Review on Dynamic Voltage Restorer Based Fuzzy Logic Controller

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***Abstract*— Different types of voltage fluctuations exists which can cause voltage sag, voltage swells, harmonics, surges and spikes but in these, voltage sag and swell are the common problems on the systems. These problems can be mitigated by custom power device i.e. Dynamic Voltage Restorer. A DVR is a series connected device which can use to mitigate voltage sag and swell in the system. In this paper, we propose a review on DVR with fuzzy logic control technique.**

I. INTRODUCTION

The various power quality problems[1] encompass the voltage sags, voltage dips & voltage swells, flickers, harmonics & transients accompanied by unbalanced power, which are results of various faults with three phase fault being the most severe among all, starting of induction motor which is most often used due to its rugged construction, switching off large loads and energizing of capacitor banks. The higher index of reliability & power quality [2] to satisfy the customer has reflected the need for the development & application of compensation systems. Compensating systems [3] also known as the custom power devices (CPD) offer a handful of protection & security to the system under observation. They tend to absorb the various disturbances by injecting appropriate voltage, current or both into the system; thereby relieving the main source from meeting the reactive power demand of the load. This dissertation attempts to explain the various control strategies providing a reliable solution to the faulted system with the help of DVR (Dynamic voltage restorer).This series conditioner device is capable of generating or absorbing real and reactive power with the help of its essential components, namely power circuit & control circuit. Various control techniques are available to obtain a controlled output voltage, to be injected into the system. They are known as Linear & Non-linear techniques. A PI controller with a linear structure offers satisfactory performance over a wide range of operation [5]. The problem encountered by the controller is the setting of PI parameters i.e. the gains (K_p, K_i). In the influence of varying parameters and operating conditions, the fixed gains of linear controller don't adapt accordingly to give good dynamic response. To overcome the problems faced by a linear technique, non-linear technique is an effective solution [10].

The recommended system uses Fuzzy controllers to investigate the performance level of various controllers in a regard to increase the capability of existing system by creating immunity from disturbance.

II. DYNAMIC VOLTAGE RESTORER

DVR is a static series compensator that injects voltage in series to the distribution system, regulating the load side voltage. It is connected between the supply and the sensitive load to compensate the line voltage harmonics, reduction of transients in addition to compensation of voltage sags & swells.

The basic function of the DVR is to inject a dynamically controlled voltage V_{DVR} generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V_L.

The main aim of DVR is to regulate the voltage at the load terminals irrespective of sag, distortion or unbalance in the supply voltage. The basic operating principle is to inject a voltage of required magnitude & frequency to restore the load voltage under voltage sag or distortion. Generally; it employs solid state power electronic switches such as GTO, IGBT or IGCT in the VSI, which can be operated in various pulse width modulation techniques such as SPWM(sinusoidal pulse width modulation), MSPWM (multiple sinusoidal pulse width modulation) .They inject a set of three phase AC voltage in series & synchronism with the distribution system.

In normal condition it operates in the standby mode. During the disturbance, the nominal voltage is compared with the voltage variation in order to calculate the voltage to be injected by the DVR to maintain the supply voltage within limits. The DVR is capable of providing the reactive power compensation but the real power is provided by the energy storage system.

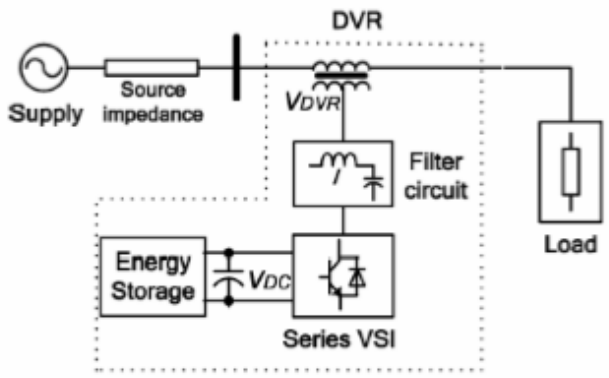


Fig. 1 : Basic Circuit of DVR

The vital components of DVR are the power circuit which injects the desired voltage & control circuit that controls the load voltage of the system within prescribed limits. It consists of the following main components whose description is given below:

i) VOLTAGE SOURCE INVERTER

It forms the building block of compensating device. It performs the power conversion process from DC to AC. VSI consists of fully controlled semiconductor power switches to form a single phase or three phase topologies. For medium power inverters, IGBT"s are used and GTO"s or IGCT"s due to compact size & fast response for high power inverters are employed. The single phase VSI topology encompasses a low-range power applications and medium to high power applications are covered by the three phase topology [10].

ii) SERIES INJECTION TRANSFORMER

It provides electrical isolation & voltage boost to the system. In a 3-phase system, either 3 single phase units of isolating transformer or 3-phase isolating transformer can be employed for the purpose of voltage injection. While selecting the injection transformer, the determination of expected maximum output voltage is prime significance, both economically & technically.

iii) FILTER

These are electronic circuits comprising of combination of passive elements; resistors, inductors & capacitors. They perform signal processing functions to remove the unwanted frequency signals to enhance the desired signal output.LC type of filters corrects the harmonic output from VSI to provide compensation in the required phase of the 3 phase system boosted by DVR.

iv) ENERGY STORAGE UNIT

The purpose of storage systems is to protect sensitive equipments from shutdowns caused by voltage sags or interruptions. They provide necessary energy to the VSI via a dc link for the generation of injected voltages. There are different types of storage systems such as superconducting magnetic energy storage system (SMES), DC batteries, flywheel energy storage system, battery energy storage system (BESS) etc. Capacity of the storage system directly determines the duration of the sag which can be mitigating by the DVR. Among the above mentioned storage systems, Batteries are more common & can be highly effective if high voltage configuration is used. There are different types of battery energy storage technologies such as lead-acid battery, flooded type battery, valve regulated type battery (VLRA), sodium sulphur battery (NaS) etc [6].

v) CONTROL CIRCUIT

Several techniques & control philosophy of the DVR have been implemented for power quality improvement in the distribution system. The DVR is equipped with a control system to mitigate voltage sags/swells. The control of the DVR is very important as it involves the detection of voltage sags (start, end & depth of voltage sag) by appropriate detection algorithm [7]. The control strategy can depend on the type of load connected. Its main purpose is to maintain constant voltage magnitude at the point where the sensitive load is connected under system disturbances.

III. CONTROL PHILOSOPHIES OD DVR

Voltage sags are one of the most severe power quality problems & DVR is an effective solution to mitigate it. The purpose of control scheme is to control the system output by generating an appropriate control signal prior to the unbalanced condition prevailing in the system. It generates the signals to enable the VSI (voltage source inverter) by providing proper firing sequence to the circuit. In this work, different control strategies for dynamic voltage restorer are investigated with emphasis on voltage sag compensation and here we are discussed about fuzzy controller.

i) FUZZY CONTROLLER BASED DVR

The drawback suffered by PI controller is overcome by Fuzzy. In comparison to the linear PI controller, this is a non-linear controller that can provide satisfactory performance under the influence of changing system parameters & operating conditions [8][9]. The function fuzzy controller is very useful as relieves the system from exact & cumbersome mathematical modeling & calculations. The performance of fuzzy controller is well established for improvements in both transient & steady state [10].

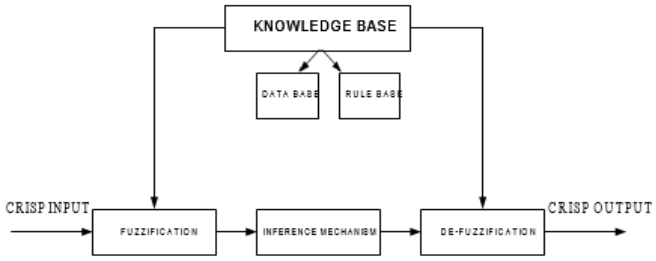


Fig. *2* : Schematic Diagram of Fuzzy Logic

The fuzzy controller comprises of four main functional modules namely; Knowledge base, Fuzzification, Inference mechanism & Defuzzification as in Fig. 2.

a) KNOWLEDGE BASE

It consist of data base and rule base that maps all the inputs and outputs with certain degree of uncertainity in process parameters and external disturbances to obtain good dynamic response. Data base scales the input-output variables in the form of membership functions that defines it in a range appropriate to provide information to the fuzzy rule-based system & output variables or control actions to the system under observation. Fuzzy rule-based system utilizes a collection of fuzzy conditional statements derived from a knowledge base to approximate and construct the control surface.

b) FUZZIFICATION

It is the process of defining a crisp data or digital data operating on discrete values of either 0 or 1 in terms of logical variables that take on continuous values between 0 and 1 i.e. fuzzy set. Fuzzy set maps the input-output variables into membership functions & truth values as in Fig 3- 5.

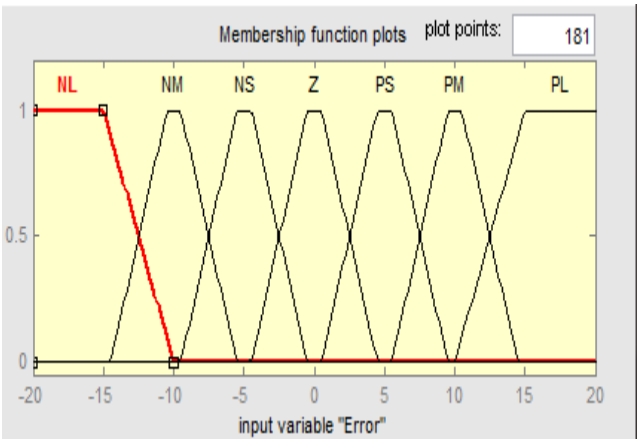


Fig. 3 : Input Membership Function of "Error"

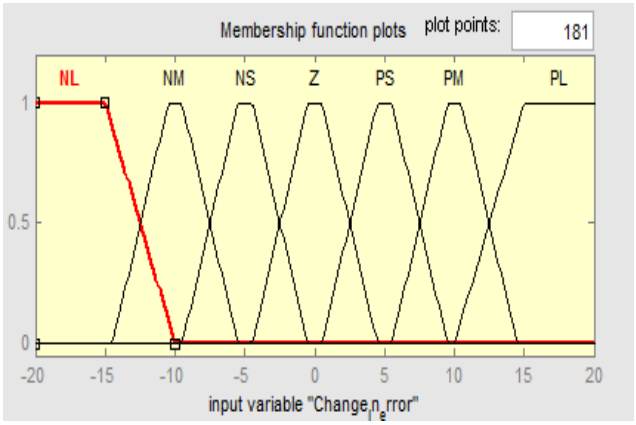


Fig. 4: Input Membership Function of "Change in Error"

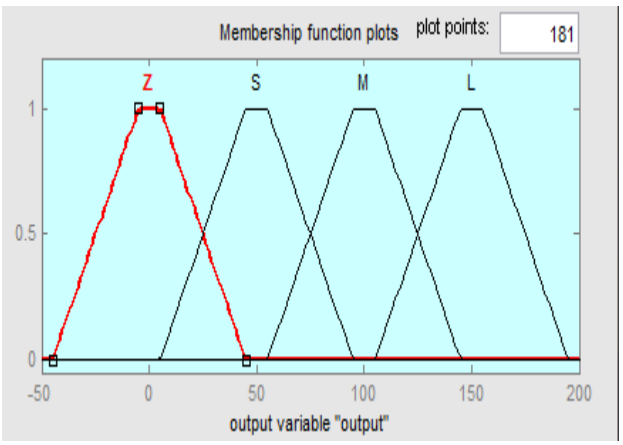


Fig. 5: Output Membership Function

c) INTERFERENCE MECHANISM

It is referred to as approximate reasoning that uses knowledge to conduct deductive inference of IF-THEN rules. This mechanism encodes knowledge about a system in statements form of linguistic IF -THEN propositions with antecedents & consequents. There are three types of fuzzy inference mechanism:

- Mamdani System (1975)
- Sugeno models: Takagi and Sugeno(1985) & Sugeno & Kang(1988)
- Tsukamoto models(1979)

d) DEFUZZIFICATION

It is a conversion process of fuzzy quantity to a precise quantity and is reverse process of fuzzification. A logical union of two or more membership functions in the universe of discourse requires a crisp decision with approximate solution for the output of fuzzy which is uncertain in nature to be a single scalar quantity Various methods for defuzzyifying the output membership functions have been proposed; out of them four of widely used are summarized as follows:

- Centroid method
- Centre of sums method(cos)
- Weighted average method
- Mean-max membership

The FLC controller of the tested system exploits the Mamdani type of inference method. It defuzzifies the crisp input-output variables into fuzzy trapezoidal membership function and reverse process of Defuzzification is based upon the Centroid method. The controller core is the fuzzy control rules as shown in table I. which are mainly obtained from intuitive feeling and experience [11].

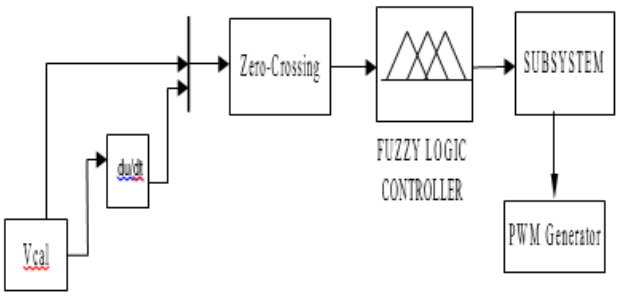


Fig. 6: Control Strategy of Fuzzy Controller

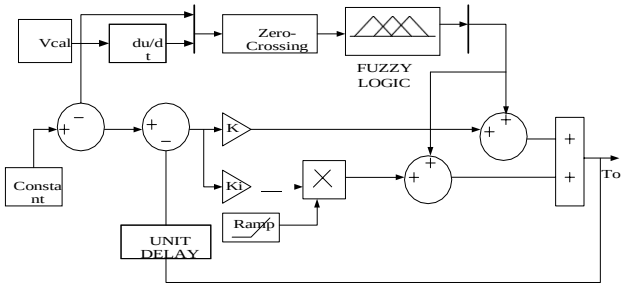
Table 1: Fuzzy Rule Based System

"e" / "ce"	NL	NM	NS	Z	PS	PM	PL
NL	L	L	L	M	Z	S	Z
NM	L	L	M	Z	Z	Z	S
NS	L	M	S	Z	Z	S	S
Z	M	S	S	Z	S	S	M
PS	S	S	Z	Z	S	M	L
PM	S	Z	Z	Z	M	L	L
PL	Z	S	Z	M	L	L	L

ii) HYBRID PI-FUZZY BASED DVR

The hybrid PI-Fuzzy control scheme uses fuzzy as adjustor discussed to adjust the parameters of proportional gain Kp

and integral gain Ki based on the error e and the change of error Δe [11]. PI-Fuzzy based Controller has been designed by taking inputs as error which is difference between measured voltage and reference voltage of DVR for voltage regulator and its derivative while ΔKp and ΔKi as output for voltage regulator where Kp and Ki are proportional gain and integral gain respectively [12] as shown in Fig. 4.



IV. CONCLUSION

In this paper, review on DVR based fuzzy controller and its modules have been presented. The performance of DVR based Fuzzy Controller better than DVR based PI Controller. Its fuzzy structure makes it to be applicable for a wider area. the performance of this approach, like the other controlling methods depends on fault detection (voltage sag in this paper) signal and its precision.

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