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POWER QUALITY IMPROVEMENT IN ELECTRICAL DISTRIBUTION SYSTEM

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Abstract : Power quality is a problem that is becoming more prevalent in industry and industrial applications. To maximize energy efficiency and productivity, modern factories use sensitive and sophisticated equipment. Voltage sags and swells in the form of voltage To solve these problems There are several custom power devices in use.
DVR or Dynamic voltage restorer is one of many devices, and it is the most powerful and reliable custom power unit. DVRs are usually wired in series between the source voltage and the sensitive load. DVR's key role is to rapidly mitigate voltage sags in the device and restore load voltage to pre-fault levels. This project shows how to model and monitor a DVR using When a three phase load is connected with the system how the voltage performs with respect to the fault that is applied and how DVR is capable of reducing those faults/sags. load is linked to the network, a proportional and integral (PI) controller is used to alleviate voltage sag swell. The simulation is supported by the result of the simulation simulink method.

Keywords : Power Quality , Voltage Sag , Dynamic Voltage restorer , Modes of Operation DVR.

INTRODUCTION

Nowadays, reliability and quality of electric power is one of the most discuss topics in power industry. There are numerous types of Quality issues and problems and each of them might have varying and diverse causes. The types of Power Quality problems that a customer may encounter

classified depending on how the voltage waveform is being distorted. There are transients, short duration variations (sags, swells and interruption), long duration variations (sustained interruptions, under voltages, over voltages), voltage imbalance, waveform distortion (dc offset, harmonics, inter harmonics, notching, and noise), voltage fluctuations and power frequency variations. Among them, three Power Quality problems have been identified to be of major concern to the customers are voltage sags, harmonics and transients. This paper is focusing on these major issues.

II. POWER QUALITY

It is often useful to think of power quality as a compatibility problem is the equipment connected to the grid compatible with the events on the grid. Compatibility problems always have at least two solutions i.e., either clean up the power, or make the equipment tougher. Both electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. Electrical PQ is the degree of any deviation from the nominal values of the voltage magnitude and frequency. PQ may also be defined as the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment. From a customer perspective, a PQ problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or misoperation of customer of equipment. describe the demarcation of the various PQ issues defined by IEEE Std. 1159-1995.

III. NECESSITY OF POWER QUALITY AUDIT

a. Newer generation load equipment with microprocessor based controls and power electronic devices are more sensitive to power quality variations.
b. Any user has increase awareness of power quality issues. Such as interruptions, sags and switching transients.
c. Many things are now interconnected in a network. Failure of any component has more consequences.
d. Power quality problem can easily cause losses in the billions of dollars. So entire new industry has grown up to analyse and correct these problems.
e. The increase in emphases on overall power efficiency has resulted in continuous growth of application. Such as high efficiency adjustable speed motor drives capacitor use for power factor correction. These results in increase harmonic level which degrade the Power quality.

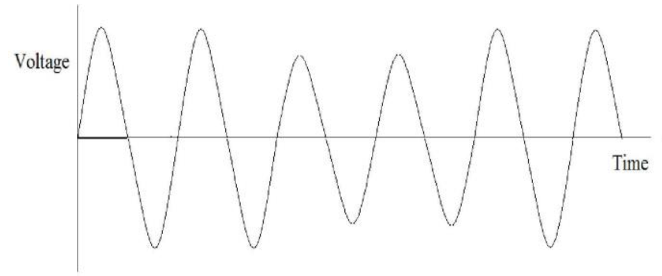
V. POWER QUALITY ISSUES

Poor PQ problems ultimately results in economic loss of the power system network. PQ mainly concerns to maintain voltage and current profile i.e. any deviation in these parameters

can cause severe damage to the electrical utility and end consumers. An overview of many PQ problems along with their causes and consequences are presented.

Voltage sag/dip:

The voltage sag or dip can be stated as decrease in nominal voltage level by 10-90% for short duration for half cycle to one minute as shown in fig.2.1. Sometime, voltage sag last for long duration such prolonged low voltage profile referred as 'under-voltage'. Voltage sag is further divided in three categories: instantaneous, momentary and temporary sags respectively.
Voltage sag are mainly caused due to occurrence of faults in power system, overloading of the electrical network and starting current drawn by heavy electrical loads like motors and refrigerators.
Voltage sag in power system network results in



failure of relays and contactor, dim light and fluctuating power.

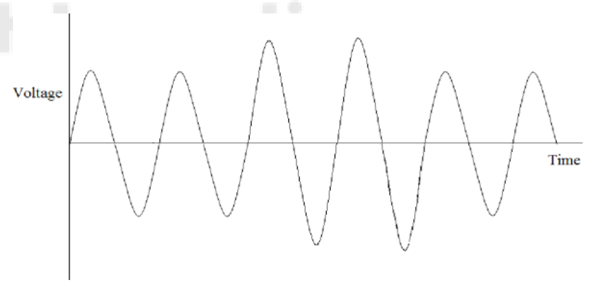
Voltage Swell:

Voltage swell can be stated as voltage rise by 10-80% of normal value for duration of half cycle to one minute as shown in fig.2.2. Likewise voltage sag, prolonged high voltage profile is referred as 'over-voltage'. Voltage swell is subdivided as:

i. Instantaneous swell
ii. Momentary swell
iii. Temporary swell

3 Voltage swell is mainly caused by disconnection of large load, Single Line to Ground fault (SLG) results in voltage rise in unfaulted phases and loose connection of neutral wire.

4 Voltage swells results in breakdown of insulation, overheating of electrical equipment and damage to electronic equipment.



Voltage Interruption:

Voltage interruption can be stated as reduction in rms voltage by below 0.1 pu of nominal orcomplete failure of supply voltage. It can be further divided into two classes based on interruption time period:

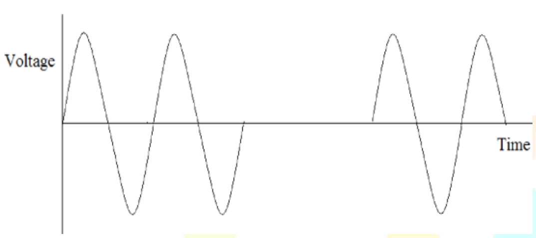
1. **Short interruption**:

   If the interruption duration occurs for few milli-seconds then it is termed as short interruption. This is due to malfunctioning of switching devices which may affect the data stored in sensitive devices like PLCs.

2. **Long interruption**:

   If the interruption duration occurs for range between few milli-seconds to several seconds then it is termed as long interruption as shown in fig.2.3.

The main cause is disconnection of electrical power system for maintenance and faults in electrical network which may result in complete stoppage of supply.



Waveform distortion:

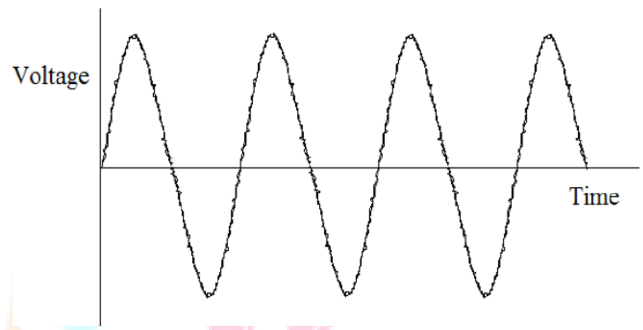
Distortion means change in original waveform shape as shown in fig.2.4. In a power system network, the voltage and current waveform should be sinusoidal in nature. Waveform distortions are due to:

1. Harmonics:

   A harmonic is an integral multiple of fundamental frequency of electrical quantities. This is due to presence of non-linear loads which results in overheating of electrical equipment. Hence its reduction is desirable.

2. Noise:

   Any unwanted signals that results in fluctuation of voltage and current signals is termedas noise. Noise is due to communication line running in parallel with power lines.



Transients:

Transients results in oscillatory response of electrical circuit. These are the momentary changes in electrical signals for short duration of time. The cause can be external, internal orboth.

It can be further categorized as:

1. Impulsive transient:

   It is an unexpected, frequency change in the steady state value of electrical signals, andthe change is unidirectional either positive or negative. This duration exist between 5μs to 50ms. They are specified by their rise & decay time and spectral content.

2. Oscillatory transient:

   It is an unexpected frequency change in the steady state value of electrical signals, andthe change is bidirectional i.e. both positive and negative polarity. This duration exist for less than50ns. Oscillatory transient is specified by the magnitude, duration and spectral content.

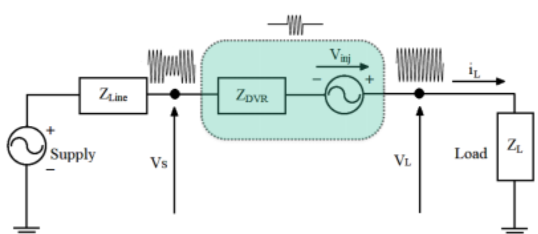
Transients are produced due to sudden switching on/off of load, loose connection and lightning stroke. This may result in overheating of motors and reduces the overall performance and shorten the lifetime of equipment.

DVR (DYNAMIC VOLTAGE REGULATOR.)

Dynamic Voltage Restorer is a custom power device which is used to mitigate the power quality issues happening in the system by the help of voltage injection circuit and controller. IN the particular circuit, the DVR subsystem consist of Voltage Injection circuit which is in the right and PI-Controller Circuit which is in the left. The Voltage Injection circuit consist of PWM Generator,2-Level inverter, Three-Phase breaker, filter Circuit, load measurement and 12-winding transformer. The Controller used here is PI-Controller with parks transformation. The Pi controller circuit consist of Discrete PLL, abc to dq0 transformation, Selector, Mux, Demuxer, dq0 to abc, constants.

VL = Vs + Vinj.

(VL is Load voltage, Vs is source/supply voltage, Vinj is Voltage Injected by DVR).



Equivalent circuit Diagram of DVR

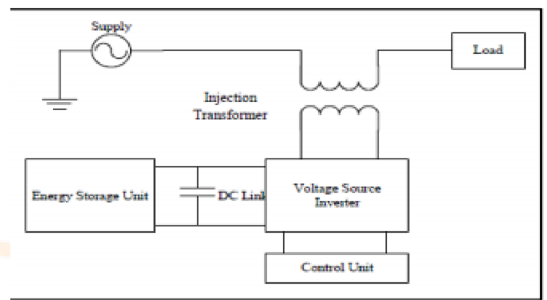
Modes of Operation Of DVR

Dynamic voltage restorer has 3 modes of operation. The modes are described as follow.

1. Protection Mode - In this mode of operation the DVR system is in protection mode with the help of the capacitors that ensure no harm to the DVR circuit from the short circuit currents or large currents and over voltage.

2. Standby Mode - In this mode of operation the DVR system is in standby mode where if doesn't come into play until the voltage problem is too high. The DVR works in a certain limit of range to mitigate the issues.

3. Injection Mode - In this mode of operation DVR plays a major role as it take the error voltage section from the supply voltage and with the help of PI controller and Voltage Injection circuit it generates the desired voltage required and feeds back the original voltage signal that's has been sent to the load.



Block diagram of DVR

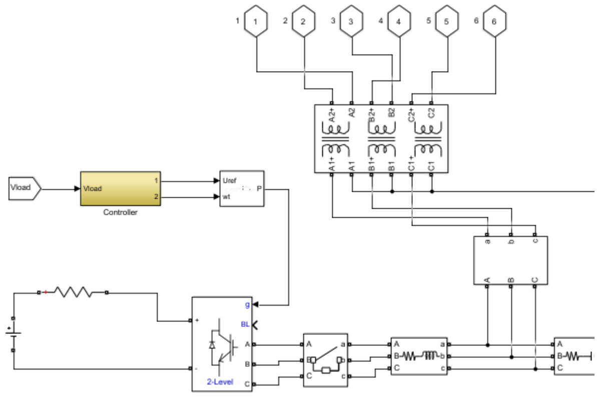
MODELLING OF DYNAMIC VOLTAGE RESTORER

COMPONENTS

1. Injection Transformer
2. Storage device
3. Voltage Source Converter
4. Harmonic Filter
5. Control and Protection System
6. Three-Phase Source
7. Three Phase Breaker

MODELLING

Figure. illustrates the DVR subsystem. The controller provides the magnitude of deficit voltage to be pumped so as to obtain the pre-fault voltage levels can be observed. The PWM generator provides the firing pulses required for switching operation of 2-level converter. The 2-level converter converts the DC voltage to AC voltage. The amount of DC voltage to be converted to AC is the deficit amount of voltage whose value is provided by the controller. Since the Switching takes place very rapidly; the waveform generated will have huge distortions. To get rid of the distortions we connect a 3-phase RLC filter in series the output of 2-level converter. Now the deficit voltage is added with help of mutual induction in the transformer. The lines namely 4, 5, 6 carry forward the pre-fault Voltage levels and connect it back to the original circuit.



DESIGN OF PROPORTIONAL INTEGRAL CONTROLLER

COMPONENTS

1. Discrete PLL
2. Selector
3. ABC to DQ0
4. MUX
5. DEMUX
6. Stair Generator
7. Under Voltage and Over Voltage Block
8. Modelling of PI Controller

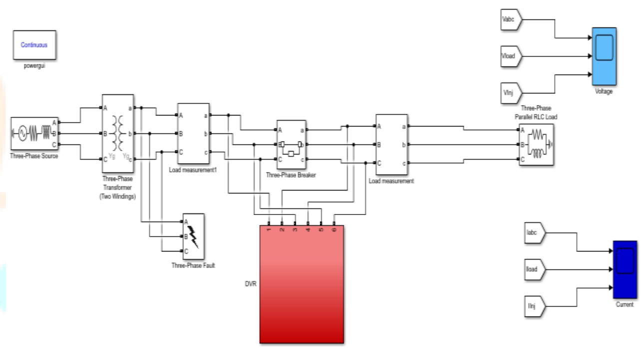
Simulation Model of SMIB System with DVR

Modelling of 11/0.4Kv System and working mechanism

General Working:

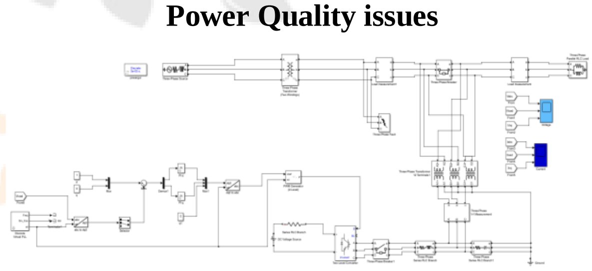
The following system consist of Three phase source which help us to supply 11Kv voltage to the circuit. Then, the voltage is fed to Three Phase Transformer with Delta to Star transformation. This act as a step-down transformer steps-down 11Kv voltage to 0.4Kv. The Load Measurement is used to check the same amount of voltage is passing to the Three Phase Parallel RLC Load. Then, the step-down voltage is passed through the Three Phase Breaker. The work of this breaker is to allow the 3-Phase Sinusoidal voltage waveform to pass when it is closed and when the breaker is opened it only allows the fault to pass.

In the above circuit the fault is included when the voltage is stepped down. The fault is applied to a particular time frame given. To compensate this fault, DVR is introduced. DVR stands for Dynamic Voltage Regulator. It is a Voltage Mitigating Device which helps to restore the voltage value that is lost due to many power quality problems such as Fault, Voltage Sag, Over-Voltage, Drop-Voltage



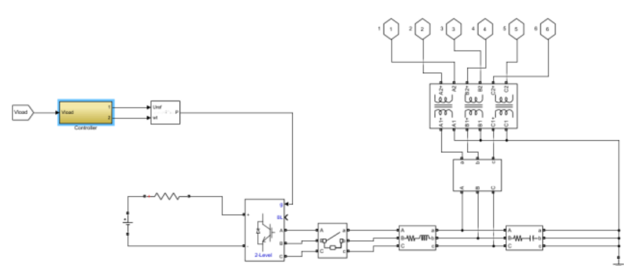
11/0.4Kv System with fault Included.

Working of DVR to Mitigate the Power Quality issues



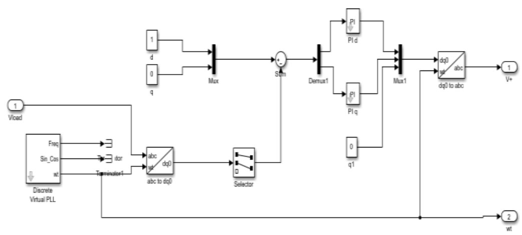
Fault Circuit with DVR system

In the particular circuit, the DVR subsystem consist of Voltage Injection circuit which is in the right and PI-Controller Circuit which is in the left. The Voltage Injection circuit consist of PWM Generator,2-Level inverter, Three-Phase breaker, filter Circuit, load measurement and 12-winding transformer.



Voltage injection Circuit (DVR)

The Controller used here is PI-Controller with parks transformation. The Pi controller circuit consist of Discrete PLL, abc to dq0 transformation, Selector, Mux, Demux, dq0 to abc, constants.



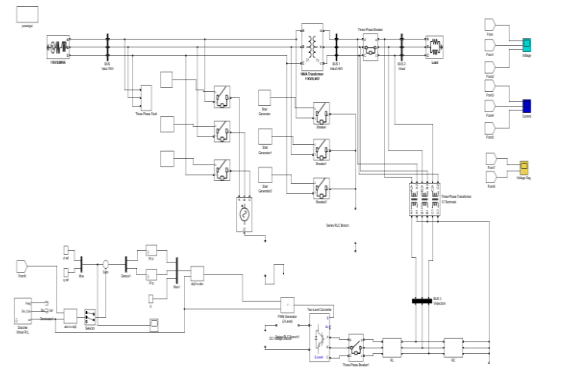
PI Controller with Parks Transformation

Working of Voltage Injection Circuit and PI Controller Circuit:

After the Fault or any other issues are included in the circuit. The section of the waveform where the issues has happened is sent to DVR input connection ports. The voltage issues has been recognized by the controller circuit. Here the controller circuit act as the parent circuit and the injection circuit act as the child circuit. The fault voltage signal is fed to abc to dq0 transform block where the Three Phase signal is converted to Two phase signal. Then the signal is passed through the selector which selects the d and q phase from the transformed signal. The dq0 transformation and Pi controller have one thing in common. They both use the reference signal and the load signal to form the resultant signal. Here the load signal is coming from the selector and the reference signal is the one which is considered with block 1 and 0. Both are summed up and the resultant is passed through the Demux. Then the resultant signal is passed through the Pi block to achieve the final gain. In the last section the resultant signal and the signal from Discrete PLL is sent through dq0 to abc transformation. The main function of Discrete PLL is to help us achieve the final waveform that is required to be injected in order to mitigate the power quality issue.

After the work of Pi controller circuit is completed. The resultant signal is sent to the PWM generator that signals the DC source through 2-Level Converter to generate the required voltage. Then the generated voltage is passed through 2-Level converter where the DC value is converted to AC value. The filter circuits are used to remove any unwanted harmonics. The voltage that has to be injected in the load signal is added into the circuit. Then the output signal is checked to verify the voltage injected is done in the right time frame, so the load is not affected.

Power Quality Issues Mitigation With DVR

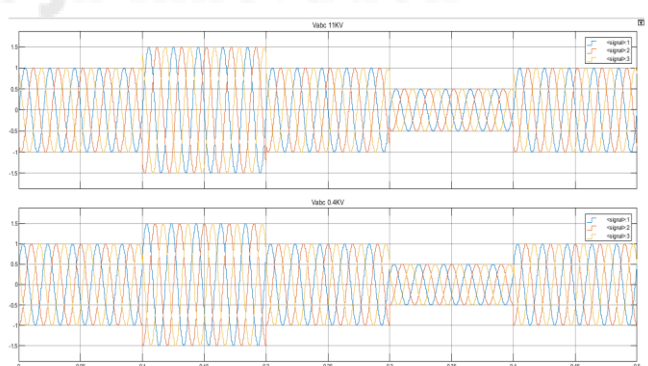


Power Quality issues with DVR

The above circuit is consist of 4 major power quality issues Fault, Voltage Sag, Over-Voltage, Drop-Voltage. This circuit is using the same DVR setup which is discussed above.

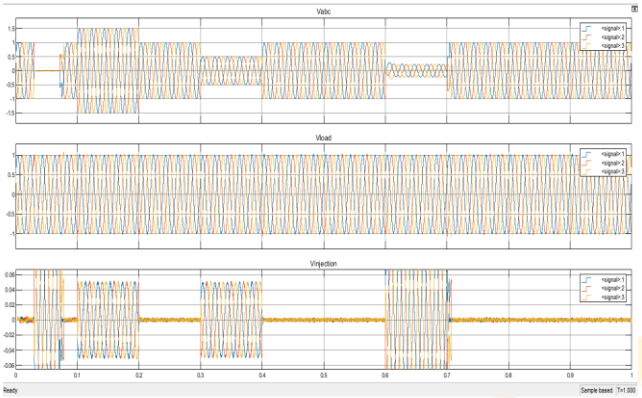
1. Three Phase fault – It is defined as the voltage value drop to 0% from its original value means the voltage is not present in that particular time frame.
2. Voltage Sag – It is defined as the power quality issue where the voltage value drop to the 90% of its original value.
3. Over-Voltage – It is defined as the power quality issue where the voltage value is 110% of its original value.
4. Drop-Voltage – It is defined as the power quality issue where the voltage value is between the voltage sag and the over voltage.

The over voltage, drop voltage and voltage sag is injected in the circuit with the help of Staircase Generator. By providing the particular time frame and the amplitude we can include these issues and check if the DVR is capable is mitigating all the issues at once. The following output graph will help to understand well.



Issue in Supply and Load Voltage

The interval between 0.03-0.07s in figure 5.7 denotes the displays the occurrence of fault, followed by overvoltage in interval 0.1-0.2 and undervoltage during 0.3-0.4. The voltage sag occurs during 0.6-0.7 interval.



Power Quality issue Mitigation

CONCLUSION

The main objective of this project is to improve the power quality issues with the help of Custom Power Devices (Dynamic Voltage Restorer). The basic introduction of the power quality and its issues are highlighted in the chapter 1 which helped to lay foundation of this project and provide insight how to tackle the issues of the power quality. This was followed by the literature review which provided the insights about the different work on the power quality and ideate phase of the project.

The implementation of the different electrical/electronic components are done. The subsystem of Dynamic Voltage Restorer is implemented which is controlled with the help of Pi controller with dq0 transformation that signals the injection of voltage in the fault section of the voltage signal. To justify the working of the 11kv system with Dynamic Voltage Restorer and Pi controller. The output graphs are taken which provide much clear insights about the normal working of the system with inclusion of any unwanted faults. The graph output made it cleared the voltage injection is done in the correct time interval.

The project has taught us about different aspects of the power quality and its importance and the different mitigation methods to mitigate the such issues in the real life which also stated a minor change in the power may lead to different issues in the load side of the system.