

Mitigation of Voltage SAG using Dynamic Voltage Restorer

A.Praveena, M.Jayashree

Abstract—Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in failure of end use equipments. One of the major problem in power quality is voltage sag. To improve the power quality, custom power devices are used. The custom power device used here is DVR (Dynamic Voltage Restorer) is role to compensate load voltage during the different fault conditions like voltage sag, single line to ground, double line to ground faults. In this work, PI controller and discrete PWM pulse generator are used for the control purpose

Keywords—component; PWM (pulse width modulation) technic, DVR (dynamic voltage restorer), PI (proportional integral) controller

I. INTRODUCTION

The IEEE standards defines power quality as “the concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment”. Power quality may also be defined as “the measure, analysis, and improvement of bus voltage, usually a load bus voltage, to maintain that voltage to be a sinusoidal at rated voltage and frequency”.

The electric power system is considered to be composed of three functional blocks—generation, transmission and distribution. The distribution systems must deliver electric power to each customer’s premises from bulk power systems. Distribution system locates the end of power system and is connected to the customer directly, so the power quality mainly depends on distribution system. In the earlier days, the major focus for the power system reliability was on generation and transmission only as these more capital cost is involved in these.

Initially for the improvement of power quality or reliability of the system FACTS devices like static synchronous compensator (STATCOM), static asynchronous series compensator (SSSC), interline power flow controller (IPFC), and unified power flow controller (UPFC) etc are introduced. These FACTS devices are designed for the transmission system. But now a days, more attention is on the distribution system for the improvement of power quality, these devices are modified and known as custom power devices.

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The main custom power devices which are used in distribution system for power quality improvement are distribution static synchronous compensator (DSTATCOM), dynamic voltage restorer (DVR), active power filter (APF), unified power quality conditioner (UPQC) etc. Here we use the custom power device is DVR which gives 50% improvement in mitigation of voltage sag than the other devices. The dynamic voltage restorer is used with PI controller for the power quality improvement in the distribution system.

II. POWER QUALITY

Both electric utilities and end users of electric power are becoming increasingly concerned about the quality of electric power. The term power quality has become one of the most prolific buzzwords in the power industry since the late 1980s. It is an umbrella concept for a multitude of individual types of power system disturbances. The issues that fall under this umbrella are not necessarily new. What is new is that engineers are now attempting to deal with these issues using a system approach rather than handling them as individual problems.

The power quality has serious economic implications for customers, utilities and electrical equipment manufacturer. Large number industries involves increasing use of computers, microprocessors and power electronic system such as adjustable speed drives. The power electronic systems also contribute to power quality problems (generating harmonics). The impact of power quality problems is increasingly felt by customers—industrial, commercial and even residential.

III. PROBLEMS ASSOCIATED WITH POWER QUALITY

a) Transients

A transient is that a part of change in a system variable that disappears during transition from one steady state operation to another. Transient can be classified into two categories—*impulsive transients and oscillatory transients*. An impulsive transient is a sudden, non power frequency change in voltage, current etc that it is unipolar in nature. The polarity of such a transient can be either positive or negative. An oscillatory transient is a sudden, non power frequency change in the steady-state condition of voltage, current, or both that includes both positive and negative polarity values.

b) Long Duration Voltage Variations

When RMS (root mean square) deviations at power frequency last longer than one minute, then we say they are long duration voltage variations. They can be either over voltages which is greater than 1.1p.u or under a voltage which is less than 0.9p.u. Over voltage is due to switching off a load or energizing a capacitor bank. Also incorrect tap settings on transformers can result in over voltages .under voltage are the results of actions which are the reverse of events that cause over voltages i.e. switching in a load or switching off a capacitor bank.

c) Sustained Interruptions

If the supply voltage becomes zero for a period of time which is greater than one minute, then we say that it is a sustained interruption. Normally, voltage interruption lasting for more than one minute is often unending and requires human intervention to restore the supply.

d) Short Duration Voltage Variations

The short duration voltage variations are generally caused by fault conditions like single line to ground and starting of large loads such as induction motors .The voltage variations can be temporary voltage dips i.e. sag or temporary voltage rise i.e. swells or a absolute loss of voltage which is known as interruptions.

i) Voltage sags

Voltage sag is defined as the reduction of rms voltage to a value between 0.1 and 0.9p.u and lasting for duration between 0.5 cycle to 1 minute. Voltage sags are mostly caused by system faults and last for durations from 3 cycles to 30 cycles depending on the fault clearing time. It is to be noted that under-voltages (lasting over a minute) can be handled by voltage regulation equipment.

ii) Voltage swells

A voltage swell is defined as an increase to between 1.1 and 1.8p.u in rms voltage or current at the power frequency for durations from 0.5cycle to 1 minute .As with sags, swells are usually associated with system fault conditions, but they are not as common as voltage sags.

iii) Interruption

An interruption occurs when the supply voltage or current decreases to less than 0.1p.u for a period of time not exceeding 1 minute .Interruptions can be the result of power system faults, equipment failures, and control malfunctions.

IV. SOLUTION OF POWER QUALITY PROBLEMS

For the improvement of power quality there are two approaches. According to first approach the solution to the power quality problems can be done from the utility side .The first approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion.

The other solution is to install line conditioning systems that suppress the power system disturbances. In this approach the compensation device is connect to low and medium voltage

distribution system in shunt or in series. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are preferable with voltage source PWM inverters, with a dc source having a reactive element such as a capacitor.

V. NEED OF CUSTOM POWER DEVICES

Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. The electrical distribution network failures account for about 90% of the average customer interruptions. One of the major problems dealt here is power sag. Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency.

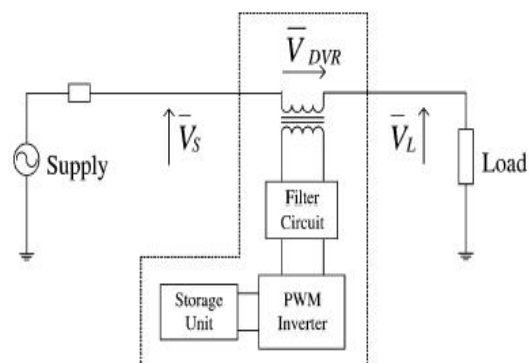
As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. A power voltage spike can damage valuable components. To solve this problem, custom power devices are used.

One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance.

VI. DYNAMIC VOLTAGE RESTORER

A power electronic converter based series compensator that can protect critical loads from all supply side disturbances other than outages is called a dynamic voltage restorer (DVR) .This device employs IGBT solid state power electronic switches in a pulse-width modulated (PWM) inverter structure. The DVR is capable of generating or absorbing independently controllable real and reactive power at its ac output terminal. Like in a DSTATCOM, the DVR is made of a solid-state dc to ac switching power converter that injected a set of three-phase ac output voltages in series and synchronism with the distribution feeder voltages.

The amplitude and phase angle of the injected voltages are variable thereby allowing control of the real and reactive power exchange between the DVR and the distribution system.



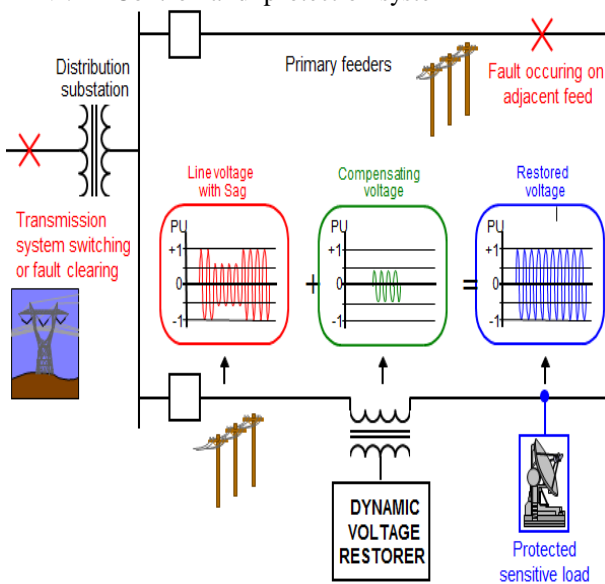
Schematic diagram of Dynamic Voltage Restorer

The dc input terminal of a DVR is connected to an energy source or an energy storage device of appropriate capacity. The reactive power exchanged between the DVR and the distribution system is internally generated by the DVR without ac passive reactive components. The real power exchanged at the DVR output ac terminal is provided by the DVR input dc terminal by an external energy source or energy storage system.

BASIC ARRANGEMENT OF DVR

The DVR mainly consist of the following components:

- i. An injection transformer
- ii. DC charging unit
- iii. Storage Devices
- iv. A voltage source Inverter(VSI)
- v. Harmonic filter
- vi. A Control and protection system



Working principles of DVR

INJECTION TRANSFORMER

Three single phase transformers are connected in series with the distribution feeder to couple the VSI (at the lower voltage level) at the higher distribution voltage level. It links the DVR system to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

DC CHARGING UNIT

The dc charging circuit is used after sag compensation event the energy source is charged again through dc charging unit. It is also used to maintain dc link voltage at the nominal dc link voltage.

VOLTAGE SOURCE INVERTER

A VSI is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. It could be a 3 phase -3 wire

VSI or 3 phase - 4 wire VSI. Either a conventional two level inverter or a three level inverter is used. For DVR application, the VSI is used to momentarily replace the supply voltage or to generate the part of the supply voltage which is absent. The function of storage devices is to supply the required energy to the VSI via a dc link for the generation of injected voltages. Here the energy storage devices are capacitor.

HARMONIC FILTER

As DVR consist of power electronic devices, the possibility of generation self harmonics is there so harmonic filter is also become a part of DVR. The main task of harmonic filter is to keep the harmonic voltage content generated by the VSI to the acceptable level.

CONTROL AND PROTECTION

A controller is also used for the proper operation of the DVR system. Load voltage is sensed and passed through a sequence analyzer. The magnitude of load voltage is compared with reference voltage. Pulse width modulated (PWM) control technique is applied for inverter switching so as to generate a three phase 50 Hz sinusoidal voltage at the load terminals. Chopping frequency is set aside in the range of a few KHz.

PI controller is used with the IGBT inverter to maintain 1p.u. voltage at the load terminals. The controller input is an actuating signal which is the difference between the V_{ref} (reference voltage) and V_{in} (actual voltage). An advantage of a proportional plus integral controller is that its integral term causes the steady-state error to be zero for a step input.

Output from the controller block is in the form of an angle that is used to establish an additional phase-lag/lead in the three-phase voltages. All protective functions of the DVR should be implemented in the software.

VII. OPERATING MODES OF DVR

The DVR is designed to inject a dynamically controlled voltage i.e. V_{DVR} , which is generated by a forced commutated converter. This voltage is injected in series to the bus voltage by means of an injection transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to remove any harmful effects of a bus fault to the load voltage V_L .

This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by a equivalent voltage generated by the converter and injected on the medium voltage level through the injection transformer. The DVR has three modes of operation which are: protection mode, standby mode, injection/boost.

In protection mode, if the current on the load side exceeds a tolerable limit due to any fault or short circuit on the load, DVR will isolate from the system. In standby mode the voltage winding of the injection transformer is short circuited through converter. In the Injection/boost mode the DVR is injecting a compensating voltage through the injection

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transformer due to the detection of a disturbance in the supply voltage.

VIII. ADVANTAGE OF PROPOSED SYSTEM

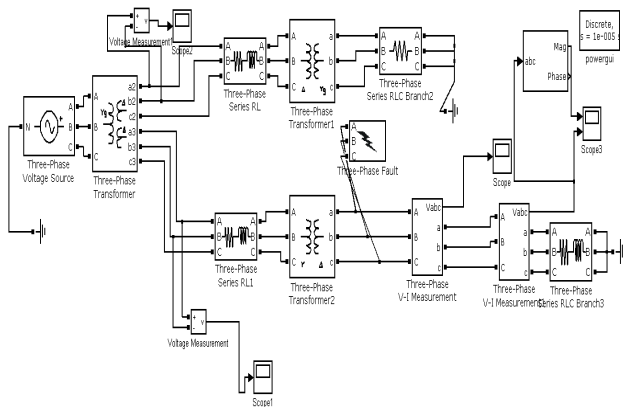
The DC Link capacitor is eliminated. The size, volume and cost of the DVR are low. Energy storage is possible even during fault occurrence. It can compensate the unbalance voltage sags and swells. It will give a guarantee that the regulated voltage can be achieved for sensitive loads.

IX. APPLICATION

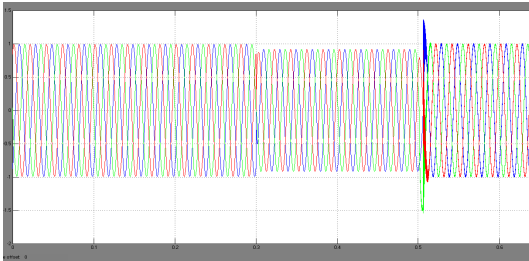
Practically, the capability of injection voltage by DVR system is 50% of nominal voltage. This allows DVRs to successfully provide protection against sags to 50% for durations of up to 0.1 seconds. Furthermore, most voltage sags rarely reach less than 50%.

X. SIMULINK RESULTS

SIMULINK MODEL FOR FAULT

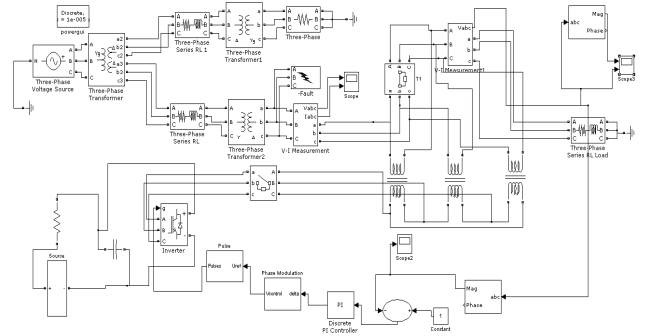


SIMULINK OUTPUT FOR FAULT

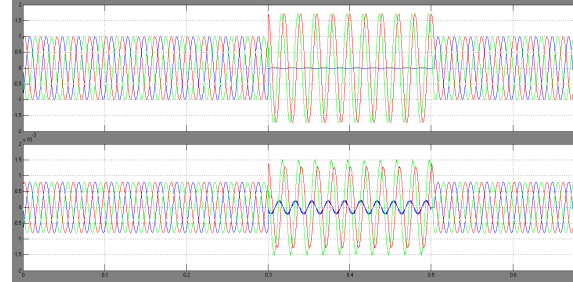


SIMULINK MODEL OF THE PROPOSED SYSTEM WITH SINGLE PHASE GROUND FAULT CONDITION

In this model a single line to ground fault has the fault resistance is 0.001 ohms and the ground resistance is 0.001 ohms. The fault time is 0.3 to 0.5s. The result of the load voltage is given



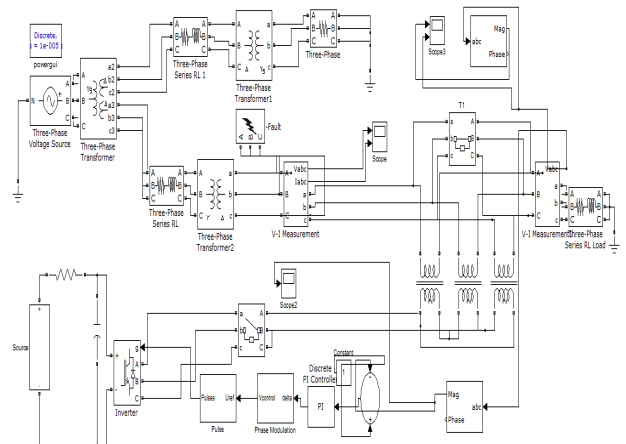
Simulink Model with single line to ground fault



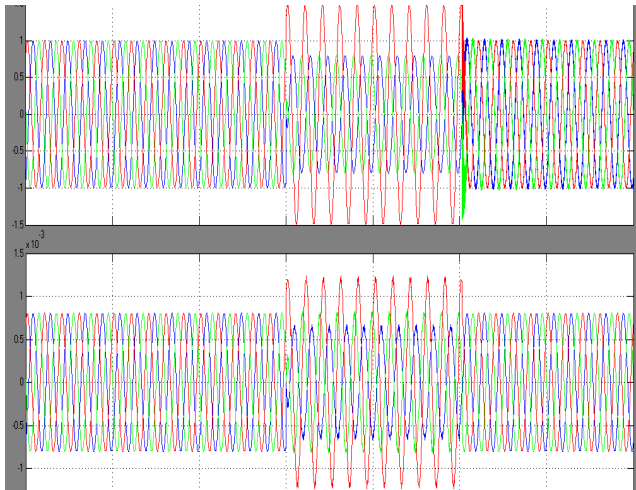
Output results for single line to ground fault

SIMULINK MODEL OF THE PROPOSED SYSTEM WITH DOUBLE LINE TO GROUND FAULT CONDITION

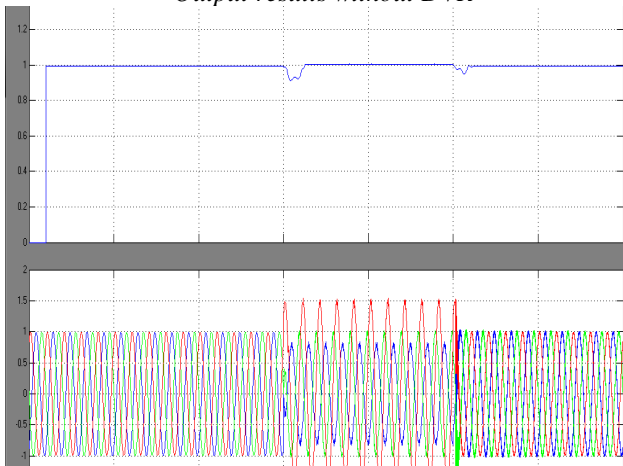
In this model a double line to ground fault has the fault resistance is .44ohms and the ground resistance is 0.001. The fault time is 0.3 to 0.5s. The result of the load voltage is given



Simulink Model with Double line to ground fault



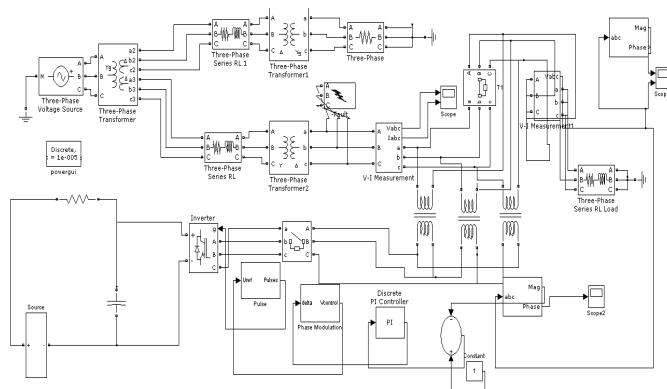
Output results without DVR



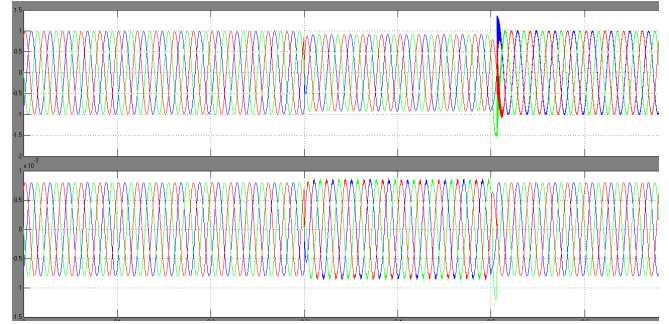
Output waveform with DVR

SIMULINK MODEL OF THE PROPOSED SYSTEM WITH TRIPLE LINE TO GROUND FAULT CONDITION

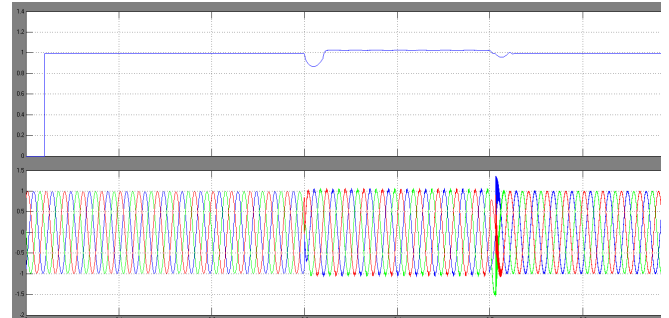
In this model a triple line to ground fault has the fault resistance is 0.44 ohms and the ground resistance is 0.001 ohms. The fault time is 0.3 to 0.5s. The result of the load voltage is given



Simulink Model with triple line to ground fault



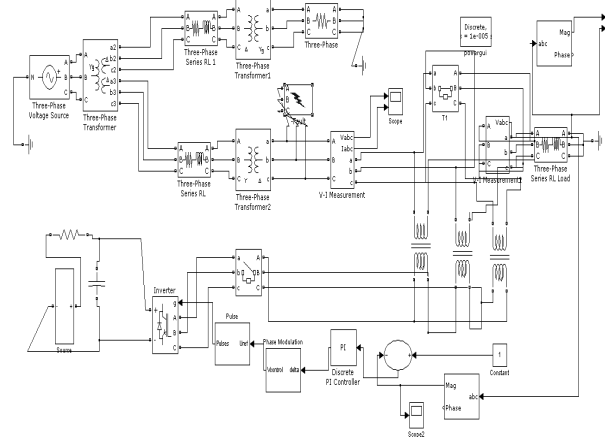
Output results for triple line to ground fault without DVR



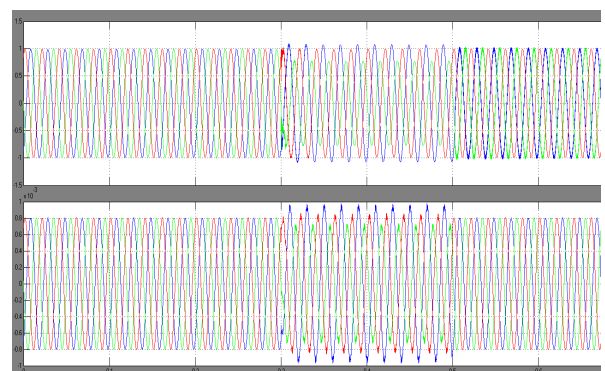
Output results for triple line to ground fault with DVR

SIMULINK MODEL OF THE PROPOSED SYSTEM WITH LINE TO LINE FAULT

In this model a line to line fault has the fault resistance 0.44 ohms. The fault time is 0.3 to 0.5s. The results of the load voltage is given by



Simulink Model with line to line fault



Output results for line to line fault

CONCLUSION

In this paper, Dynamic Voltage Restorer (DVR) is

proposed for eliminating the problem of voltage dip, swell and other voltage disturbances problem in industrial distribution system using DVR. The feed forward technique is proposed in this paper. The simulation result shows the fault clearing using DVR. From the whole it is clear from the result that, while increase in load in case of induction motor, the THD and unbalance load voltage are decreased by using DVR. The advantages of DVR using PI controller is established both for linear static load and induction motor load.

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