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Voltage sag detection and control using Dynamic Voltage Restorer (DVR): A Review

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ABSTRACT

With the increase in the number of electronic loads, also known as sensitive loads the consideration of power quality has increased rapidly. With many latest technological advancements, the quality of power that comes to the consumer becomes a necessary requirement. Various researches are going on to use the flexible AC transmission system devices at the consumer ends also known as custom power devices to improve the power quality. This paper discusses the various aspects of designing a Dynamic Voltage Restorer (DVR) to be used to protect the sensitive loads from faults which causes voltage sag problems.various algorithms of voltage sag detection and generation of compensating voltage are being discussed.

Keywords: custom power devices,dynamic voltage restorer, voltage sag, power quality problem, sag detection algorithms

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I. INTRODUCTION

The concept of using power electronic FACT devices in the distribution system was Introduced by N.G.Hingorani [1]. FACT devices in the transmission system improve the reliability of power by enhancing the power transfer capability. The FACT devices when used in a distribution system is termed as Custom power devices. It improves the quality of power which is obtained at the load side to the customer. The quality of power that reaches the customer side is judged by the following specification of power:

Magnitude and duration of overvoltage and Undervoltage that occurs due to the disturbances.

1. The low value of total harmonic distortion.
2. Low unbalancing of phase voltages and currents.
3. The low value of voltage flicker.
4. No violation of limit in the frequency of the supply.

Basically there are three types of custom power devices that can be connected at the load side for improving the power quality. These custom power devices can be connected individually or by some combinations to improve power quality. The three types of custom power devices are:

1. Shunt connected custom power devices to improve current quality
2. Series connected custom power devices to improve voltage quality.
3. Current breaking devices for doing static compensation.

In this paper briefing of a series connected custom power devices called Dynamic Voltage Restorer is done which is used to improve the voltage quality of the supply power. Dynamic voltage restorer is connected in series via an injecting transformer which is used to do the voltage compensation at the customer side supply. The use of dynamic voltage restorer to eliminate short duration voltage variations is discussed along with their various connection and control strategies.

Short duration voltage variation

Variations in supply voltage for a very small interval of time (less than one minute) are known as short duration voltage variation. These variations generally occur due to faults or energization of large loads wich require large inrush currents. Short duration voltage variations are of three types voltage sag, voltage swell, and interruptions. These short duration voltage variations can be better understood in figure 1.

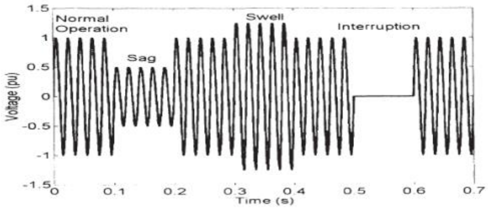

Fig 1 Short duration voltage variation

The decrease in supply voltage for a value less than 1 p.u for few seconds is known as voltage sag whereas the increase in supply voltage for value more than 1 p.u is known as voltage swell. Falling of voltage to 0 p.u for few seconds is known as voltage interruptions. The severity of voltage sag, voltage swell, and voltage interruptions depends on the location of fault that occurred in the system or the location of the equipment to be energized which requires large inrush current. These small duration voltage variations have very low effects on large loads but they are having very serious effect on sensitive loads, generally, those loads which are having digital circuits like computers, televisions, etc. In today's world, most of the loads are sensitive loads and these loads are ever-increasing so it is very much necessary to eliminate these problems. Using dynamic voltage restorer to eliminate these problems is discussed in the next section.

Dynamic Voltage Restorer

Dynamic voltage restorer is used to protecting sensitive loads in the distribution system against small duration voltage variation like sag/swell. The general idea of how a DVR can be used to protect the sensitive load can be explained in figure 2.

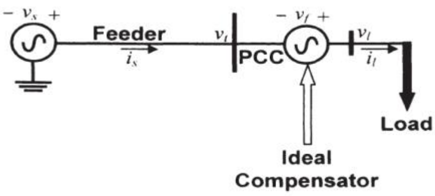

Fig 2 Ideal DVR compensation sensitive load

As seen from the figure DVR is acting like an ideal voltage source that injects a voltage vf in such a manner that it adds up with the supply voltage vs and comes to the load thus the equation becomes: Vs+vf=vl

The DVR has the capability to regulate load voltage by calculating the load voltage and compensating voltage vf which is required to maintain the load voltage level vL to 1 p.u. The current Is and IL have some value but the phase angle between load current Il and load voltage vl depends on the load power factor. For no real power or reactive power injection, the positive sequence fundamental frequency component of load voltage must be in quadrature with the positive sequence fundamental frequency component of load current.

In general, a DVR consists of three parts measuring unit, control, Power circuit.

The measuring unit provides voltage and current measurements. The outputs are voltage and current signals (V, I), which enter the control unit. Then a voltage sags detection algorithm is used to detect the voltage sag. The control unit then calculates the compensating voltage calculation Vcom, which is the voltage needed to be injected into the system in order to maintain the load side voltage of the purely sinusoidal waveform. The power section consists of a voltage source converter (VSC) equipped with an LC filter to smooth the output voltage, a DC energy storage, and an injection transformer (TR) – booster. The basic principle of DVR function is to inject or draw the compensating voltage Vinj to or from the supply voltage Vs in order to mitigate voltage sags or swells on the load side Vload. At every moment the control algorithm compares the desired voltage and actual measured voltage. The difference between these two signals is considered as a compensating voltage signal (control signal) Vcom, which is directly proportional to compensating voltage Vinj (power circuit). The VSC converts DC energy stored in a battery to injecting AC voltage that is to be superimposed to the source voltage. DVR power output depends on the amount of energy that can be stored in the energy storage unit.

Voltage sag detection algorithms

- In DVR the whole compensation is occurring immediately in the real-time just after the fault with no delay. Thus the DVR must be able to detect the voltage sags as soon as possible to improve the power quality. There are various voltage sag detection algorithms that are present in the literature:
- Peak voltage detection method: whenever the voltage sag/ swell is occurring in the system then the peak value or amplitude of the load voltage is varied. During voltage sag, the peak value becomes less than 1 P.u and during the voltage swell the peak value becomes more than 1 p.u. This change in peak value is used to detect the voltage sag/swell in this algorithm.
- Missing voltage method: In this method, the load voltage is compared with a present value of peak. When the peak of the load voltage is more than preset value then the comparator output is non zero but when the peak is lesser than preset value then the comparator output is zero. Thus there is a missing

voltage during the sag and could be fruitful in voltage sag detection.

- RMS Method: In this method, the RMS value of the load voltage is continuously monitored. During the voltage sg or swell there is a change in RMS value by which the fault is detected.
- Discrete Fourier transform: in discrete Fourier transform detection the fundamental value of the load voltage is continuously monitored. Along with that, some other frequency component is also monitored. During a fault, the value of the fundamental component decreases while the non-fundamental component increases. So by obtaining and monitoring various components the voltage sag/ swell is detected.
- DQ transformation: In the DQ transformation method the three-phase load voltage is converted into the Dqo reference frame. The Dqo axis is the sinusoidal varying reference frames with the same angular speed as the three load voltages. A phase-locked loop is used so as maintain the rotation in phase with the source voltage. The load voltage and the reference voltage are converted into the Dqo system with a phase-locked loop along with the source voltage. The difference in the Dqo value of the load voltage and the reference voltage can detect the fault and also it generated the compensating voltage required. The obtained compensating voltage is used as a reference signal for the power circuit and it injects or draws the necessary voltage to maintain the load voltage to be sinusoidal.

The Dqo transformation is carried as follows:

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\omega t & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin(\omega t + \frac{2\pi}{3} \\ \cos\omega t & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

II. RESULT AND CONCLUSION

Use of Dynamic Voltage Restorer for protection of the sensitive load and to increase the power quality is being discussed along with hat various sag detection algorithms have been discussed and implementation technique is proposed.

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