to implement

A small section of distribution network showing use of OLTC transformer and AVC relay with Fuzzy logic Controller:

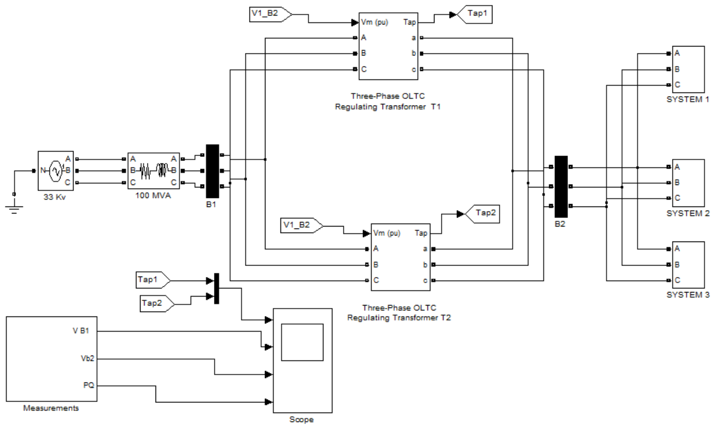

Fig. 4. A section of distribution network showing OLTC transformers in parallel condition

33/11KV distribution network is shown in figure 4. Here 33KV programmable voltage source is taken and 100 MVA RL series branch is connected. Two OLTC Regulating transformers are connected in parallel between Bus B1 and Bus B2. At the second end of Bus B2 three types of systems are connected namely system 1 which contains distribution generation, system 2 contains the load at different feeder and system 3 contains variable load.

When the above circuit is simulated then following results are obtained as in figure 5.

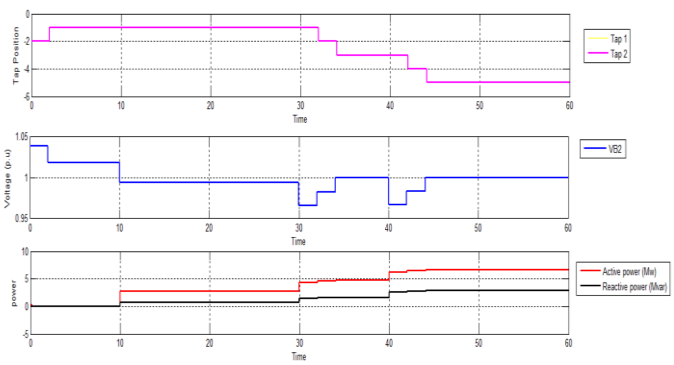

Fig. 5. Fig. 4 Tap position, Voltage at Bus B2, Active and Reactive power output with fuzzy controller

ACKNOWLEDGMENT

Regulated voltage is one of the most important elements of a power system. The voltage supplied to consumers’ needs to be maintained within statutory limits. Failure to maintain system voltage can result in unsatisfactory performance of consumers' equipment or even complete failure resulting in damage AVC relay are used to reduce these variations and keep the voltage within predicted limits. When the voltage is fluctuating and the transformer’s secondary voltage is outside the permitted margin then the voltage has been controlled by automatic voltage control relay (AVC Relay). Its role is to detect voltage variations compared to the reference voltage value at the controlled bus then AVC relay issues a command to tap changer to restore it to within preset limit.

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The AVC relay provides real time automatic control for the on-load transformer tap changer (OLTC). The advantages of the proposed FL controller based-AVC relay are- it is simple and fast, reduce the design development cycle, simplify design complexity, improve control performance, simplify implementation and reduce the hardware costs etc.

Thus, it has been found that the proposed fuzzy logic controller based AVC relay has the ability to control the voltage magnitude of distribution network as load changes.

REFERENCES

[1] S. Minneci H. E. Pinney "Line-Drop Compensator Settings for Automatic Parallel Operation or Load-Tap-Changing Transformers".

[2] Ye Li, Nirmal-Kumar C Nair and Sing-KiongNguang, "Improved coordinate control of on-load tap changer".

[3] A. Darabi, S.A. Soleamani and A. Hassannia, "Fuzzy Based Digital Automatic Voltage Regulator of a Synchronous Generator with Unbalanced Loads".

[4] Omar A.S.Youssefis, "Applications of Fuzzy Inference Mechanisms to Power System Relaying"

[5] Murray Thomson , "Automatic-voltage-control relays and embedded generation".

[6] Krishna Vasudevan,. G. Sridhara Rao, P. SasidharaRao , "Transformer voltage control and Tap changing".