Elimination of Voltage Sag/Swell using Dynamic Voltage Restorer

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Abstract— *Voltage sag disturbances are the most frequently occurring Power Quality problems in the distribution system. This paper explains modelling and simulation of a dynamic voltage restorer as a voltage sag and swell mitigation device in electrical power distribution networks. A Dynamic Voltage Restorer (DVR) is proposed to handle deep voltage sags, swells and outages on a low voltage single phase residential distribution system. The dynamic voltage restorer with its excellent dynamic capabilities, when installed between the supply and a critical load feeder, can compensate for voltage sags/swells, restoring line voltage to its nominal value within a few milliseconds and hence avoiding any power disruption to the sensitive load. Otherwise, it will operate as an Uninterruptable Power Supply across the sensitive load when disturbance occurs on the supply voltage. It is also designed to reduce the usage of utility power. A series injection transformer is connected in series with the sensitive loads which restoring voltage sag and swell to a nominal voltage by protecting the sensitive load from damage. In this paper the technical aspect feasibility related to the use of dynamic voltage restorer (DVR) with series injection transformer are evaluated. The modelling of dynamic voltage restorer is carried out component wise and their performances are analysed using MATLAB software. The simulation result shows that the control technique is very effective and yields excellent compensation for voltage sag/swell Mitigation. The proposed system is validated with the MATLAB simulation for experimental setup for Voltage sag /swell occurrence is connected to the load. And simulation results are verified with the same output for experimental setup.*

Keywords— Dynamic Voltage Restorer (DVR), Magnitude traction, Power Quality, Series injection transformer, Voltage compensation

I. Introduction

In the early days of power transmission voltage deviation occurs during load changes, power transfer limitation was observed due to reactive power unbalances. Modern power systems are complex networks, where hundreds of generating stations and thousands of load centres are interconnected through long power transmission and distribution networks. The main concern of customer is the quality and reliability of power supply at various load centres. Even though power generation in most well-developed countries is fairly reliable, the quality of supply is not. there are two major challenges that the modern power grid must deal with voltage fluctuations and short circuit faults. With wide use of nonlinear loads, the grid suffers from voltage fluctuation, voltage unbalance, and other power quality problems Power distribution system should ideally provide their customers an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude and frequency. However, in practice power system especially the distribution system, have numerous nonlinear loads, which are significantly affect the quality of power supply. As a result, the purity of waveform of supply lost. This ends up producing many power quality problems such as voltage sag, voltage swell.. Voltage sag is a sudden reduction of utility supply voltage from90% to 10% of its nominal value. On the other hand, voltage swell is a sudden rise of supply voltage from 110% to 180% of its nominal value. A typical duration of voltage sag and swell is 10 ms to 1 minute. The voltage sags and swells often caused by starting of large induction motors, energizing a large capacitor bank and faults such as single line to ground fault, three phase to ground fault, double line to ground fault on the power distribution system At the same time, many power loads become more sensitive to these disturbances. To improve power quality, custom power devices are used. Dynamic Voltage Restoration (DVR) is a method and apparatus used to sustain, or restore, an operational electric load during sags, or spikes, in voltage supply. DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating sags/swells.

II. Objective

- Fast mitigation of power quality problems
- Power quality improvement
- Voltage compensation against voltage disturbances such as voltage sag voltage swell
- Short Circuit Protection

III. Block diagram of proposed method

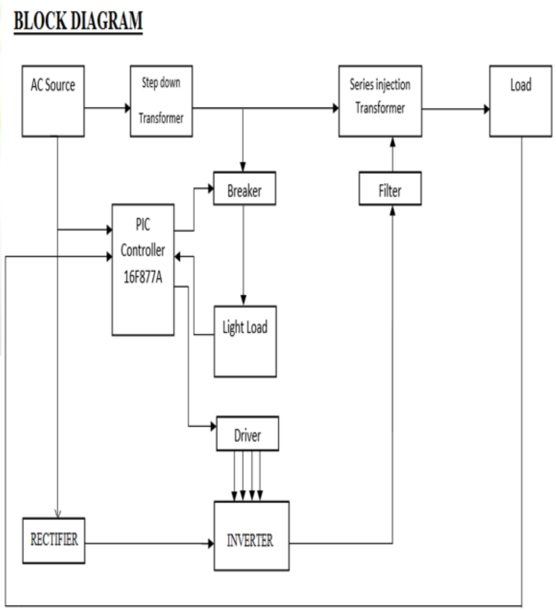

Fig. 1: Block diagram

Figure 1 illustrates the block diagram of proposed method. It consists of an Ac supply from distribution lines, step down transformer, Microcontroller, single phase inverter, series injection transformer and sensitive load. Supply voltage from distribution transformer i.e. 230v is stepped down to desire voltage with the help of tap changing transformer is fed into rectifier and then converted into DC. The obtained DC voltage is maintained constant with the help of the voltage regulator applied to the microcontroller where the reference voltage and magnitude traction is programed, where the input voltage magnitude is compared with this reference voltage magnitude, when equal supply is directly connected to the load. In case voltage magnitude less than required voltage it will boost the required amount of voltage injected by means of phase to neutral injection in series injection transformer then it is connected to the sensitive load. If voltage magnitude is greater than required voltage, it reduces to the desired voltage and fed to the sensitive load with the help of neutral to phase current injection in series injection transformer.

IV. System Configuration

The basic idea of a DVR is to inject the missing voltage cycles into the system through series injection transformer whenever voltage sags are present in the system supply voltage. As a consequence, sag is unseen by the loads. During normal operation, the capacitor receives energy from the main supply source. When voltage dip or sags are detected, the capacitor delivers dc supply to the inverter. The inverter ensures that only the missing voltage is injected to the transformer. A relatively small capacitor is present on dc side of the PWM solid state inverter, and the voltage over this capacitor is kept constant by exchanging energy with the energy storage reservoir. The required output voltage is obtained by using pulse-width modulation switching pattern.

V. Simulation

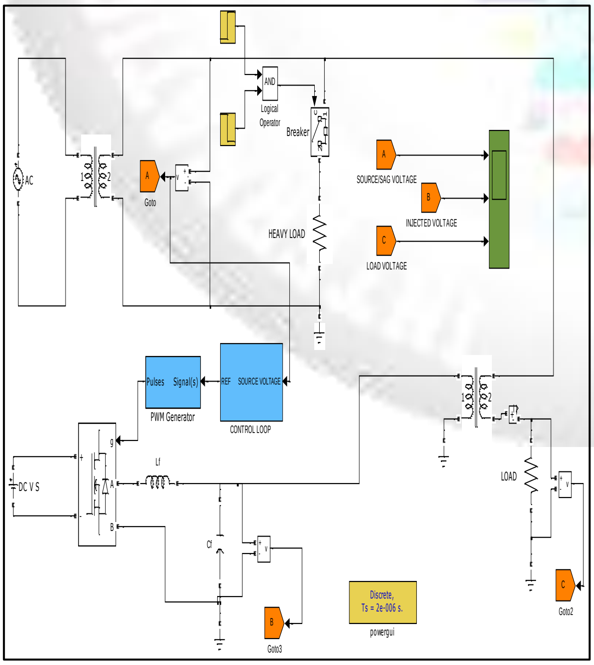

Fig. 2: Simulation for DVR

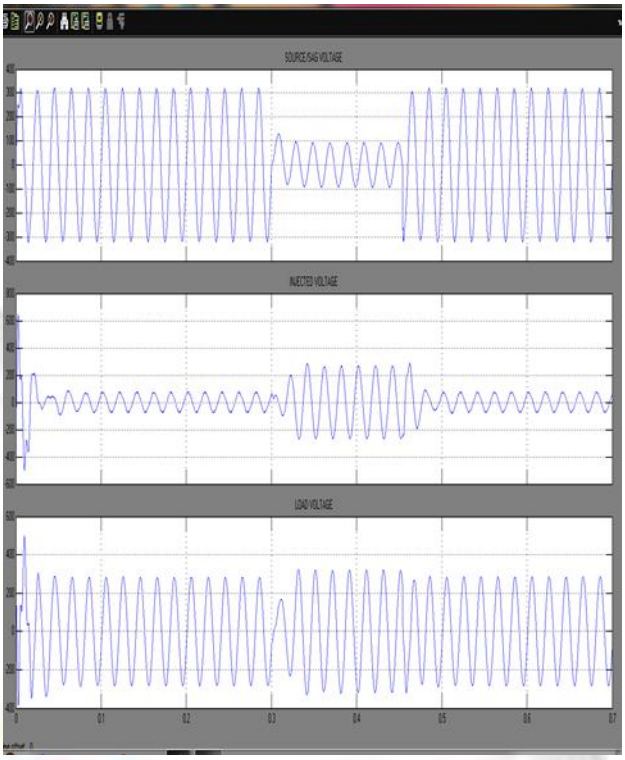

Fig. 3: Simulation output for voltage sag recovery by using DVR

In above diagram Fig 2,3 are the circuit diagram, simulation output of a DVR respectively The simulation is simulated by using MATLAB A whole simulation will be kept under a discrete mode because to occur an instant output in a discrete manner. An input voltage of 230 rms is fed to the sensitive load when there is no interruption and sag occurs at 0.3ms to 0.45ms where the peak voltage is reduced till Vp = 200V. this is eliminated by generating waveform using pulse width modulation(PWM) generator and adding it with sag waveform with the help of Series injection Transformer so that it will compensates the losses occurs during voltage sag through which sensitive equipment are saved

Vp= Peak-Peak Voltage

V_{pinj}=Injected voltage

V_L=Load Voltage

V_L=Vp + Vpinj (1)

While sag occurs at t=0.30 ms to t=0.45ms

Vp=400 V (2)

$V_{pinj=}$400V (3)

Substitute (2), (3) in (1)

V_L=400+400 =800V (4)

SIMULATION PARAMETERS	
Input voltage	230*1.414V
DC Source	12 V
Load resistance	10 ohm
Frequency	50Hz
Isolation transfer	1:1 (250 Watt)
Series injection transformer	1:1 (250 Watt)
Inductive filter	38mH
Capacitive filter	20uF

Table 1: Parameters for DVR

VI. SUBSYSTEM-CONTROL LOOP

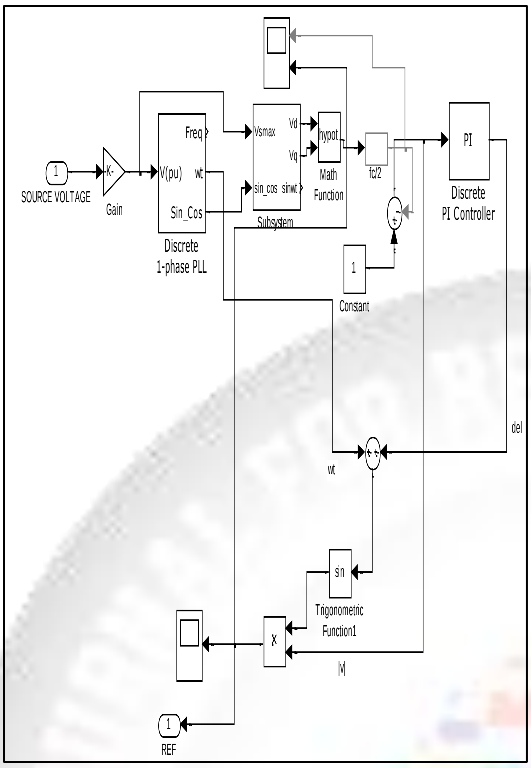

Fig. 4: Circuit diagram for controller loop

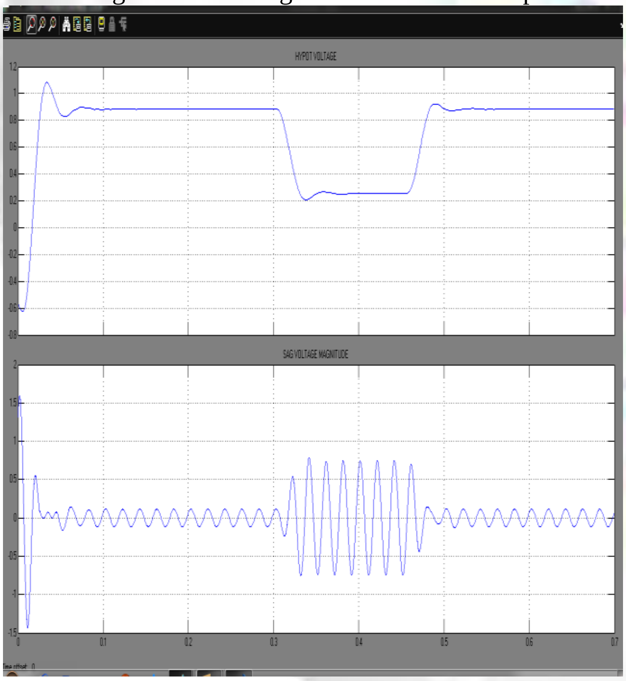

Fig. 5: Simulation output for controller unit

From fig 4,5 shows the simulation output of control unit ,Control unit control the load voltage by magnitude traction or magnitude extraction method, where the real voltage is obtained from multiplication of source voltage and sinusoidal angle similarly imaginary voltage is obtained from multiplication of inversed source voltage and cosine angle from which Vd and Vq are calculated which fed to hypot where the voltage is compared with reference voltage and produce a nominal waveform in case sag occurs it will show the difference as shown in figure 5. Pulse Width Modulation (PWM) generator will generate sinusoidal pulse only when the difference in nominal waveform occurs which is injected to the source voltage with the help of series injection transformer to obtain constant load voltage to the sensitive load

For Magnitude traction

$$V_{source} * Sin_{wt} = V_{real} \quad (5)$$

$$-V_{source} *cos_{wt} = V_{img} \quad (6)$$

$$V_d=V_{real}*sinwt-V_{img}*cos_{wt} \quad (7)$$

$$V_q=V_{real}*coswt+V_{img}*sin_{wt} \quad (8)$$

VII. HARDWARE IMPLEMENTATION

Fig 6, a single-phase DVR is proposed to compensate voltage sag/swell and harmonics and limit downstream fault currents with a simple topology. Although, the proposed topology is single phase, it can be extended to any n-phase (such as three-phase) system. The use of Custom Power Device (CPD) is one of the most efficient methods to mitigate voltage sag or swell. Custom power device is powerful tool based on semiconductor switches concept to protect sensitive load if there is a disturbance from power line. Among the several novel CPD, Dynamic Voltage Restorer (DVR) are now being established in industrial areas to mitigate voltage disturbances on sensitive loads. In our DVR concept propose the new technique to compensate voltage by using Magnitude traction or Magnitude estimation method. Ac supply is given to the step down tap changing transformer. The output voltage from the step down tap changing transformer is compared with the reference voltage which is programed in the PIC. To correct the error between a measured process variable and a desired set point, the PIC controller is used and controller is also used for magnitude traction of supply voltage. To decrease the error signal, it is compared with a reference signal to produce sine PWM pulses. This sine PWM pulse is generated only when the difference in voltage waveform occurs. The driver circuit consists of opto coupler, transistor and driver IC act as a driver for MOSFET to provide required pulses from the Microcontroller. Solid-state semiconductor devices with turn off capability are used in inverter circuits. A VSI is energized by a stiff DC voltage supply of low impedance at the input. The output voltage is independent of load current.

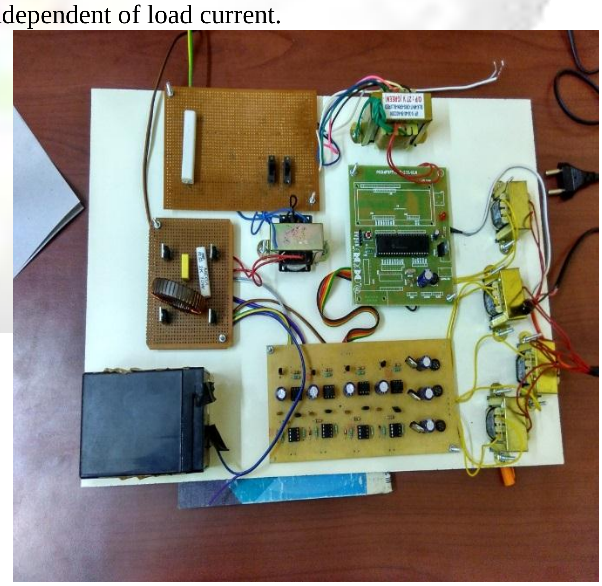

Fig. 6: Hardware implementation

The nonlinear characteristics of semiconductor devices cause distorted waveforms associated with harmonics at the inverter output. To overcome this problem and provide high quality energy supply, filter unit is used. The output voltage from filter is given to the series injection transformer. The series injection transformer is used to inject missing voltage to the load. If the input AC voltage is need not to step down means we can directly use rectifier and it converts AC to DC. The DC supply is given as input to inverter and the remaining processes are same.

VIII. RESULTS

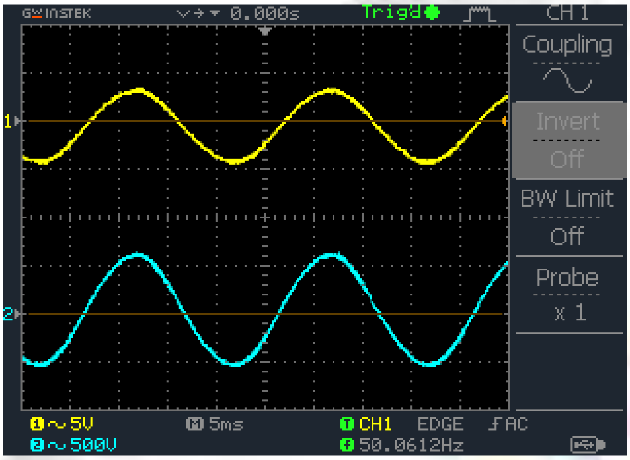

Fig. 7: Voltage sag occurs

Where green is the input voltage with sag, from our proposed method load voltage is matched with the help of series injection transformer and obtain the constant load voltage as in the above fig

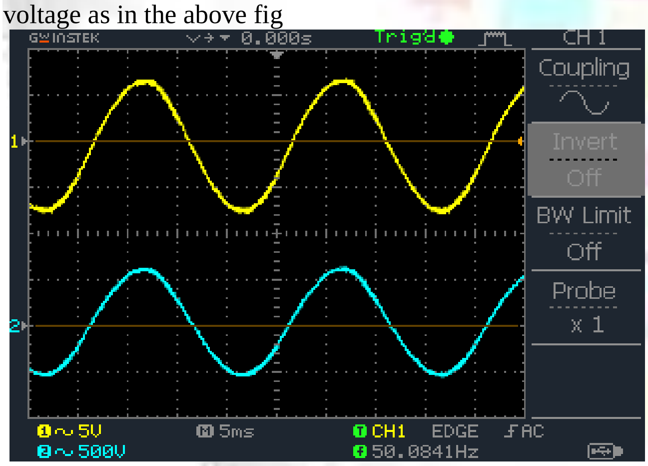

Fig. 8: Voltage swell occurs

When swell occurs our propoed method will reduce the input voltage to the required amount of load voltage and protecting the load from damage

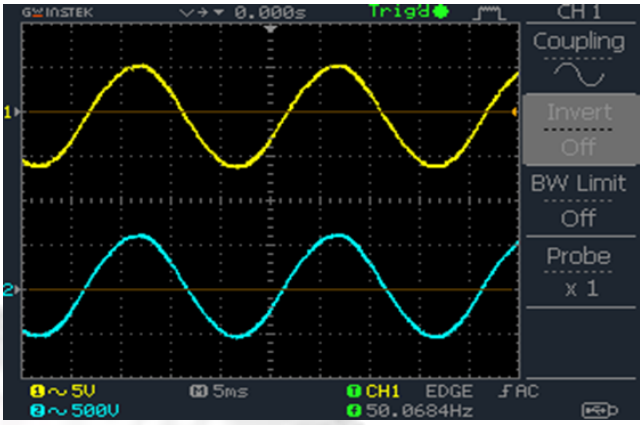

Fig. 9: Normal Voltage

When the input voltage mathe the required desired voltage. PIC sends signal to the driver and series injection transformer to connect the load without any changes

Fig. 10: Filter Output

Fig 10, filter output which will injects the required amount of voltage to the series injection transformer to meet the load voltage when sag occurs it will induce the required voltage with the supply voltage, when swell occurs it will reduce the voltage to the desired level

IX. CONCLUSION

A design and development of Dynamic Voltage Restorer (DVR) for voltage Sag and Swell compensation for improving power quality is stimulated by using MATLAB. when compared with the existing method Where Fast Mitigation of voltage sag is achieved by mathematical modeling simulation done in MATLAB as mentioned in the graphs and the proposed method is capable to compensate the power quality problems like voltage sag and voltage swell within a milliseconds. This proposed method can be used in the distribution sides to protect the sensitive loads getting damage and increase its life time.

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