Power Quality Improvement by Using DVR

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Abstract-This project is about voltage sag and swell the 21st century the increasing demand of power has led to increasing complexity of load this rises the issue of power quality . power quality actually the quality of the voltage there are certain problems associated with power quality such voltage sag, swell, notch spike, transient etc .,so its necessary that power supply to load is stable and sinusoidal. Dynamic voltage restorer is such a device which is used to control voltage waveform and provide stable voltage output.

Keywords-Dynamic Voltage Restorer ,Voltage source converters, voltage sag ,voltage swells.

INTRODUCTION

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices very sensitive to disturbances and become very less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

The power solution to the voltage regulation is the use of a Dynamic Voltage Restorer (DVR).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 voltage sags / swells. The DVR applications are mainly for sensitive loads that may be drastically effected by fluctuations in system voltage.

POWER QUALITY PROBLEMS

Sources and effects of power quality problems

Power distribution systems ideally should provide their customers with an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice power systems especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing may power quality problems.

While power disturbances occurs on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality power supply. For some sensitive devices, a momentary disturbances can cause scramble data, interrupted communications ,a frozen mouse system crashes and equipment failure etc.

Power quality issues

Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

Voltage sag: Voltage sag can occur at any instant of time, with amplitudes ranging from 10-90% and a duration lasting for half a cycle to one minute.

Voltage swell: Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

Voltage transients: They are temporary undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (upto 20KV) that last for a very short time.

Harmonics:

The fundamental frequency of the AC electric power distribution system is 50Hz.A harmonic is a any sinusoidal frequency, which is the multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

Causes of dips, sags and surges:

1.Rural location power from remote source

2.Unbalanced load on a three phase system

3.Switching of heavy loads

4.Long distance from a distribution transformer with interposed loads

5.Unreliable grid systems

Causes of transients and spikes:

1.Lightening

2.Arc welding

3.Switching on heavy equipments such as motors, transformers ,motor drives

4.Electric grade switching

DYNAMIC VOLTAGE RESTORER

Among the power quality problems voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently.

One of those devices is the DVR which is the most efficient and effective modern custom power devices used in power distribution networks.

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling(PCC).

Other than voltage sags and swells compensation. DVR can also other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations. Dynamic Voltage Restorer diagram shown in fig1.

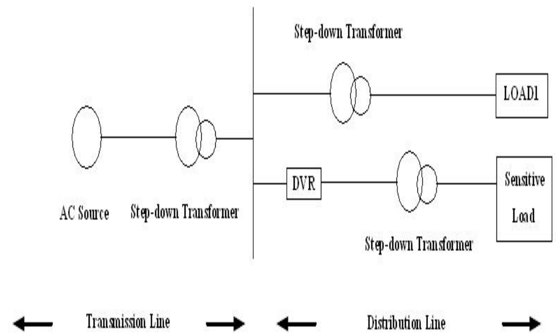

Fig1. Location of DVR

Block Diagram of DVR

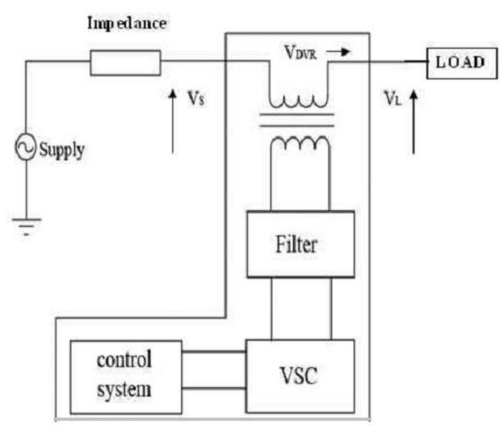

Fig 2 Block Diagram of DVR

Basic configurations of DVR:

The general configuration of the DVR consists of:

1.An injection transforrmer

2.A harmonic filter

3.Storage device

4.A voltage source converter(VSC)

5.DC charging circuit

6.A control and protection system

Injection Transformer:

The Injection transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from primary side to the secondary side. The main tasks are:

It connects the DVR 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.

In addition ,the injection transformer serves the purpose of isolating the load from the system.

Harmonic Filter:

The main task of the harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

Voltage Source Converter:

A VSC is a power electronic system consists of storage device and the switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude and phase angle. In the DVR application, VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing.

The purpose of storage device is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages.

DC Charging Circuit:

The dc charging circuit has two main tasks. The first task is to charge the energy source after a sag compensation event.2The second task is to maintain dc link voltage at the normal dc link voltage.

Control and protection:

The control mechanism of the general configuration typically consists of hardware with programmable logic. All protective functions of the DVR should be implemented in the software. Differential current protection of the transformer, or short circuit current on the customer load side are only.

DVR Operating Modes

During the voltage sag/swell in the line:

The DVR injects the difference between the pre-sag and the sag voltage, by supplying the real power requirement from the energy storage device together with the reactive power. The maximum injection capability of the DVR is limited by the ratings of the dc energy storage and the voltage injection transformer ratio. In the case three single phase DVRs the magnitude of the injected voltage can be controlled individually.

During the normal operation:

As the network working under the normal condition the DVR is not injected any voltages to the system. In that case, if the energy storage device is fully charged than the DVR operates in the stand by mode otherwise it operates in the self charging mode .The energy storage device can be charged either from the power supply itself or from a different source.

During a short circuit in the distribution line:

In this particular case the by-pass switch is activated to provide an alternate path for the fault currents. Hence the inverter protected from the flow of high fault current through it, which can damage the sensitive power electronic components.

DVR Compensation Techniques:

Pre-sag compensation:

This compensation approach is suggested for the non-linear loads which requires both the voltage magnitude as well as the phase angle to be compensated. In this technique the DVR supplies the difference between the pre-sag and the sag voltage ,thus restore the magnitude and the phase angle to that the pre-sag value diagram is shown in fig 3.

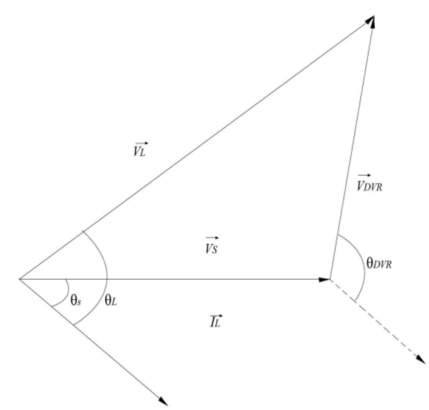

Fig 3 Pre-Sag Compensation

In-phase compensation:

The DVR compensates only for the voltage magnitude in this particular compensation method ,i.e.

the compensated voltage is in-phase with the sagged voltage and only compensating for the voltage magnitude. Therefore this technique minimizes the voltage injected by the DVR Hence it is recommended for the linear loads, which need to be compensated for the phase angle. In-phase compensation diagram is shown in fig 4.

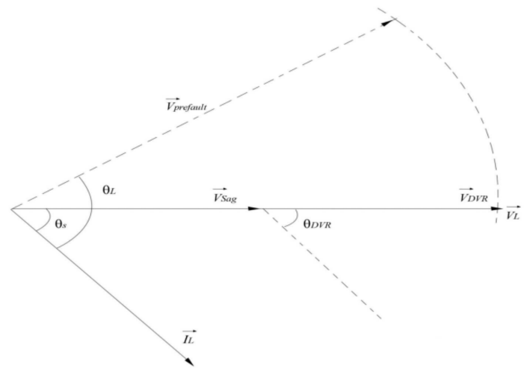

Fig 3 In-phase Compensation

Energy optimization technique:

In this particular control technique the use of real power is minimized by injecting the required voltage by the DVR at a 90 degree phase angle to the load current. However in this technique the injected voltage will become higher than that of the in-phase compensation technique. Hence this technique needs a higher rated transformer and an inverter, compared with the earlier cases.

Circuit Diagram

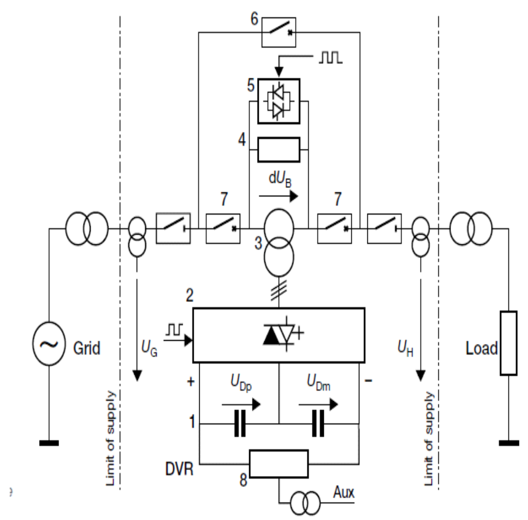

Fig 4 Circuit Diagram

Single-line diagram of the power quality device
1- DC link with capacitor bank
2- Voltage source converter
3- Booster transformer
4- Damped highpass filter
5- Crowbar
6- Bypass switch
7- Isolation switches
8- Charging unit
UG -Grid voltage
UH -Load voltage
UDp- DC link voltage, positive charge relative to midpoint
UDm -DC link voltage, negative charge relative to midpoint
dUB -Inserted, sag compensating voltage

The basic module is a phase leg for three-level, neutral-point-clamped converters. These modules can be combined to build different converter configurations and high-power DC-DC choppers. Such a platform, together with matching signal interfaces and a versatile, easily programmable control system, provides the very high level of flexibility and adaptability necessary to build units for a wide range of applications without having to make any basic changes to the design.

The active switching elements used are Integrated Gate Commutated Thyristor (IGCTs) – a kind of advanced Gate Turn Off Thyristor (GTO). Compared with GTOs, IGCTs have the advantage of lower conduction and switching losses, plus much better switch-off characteristics, allowing a snobberies converter design.

What set this contract apart from earlier ones was the amount of energy to be stored in the DC link capacitor bank, which serves as the energy storage device. The challenge here was not so much the amount of energy itself but rather the need to design the equipment such that no kind of internal fault – eg, a faulty capacitor unit, short circuit or fault in the converter – could cause any damage to it besides the failed component which had instigated the fault. This task is not at all trivial since during operation of the device (when a voltage sag has to be compensated) the current taken from the capacitor bank is not low and any current-limiting devices would have a detrimental effect if the current is too low, or even interrupted, as a result of its action. A reasonable solution was found to be to split the capacitor bank into two separate groups and to place a combination of damping resistors and fuses in strategically selected locations.

The power quality device:

A single-line diagram of the PQ device is shown in . The main components of the power circuit and their functions are:

DC link with capacitor bank(1)-This also serves as the energy storage medium.

Voltage Source Converter(2)-For voltage sag compensation. It consists of two NPC phase legs per phase. The active switching elements are IGCTs.

Booster Transformer(3)-Which acts as the interface between the feeder phases and the voltage source converter.

Damped High Pass Filter(4)-Connected across the line-side terminals of the booster transformer. It helps to 'clean' the shape of the injected voltage by 'short-circuiting' the residual higher-frequency harmonics. Thus, the voltage that both the load and the power grid 'sees' is virtually ripple-free.

Crowbar(5)-Consisting of controlled thyristors that bridge (ie, short-circuit) the line-side terminals of the booster transformer in the event of an internal device fault or a fault downstream (on the load-side) of the device. The latter function, is particularly valuable as a means of avoiding interference with existing protection schemes.

By-pass Switch(6)-This allows the entire device to be bypassed.

Isolation Switches(7)-For isolating the device when the bypass switch is closed for maintenance purposes, ie without having to interrupt the feeder line.

Charging Unit(8)-For charging the DC link capacitor bank prior to putting the device into operation and for recharging the capacitors after a voltage sag compensating operation.

An impression of the physical layout and arrangement of the DVR's main components is given in . By completely installing, wiring and testing the units in the factory prior to shipment, on-site installation time is reduced to a minimum and the time needed for commissioning is also significantly reduced.

Control and monitoring

The control system – the nerve center of the DVR – has to respond extremely fast and also be very reliable. The modulator and all converter related interlocking and monitoring functions require a very fast processing speed (ie, very short cycle times). They are therefore implemented on a special board equipped with an EPLD (Electrical Programmable Logic Device) and several digital signal processors. Apart from some minor modifications it is the same standard board that ABB uses to control its ACS family of medium-voltage drives.

The higher-level control is executed by ABB's PSR system (Programmable High Speed Controller), which ensures not only a very high degree of flexibility but also easy application-specific adaptation and modifications. A third, PC-based system serves as the operator control interface and is also used to monitor the operation and operating performance of the power quality device. Use is made of advanced communication technology.

In the event of an internal disturbance within the device, an e-mail describing the problem is generated and sent to preset addresses. Personnel authorized to access the system can supervise the controls from practically any location in the world, and if necessary change parameters or modify the program. This built-in, remote trouble-shooting capability is a key system feature.

Operating performance:

The design and manufacturing phases of the project were accompanied by computer (software) simulations and by tests carried out on a hardware simulator. Software simulations were used to verify the design parameters and component specifications as well as the control algorithms and their parameter settings. The entire control system was later tested on a hardware simulator to confirm that the control software and hardware, including the I/O ports, had been correctly configured and were working properly from a recording in the actual installation when a genuine voltage sag of similar magnitude took place shortly after commissioning. If the device had not been in operation, such a voltage sag would have had a negative impact on production. It can also be seen that the voltage compensation takes place extremely quickly, ie in less than one millisecond, which is faster than is actually needed or specified. This is made possible by the unique feed-forward control used for this kind of application. It almost completely does away with the delay and settling time that would be unavoidable if a more conventional control algorithm were used. Last but not least, it has to be emphasized that the specifications were considered as guidelines and minimum requirements for the devices. The sag compensation, for example, is not limited. the specified value. If a three-phase sag happens to be larger than 35% it will still be compensated – not for 500 ms, but for as long as the energy storing capacitor bank can supply the power. And if the sag is smaller, the system provides protection for up to 600 ms, so that many consecutive voltage sags are compensated.

In addition, the nominal DC link voltage is lower than its maximum permissible value, so the DC capacitor bank can also absorb a certain amount of energy. This enables not only voltage sags to be compensated but also some temporary over voltages (voltage swells) as well.

A short dip in the supply voltage, unnoticed by the majority of electricity consumers, can still stop an entire production line in highly sensitive industries, such as computer chip manufacturing, oil refining and textiles.

Severe climatic conditions often can cause the total interruption of an electric power supply for hours, rendering entire production lots useless. it has developed and successfully introduced systems to overcome such obstacles by means of advanced power electronics. These power quality systems stand out for their reliability and for their responsiveness to voltage disturbances.

The Dynamic Voltage Restorer (DVR) is the optimal solution for most customers who want protection against the bulk of these disturbances – voltage sags and swells resulting from remote system faults. A DVR compensates such voltage excursions almost immediately providing the supply grid is not disconnected entirely by upstream breaker trips.

CONTROL CIRCUIT:

In DVR the control circuit is used to derive the parameters such as magnitude, frequency, phase shift etc. Control of compensating device is implemented in 3 steps, detection of voltage sag/swell occasion in the system, comparison with reference value and generation of gate pulses to the VSI to generate the DVR output voltages which will compensate the voltage sag/swell.

Sag/Swell Detection Techniques:

The accurate detection and classification of disturbances can help in taking effective countermeasure(s) to maintain adequate power quality. To detect the voltage sag, the starting point and the ending point of sag, depth of sag and phase shift, information are required. There are some detection techniques which are summarized below.

Fourier Transform (FT) method:

To achieve the FT we use the orthogonal decomposition of power system signal. When we apply the FT to each supply phase, it is possible to get the magnitude and phase of each of the frequency components of the supply waveform. The demerit of FT is that it takes one complete cycle to give the accurate information about the sag depth and its phase. The realization in real time control is possible.

Phase Locked Loop (PLL) method:

PLL is applied to each supply phase independently and is tuned to respond to phase jumps in the supply quickly. In this method it is required to freeze the pre-sag magnitude and phase. The PLL generates the voltage in same phase with the supply voltage. It takes time delay up to half cycle. The implementation in real time control system is more difficult`

Peak value detection method:

Peak detection method is the very simplest method to observe the crest of the supply voltage. In this we find the point where the gradient of supply voltage phases is zero, and then we compare the supply value at that instant with a reference value and sense the sag. A controller could be set to distinguish if there is a deviation greater than a specified value. This method provides the information of sag depth, start and end time, although to extract phase shift information is difficult since a reference waveform is required. The drawback of this method is that it can take up to half a cycle for the sag depth information to become available.

Root mean square (RMS) method:

It detects the start and end points of sag/swell. RMS value detection is an accurate way to detect the voltage sag or interruption, but it does not give phase angle shift information. It takes more time to calculate the RMS value

Space Vector control :

This method gives the both voltage magnitude and angle shift information. Three phase voltages V_a, V_b, Vc are transformed into a two dimension voltage V_d, Vq which in turn can be transformed into magnitude and phase angle. It is faster but requires complex controller. This can be easily realized in real time control system.

MATLAB/SIMULINK

Simulation of dynamic voltage restorer

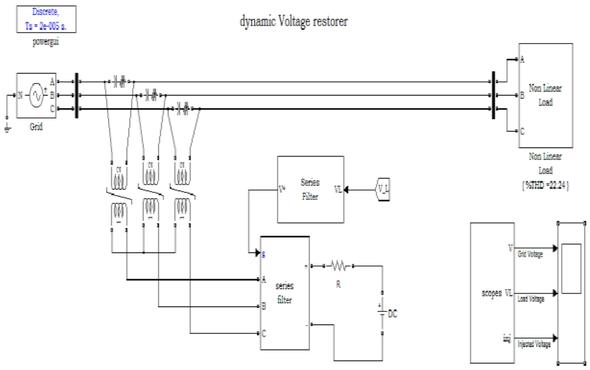

Fig 5 Simulation Diagram of dynamic voltage restorer

Figure 5 shows the rms voltage at load point when the system operates with no DVR and a three phase fault is applied to the system. When the DVR is in operation the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition.

Simulation Output

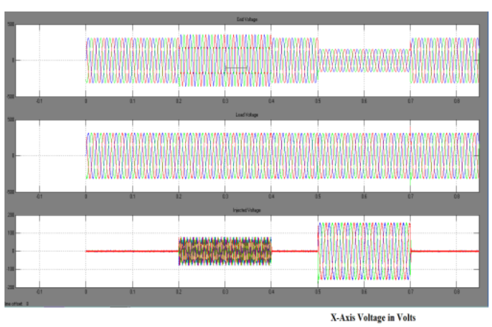

Fig 6 Simulation Output

CONCLUSION

Power quality devices with DVR functionality are not indented , to replace uninterruptable power supplies. However, they offer excellent protection for complex manufacturing processes against most disturbances occurring in power grids. hey are also very rugged and reliable and capable of extremely fast response plus they require practically no maintenance. And they can built with relatively high ratings they can employed across industry not only to protect individual production lines but also entire factories or industrial parks .Just as importantly they do not interfere with exisiting protection schemes by limiting fault currents when fault occur in downstream .

REFERENCES

- Benachaiba C, Ferdi B, "Voltage Quality Improvement using DVR", *electric power quality and utilization journal*, 2008.
- Bhaskar M, Dash S S, Subramani C, Jagdeesh M, Giresh P R, Varun M, "Voltage Quality Improvement using DVR",*International conference on recent trends in information, telecommunication and computing IEEE*, 2010.
- Buxton R, "Protection from voltage dips with the dynamic voltage restorer", *In IEE Half Day Colloquium on Dynamic Voltage Restorers — Replacing Those Missing Cycles*, 1998, pp.3/1–3/6.
- Chen S, Joos G, Lopes L, Guo W, "A nonlinear control method of dynamic voltage restorers", *In IEEE 33rd Annual Power Electronics Specialists Conference*, 2002, pp. 88–93.
- Chan K, "Technical and Performance Aspects of a Dynamic Voltage Restorer", *In IEE Half Day Colloquium on Dynamic Voltage Restorers—Replacing Those Missing Cycles*, 1998, pp.5/1–525
- Hingorani N G, "Introducing Custom Power", *IEEE Spectrum*, 1995 pp. 4l–48.IEEE standards board, "IEEE Std. 1159–1995: IEEE Recommended Practice for Monitoring Electric Power Quality", *IEEE Inc. new york*, 1995 .[3]
- Li, B H, Choi S S, Vilathgamuwa D M, "Design considerations on the line-side filter used in the dynamic voltage restorer", *IEE Proceedings Generation, Transmission, and Distribution*, 2001, pp. 1–7.
- McHattie R, "Dynamic Voltage Restorer the Customer's Perspective", *In IEE Colloquium on Dynamic Voltage Restorer—Replacing Those Missing Cycles*,1998, pp. 1/1–1/5.
- Middlekauff S W, Collins E R, "System and Customer Impact Considerations for Series Custom Power Devices", *IEEE Transactions on Power Delivery*, 1998,pp. 278-282.
- Nielsen J G, Newman M, Nielsen H, Blaabjerg F, "Control and testing of a dynamic voltage restorer (DVR) at medium voltage level", *Power Electronics IEEE Transactions* , 2004, pp.806–813.
- Nielsen J G, Blaabjerg F, " A detailed Comparison of system Topologies for Dynamic Voltage Restorer", *IEEE*

Transactions on Industry Application, 2005, pp.1272-1280.

- Snge k, Choi S S, Vilathgamuwa M "Analysis of Series Compensation and DC-Link Voltage Controls of a Transformer less Self- Charging Dynamic Voltage Restorer", *IEEE Transactions on Power Delivery*, 2004, pp. 1511–1518.