DYNAMIC VOLTAGE RESTORER USING PI & FUZZY LOGIC CONTROL

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Abstract*:* The evolution of power electronics technology replaced with the traditional power quality mitigation methods with the introduction of Custom Power System devices (CUPS). The significant power electronic controller based CUPS are DSTATCOM, DVR and UPQC. Among the CUPS, DVR is the most financially savvy one. A dynamic voltage restorer (DVR) is a solution to compensate the voltage sags and swells in distribution side and to protect sensitive loads. DVR is quick, adaptable and effective answer for voltage list issue. DVR can provide the most commercial solution to mitigate voltage sag by injecting voltage as well as power into the system. The operation of DVR is depends on the control technique used. This paper presents the modeling and simulation of DVR of the control strategy for extracting the compensation voltages in DVR is based on fuggy logic along with PI controller. The control procedure is checked through broad reproduction considers utilizing MATLAB and SIMULINK to show the enhanced execution of DVR.
***INDEX TERMS: CUSTOM POWER SYSTEM DEVICES*, DVR, VOLTAGE SAG, FUGGY LOGIC.**

INTRODUCTION:

In power distribution systems the advent of large numbers of sophisticated electrical and electronic equipment such as programmable logic Controllers and variable speed drives causes various power quality problems like voltage sag, voltage swell and harmonics. These are the real worry of the mechanical and business electrical customers because of huge misfortune as far as time and cash, in which voltage droop and swell are major power quality problems. Voltage sag is defined as decrement in the RMS value of voltage magnitude. Voltage swell is characterized as augmentation in the RMS estimation of voltage greatness. There are two types of voltage sag and voltage swell which can occur on any transmission lines. Balanced type of voltage sag and voltage swell is known as symmetrical voltage sag and swell. Unbalanced type of voltage sag and swell is known as unsymmetrical voltage sag and swell. Voltage hangs/swells brought about by unsymmetrical line-to-line, single line-to-ground (SLG), twofold line-to ground and symmetrical three stage flaws. These impacts can be over the top expensive for clients, going from minor quality varieties to deliver downtime and hardware harm. Custom power gadgets are utilized to remunerate these power quality issues in the frameworks. There are diverse sorts of Custom power gadgets utilized in electrical system to enhance control quality issues. Every one of the gadgets has its own advantages and constraints. DVR is a custom power device which provides more reliable solutions for power quality problems. The DVR is preferred compare to static VAR compensator (SVC) because the SVC has no ability to control active power flow. Another reason is the DVR has a higher energy capacity compared to the Super Conducting Magnetic Energy Storage (SMES) and Uninterrupted Power Supply (UPS) devices and also DVR is smaller in size and cost is less compared to the Distributed Static Compensator (DSTATCOM) and other custom power devices. In between power grid and consumers load the DVR is located. It infuses controlled voltage to keep dc interface voltage consistent at burden side. It is used to correct the voltage sag by injecting the voltage as well as power into the system. In secondary distribution system to mitigate the unbalance voltages and also improve the voltage profiles by using DVR. The conventional proportional integral (PI) controller requires mathematical calculations which difficult to obtain and perform satisfactorily load disturbances. The FUGGY logic controller has more advantages and greater performance characteristics in such applications. This paper presents a result of proposed controller which is designed for compensating multiple voltage sag and swell. It means the controller causes DVR to react quickly and also to maintain the constant load voltage both for a balanced and unbalanced multiple sag and swell conditions in the distribution systems. The execution of DVR depends up on control system utilized. In this paper Fuggy Logic with Proportional Integral (PI) controller technique is used for compensation of balanced and unbalanced voltage sag and swell.

DYNAMIC VOLTAGE RESTORER (DVR):

In order to overcome the voltage disturbances in power system, we are introducing the custom Power Device which is DVR. DVR is an arrangement repaying gadget which shields touchy electric burden from power quality issues like voltage droop and swell, unbalance twists through a power electronic controller. It injects the voltage at load side. The DVR was first installed in 1996. It is ordinarily introduced in an appropriation framework between the supply and the basic burden feeder at the purpose of basic coupling (PCC).

The equivalent and schematic diagram of DVR is as shown in fig. 1 and 2 respectively. It consists of mainly measuring unit, control unit, power unit.

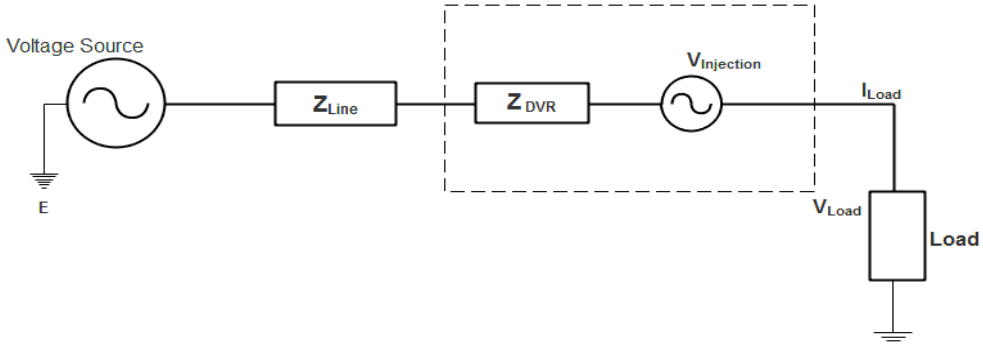

Fig1: Equivalent diagram of DVR

The DVR mainly consisting parts are

- Series Injecting Transformer
- Voltage Source Inverter (VSI)
- Output Filter Circuit
- Energy storage unit
- Control unit

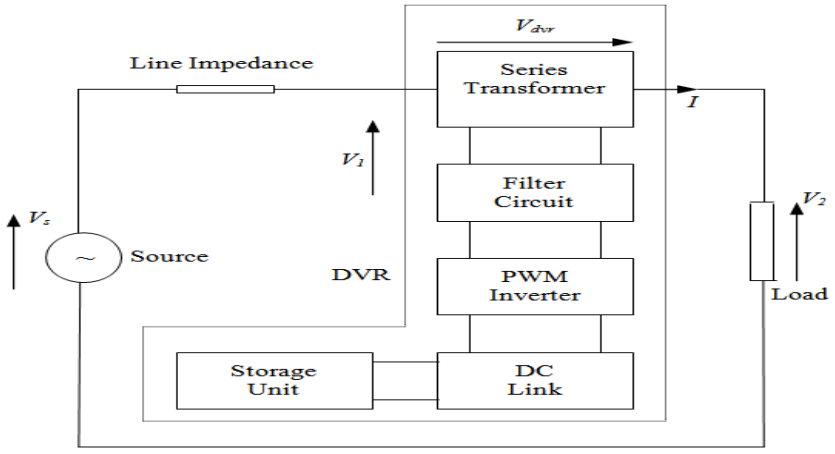

Fig2: Schematic diagram of Dynamic Voltage Restorer

OPERATION OF DVR:

- The essential rule of the dynamic voltage restorer is to infuse a voltage of required greatness and recurrence, with the goal that it can reestablish the heap side voltage to the ideal adequacy and waveform notwithstanding when the source voltage is unequal or misshaped. If the device only injects reactive power the device can be termed as series VAR compensators. The supply continues to be connected and no resynchronization is necessary as it is the case with a shunt connected converter.
- The resulting voltage at the load bus bar equals the sum of the grid voltage and the injected voltage from the DVR. The converter creates the receptive power required while the dynamic power is taken from the vitality stockpiling.
- The principle advantage with this strategy is that a solitary DVR can be introduced to secure the entire plant (a couple MVA) just as single burdens.
- Disadvantages are that it is relatively expensive and it only mitigates voltage sags from outside the site. The expense of a DVR mostly relies upon the power rating and the vitality stockpiling limit.

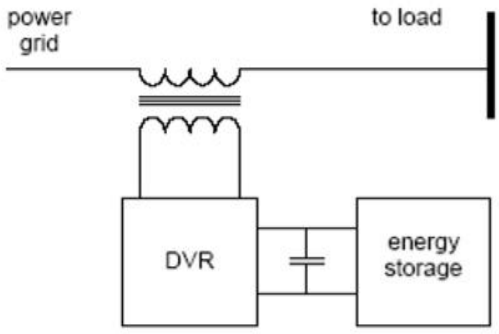

Fig: Configuration of DVR

- The DVR can be operated in 3 different modes: Bypass mode, Standby mode, and Active mode.

Bypass Mode: In this mode the DVR cannot inject voltage to improve the voltage quality.

Standby Mode: The supply voltages are at rated level and the DVR is ready to compensate for voltage sag. Amid reserve mode the DVR can have auxiliary undertakings and task modes.

Active Mode: Whenever voltage sags are detected, DVR injects the missing voltage. In this mode DVR should ensure the unchanged load voltage with minimum energy dissipation for injection due to high cost of capacitors. The available voltage injection strategies are pre-sag, phase advance, voltage tolerance and in phase method.

PRINCIPLE OF DVR:

- Dynamic voltage restorer (DVR) protects the load from voltage disturbances. Under normal operating conditions, let the three phase voltage phasors V_{a1}, V_{b1} and V_{c1}. During abnormal conditions, the phase voltage vectors may be altered to V_{a2}, V_{b2} and V_{c2}. DVR does not supply any real power in the steady state. This implies that the phase angle difference between DVR voltage phasor and current phasor must be 900 in the steady state.
- DVR operates only during the abnormal conditions and remains idle during normal operating conditions. During operation, DVR has a capability to supply and absorb active and reactive power. Dynamic voltage restorer corrects the load voltage by supplying reactive power generated internally on the occasion of small fault. DVR develops active power when it is required to balance larger faults. It requires dc energy device to develop the active power.
- Dynamic voltage restorer (DVR) is a series controller connected in series to the load. The injecting transformer injects the required voltage vector (magnitude and angle) which adds to the source voltage to restore the load voltage to pre-abnormal condition.

VOLTAGE INJECTION METHODS:

- Since the dynamic voltage restorer injects the compensating voltage in order to maintain the load voltage constant, there are certain limitations in compensating the voltage sags. The factors influencing the compensation are finite power rating, different load conditions and different types of voltage sag. The injection compensating voltage is categorized as three methods.
- **PRE-SAG COMPENSATION:** In this method DVR continuously tracks the supply voltage. The DVR injects the missing voltage between during sag and pre-sag voltages to the system. During the compensation, DVR has to compensate both magnitude and angle. In this method, the injected power cannot be controlled while load voltage can be restored ideally. Load conditions and type of fault determines the injected power.

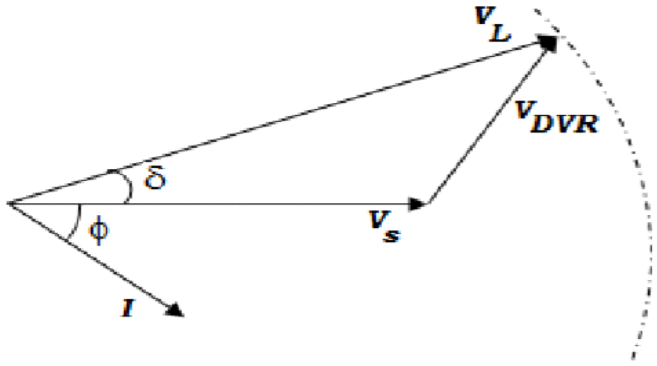

Fig: Vector diagram of pre-sag compensation

- **IN-PHASE COMPENSATION:** In this method, injected voltage is independent of the load current and pre-fault voltage. The injected voltage is always in-phase with supply voltage. The added advantage of this method is to minimize the magnitude of injected voltage for constant load voltage magnitude. The phase angles of pre-sag and load voltage are different and magnitude of load voltage is same as pre-fault voltage. During normal conditions, supply voltage and load voltage are equal with zero phase angle. During abnormal condition like sag, phase angle jump appears with reduction of load voltage magnitude. Both the parameters are compensated by DVR.

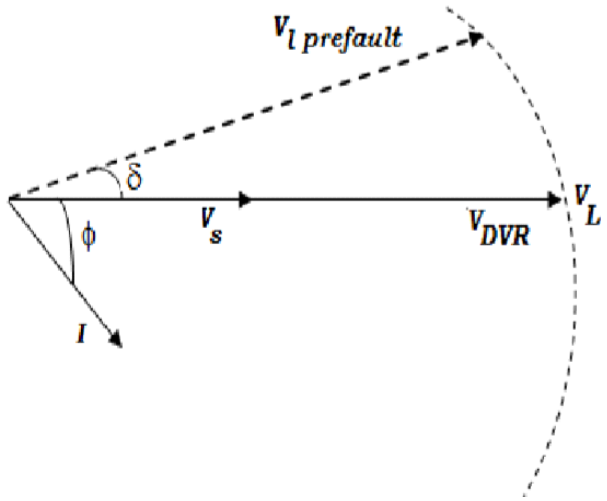

Fig: Vector diagram of in-phase compensation

3) **PHASE ADVANCE COMPENSATION:** Phase advance methods proves to better compared to other methods as it associates only reactive power injection instead of active power. The injected active power is made zero by injecting compensating voltage perpendicular to load current. The injected voltage of the phase-advance method is larger than those of pre-sag or in-phase method.

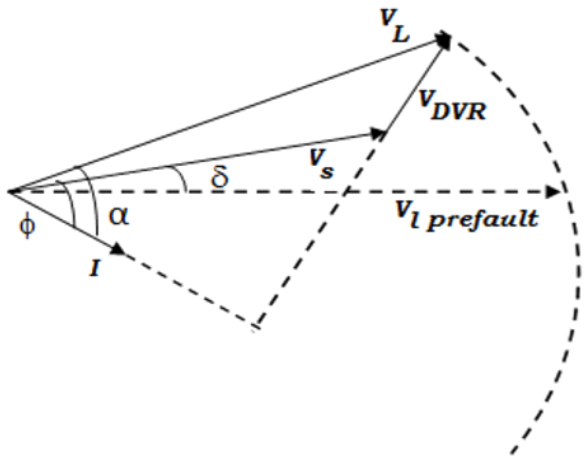

Fig: Vector diagram of phase advance compensation

ENERGY STORAGE UNIT:

- This supply the necessary energy to the VSI via a dc link for the generation of needed voltages during disturbances in the network, and most of the DVR application, the energy source can be an electrolytic capacitor bank.
- This is required to give dynamic capacity to the heap amid profound voltage hangs. Lead-corrosive batteries, flywheel or SMES can be utilized for vitality stockpiling. It is additionally conceivable to give the required power on the DC side of the VSC by a helper connect converter that is bolstered from an assistant AC supply.

CONTROL UNIT:

- The main purpose of DVR is to detect the sag/swell occurrence in the system, calculate the compensating voltage, to generate trigger pulses of PWM inverter and stop triggering when the occurrence has passed.
- The PWM provides an effective method of controlling an inverter to generate ac power from dc power to produce a three-phase 50-Hz sine wave voltage on the load side.

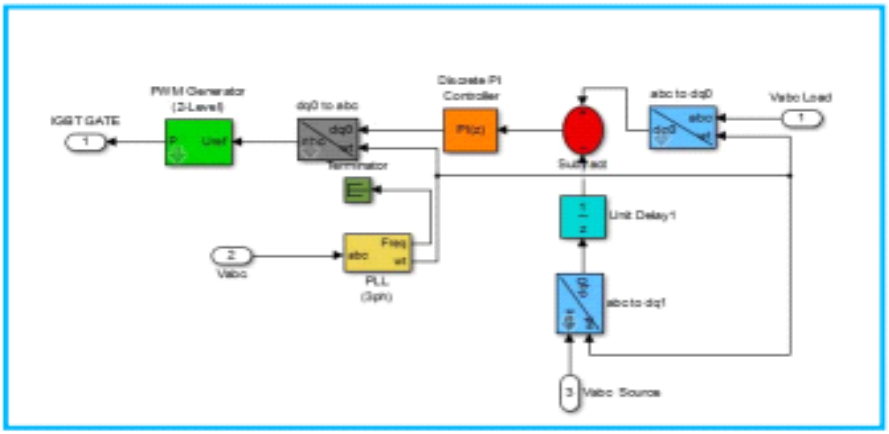

Fig: Control Circuit for PI

- The control system employs abc to dq0 transformation and again back to abc transformation.
- The value of voltage is constant during normal operating condition and d-voltage is unity in per unit and q-voltage zero in PU but the value of d-voltage and q-voltage gets changed during the abnormal condition.
- During faulty condition, the line voltage in PU is converted to dq0 frame of reference by abc to dq0 converter. This value is compared with reference dq0 frame of reference which is obtained from reference voltage when the line voltage value gets differ from reference voltage, it will generate error signal which is used for controlling purpose and to trigger PWM or SPWM inverter.
- The error signal generated between dqo voltage of the supply or line voltage and the reference voltage is responsible for detection of sag/swell. In order to convert stationary frame to rotating frame which can detect the phase angle and magnitude of supply voltages the park's transformation (abc to dqo) has been utilized. It is often use to simplify calculation for control of three phase inverters.

$$V_0 = (1/3)[V_a + V_b + V_c]$$

$$V_d = (2/3)[V_a \text{ Sin } \omega t + V_b \text{ Sin } (\omega t - 2\pi/3) + V_c \text{ Sin } (\omega t + 2\pi/3)]$$

$$V_q = (2/3)[V_a \text{ Cos } \omega t + V_b \text{ Cos } (\omega t - 2\pi/3) + V_c \text{ Cos } (\omega t + 2\pi/3)]$$

After transformation, the three-stage voltage Va, Vb and Vc end up two consistent voltages Vd and Vq and now, they are effectively controlled.

In this paper, two control procedures have been proposed which are corresponding basic (PI) controller and fluffy rationale (FL) controller.

PROPORTIONAL-INTEGRAL CONTROLLER:

- This controller is a feedback one.
- The proportional response can be adjusted by multiplying the error by proportional gain (KP).
- The contribution from integral term is proportional to both the magnitude of error and duration of error. The error is first multiplied by the integral Gain, Ki and then was integrated to give an accumulated offset that have been corrected previously.

FUZZY LOGIC CONTROLLER:

In the past area, control procedure dependent on PI controller is talked about. In any case, in the event of PI controller, it has high settling time and has substantial consistent state blunder. So as to amend this issue, this paper proposes the utilization of a fluffy rationale controller (FLC) . By and large, the FLC is a standout amongst the most imperative programming based procedure in versatile strategies.

As contrasted and past controllers, the FLC has low settling time, low consistent state blunders. The activity of fluffy controller can be clarified in four stages.

1. Fuzzification
2. Membership capacity
3. Rule-base arrangement
4. Defuzzification.

- Fuzzy logic controller is one of the most successful operations of fuzzy set theory.
- The main feature of FL controller is that it uses linguistic variables rather than numerical variables.
- The control technique relies on human capability to understand the systems behavior and is based on quality control rules.
- This logic provides a better way to arrive at a definite conclusion based upon noisy or missing input information.

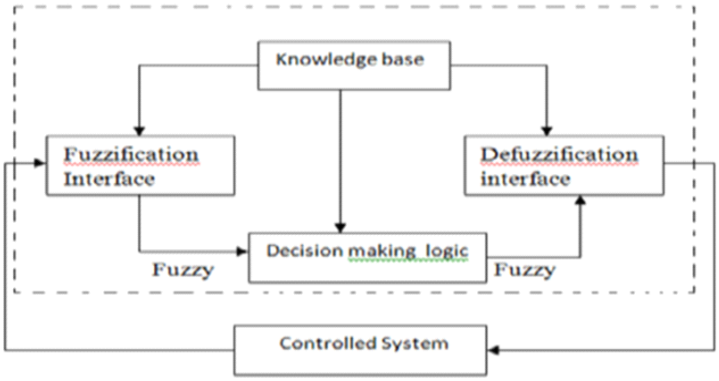

Fig: Basic structure of Fuzzy Logic Controller

SIMULATION & RESULTS FOR PI CONTROLLER:

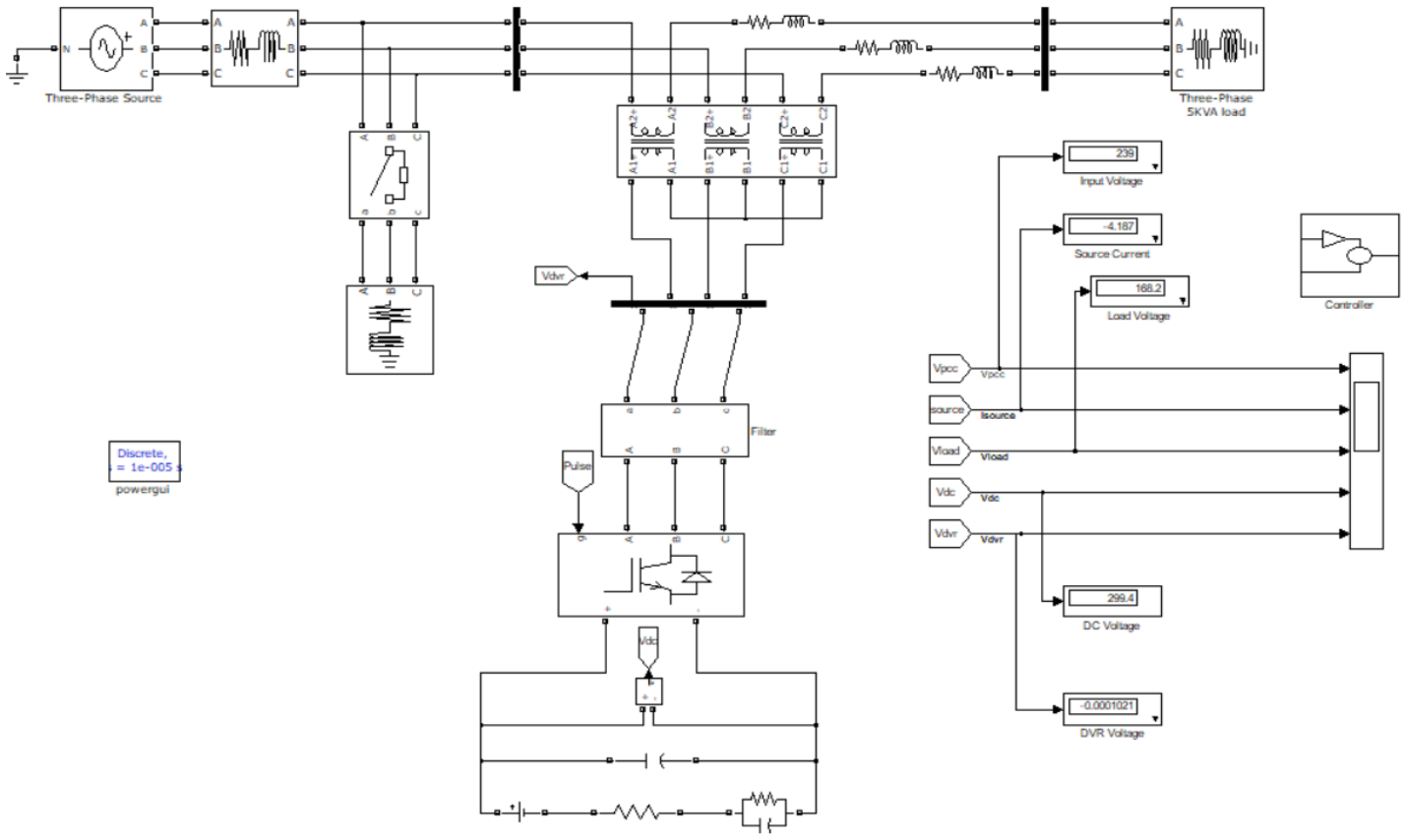

Fig: Simulation Circuit

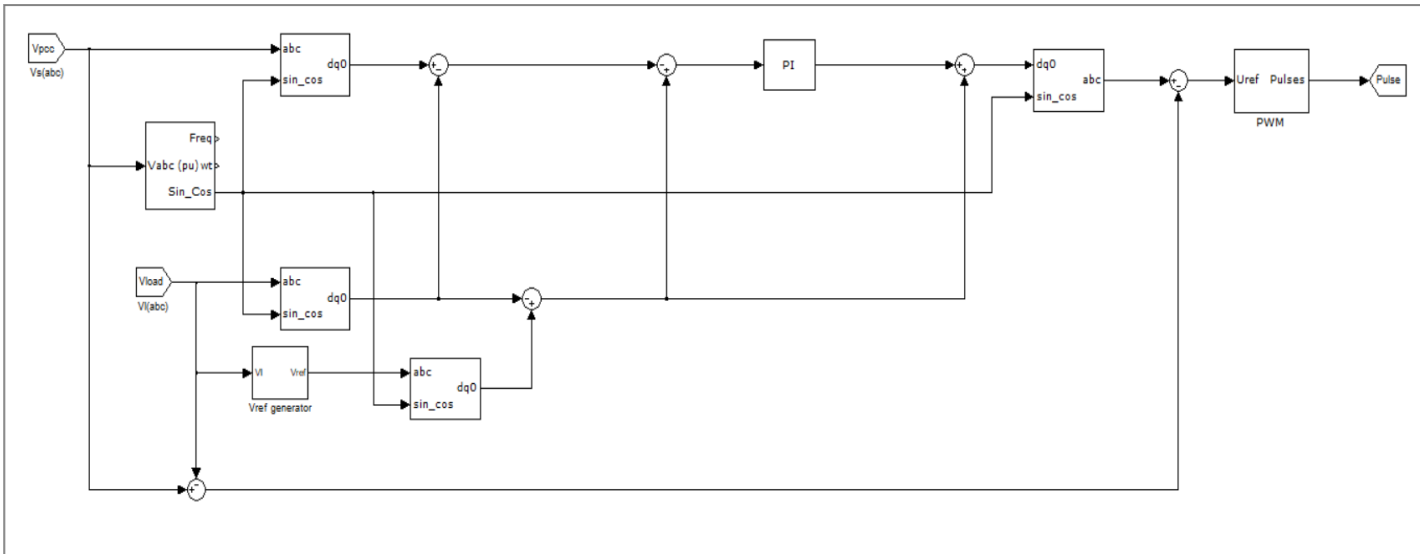

Fig: PI Controller for DVR

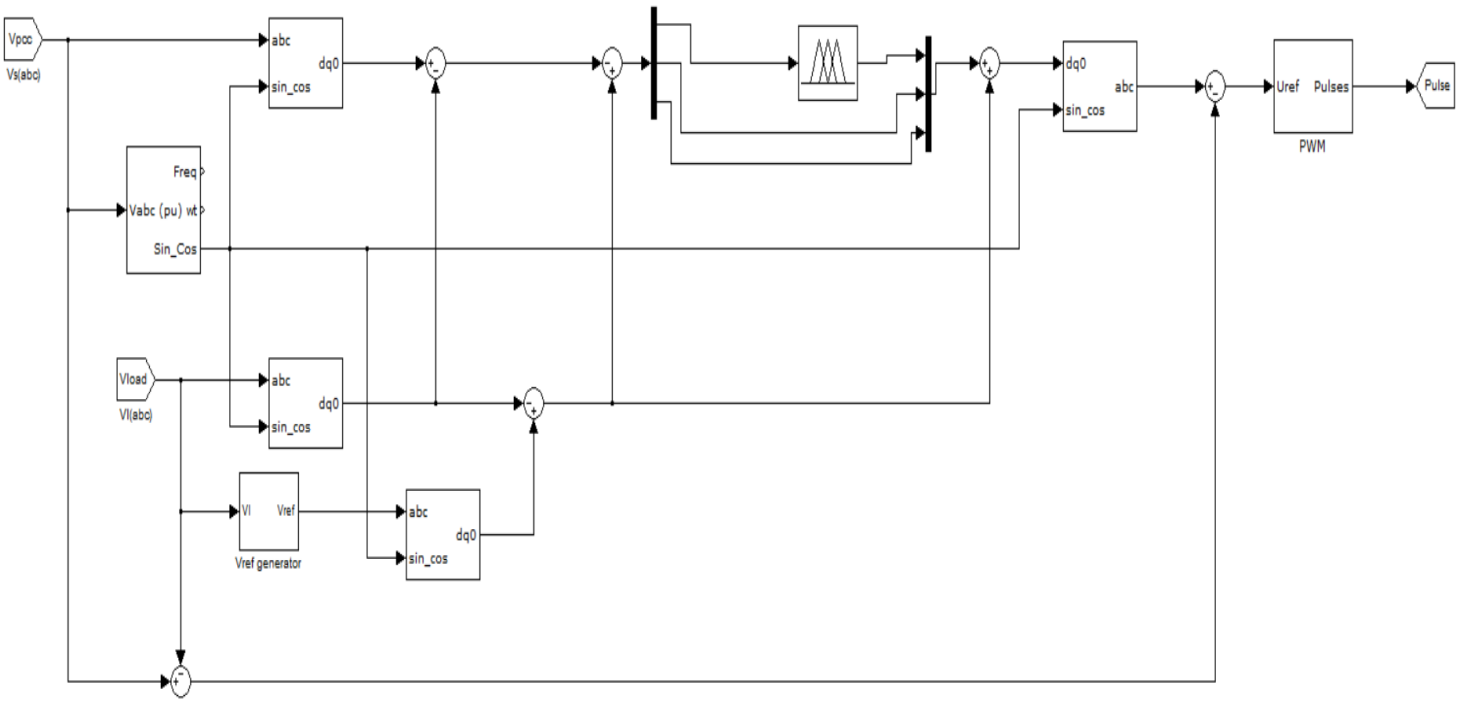

Fig: Fuzzy logic control diagram

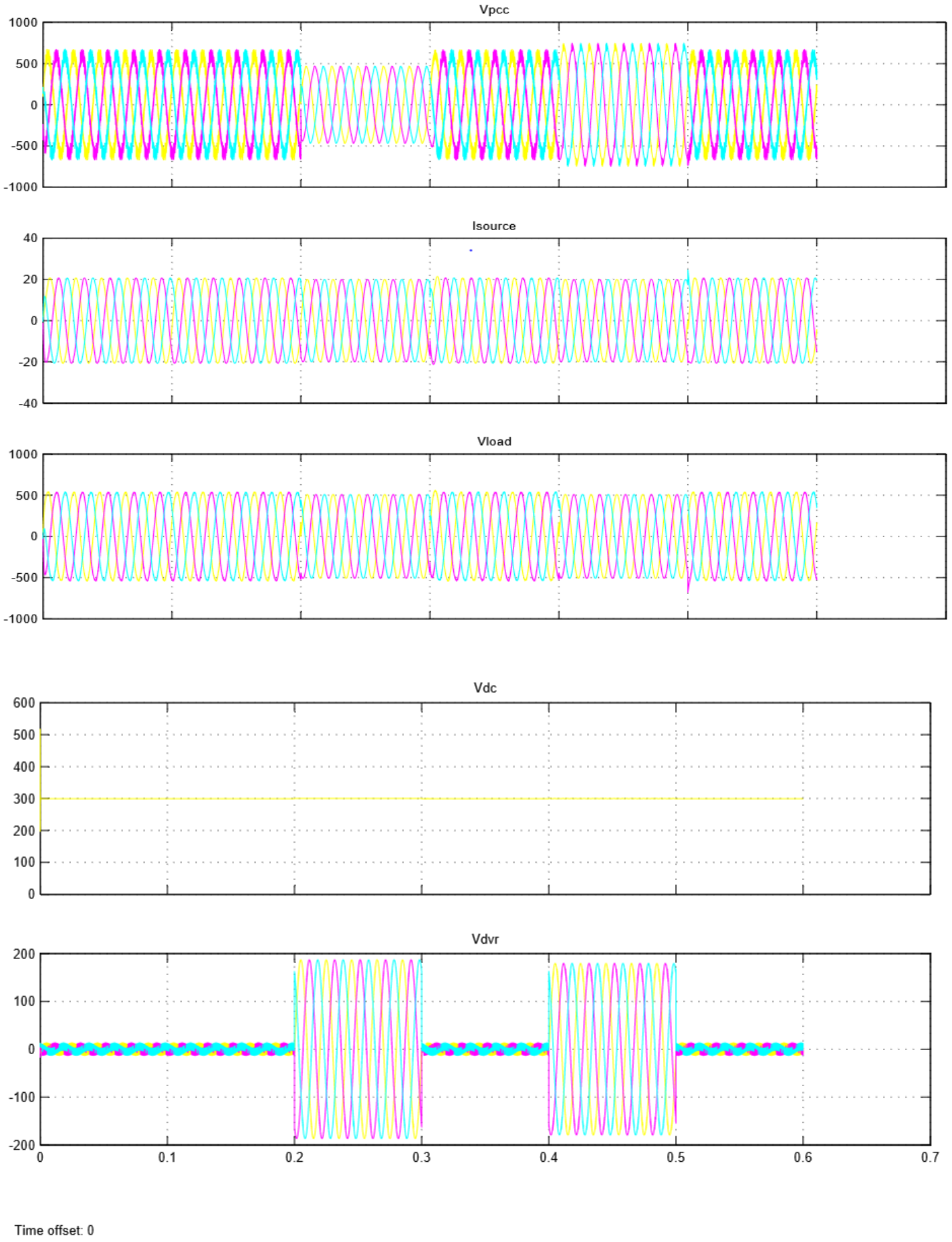

Fig: Scope for Different parameters

CONCLUSION:

This paper presents examination and reproduction of DVR with PWM inverter by utilizing MATLAB/SIMULINK. A control framework dependent on dqo method has been exhibited. The benefit of Park's change is that it streamlines figuring for controlling inverter. The MATLAB reenactment demonstrates that the execution of DVR is attractive in moderating voltage unbalances.

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