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An Overview on SVPWM Control Technique used in DVR

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***Abstract* –Good quality of power is must requirement for consumers as the use of sensitive and electronic loads and devices are increased. Voltage sag and swell is very severe problem for industry consumer. There is various ways to compensate these problems, for protecting these devices, and load etc. from power quality problems like voltage sag and voltage swell Dynamic Voltage Restorer (DVR) is mostly used. This paper discusses the operating principle of DVR, basic component, SVPWM control techniques used for controlling inverter.**

Key Words – DVR, Park's Transformation and SVPWM.

I. INRODUCTION

Electrical power system includes generation, transmission and distribution system. Average customer power interruption is of 90% because of the failure distribution system [1]. Modern human life totally depends on electricity supply. The use of sensitive equipment, solid state switching devices, nonlinear and electronic load causes to power quality problems. Power quality problem includes voltage sag, voltage swell, noise, voltage unbalance and voltage flicker. Most of the power quality problems are related to the voltage. Such voltage quality problem affects the life of sensitive equipment, reliability, energy efficiency and causes the equipment to malfunction. Most of consumers use the uninterruptible power supply but it is not economical good solution over voltage quality problems. This paper discusses overview on mitigation of voltage sag and voltage swell. To overcome power quality problems Mr. N.G.Hingorani has proposed the Custom Power Devices (CPD). Distribution static synchronous compensators (DSTATCOM), dynamic voltage restorer (DVR), active filters (AF), unified power quality conditioner (UPQC) are the main custom power devices used in distribution system. DVR is the best device from CPD to overcome voltage sag and swell problem [5] [6].

Voltage sag is defined as the dip in rms voltage ranging from 0.1p.u. to 0.9p.u. lasting for half cycle to one minute. Voltage swell is defined as increase in rms voltage from 1.1 p.u. to 1.8 p.u. for a period of 0.5 to 1 minute. Voltage sag causes due to the system faults and switching of inductive loads. It presents for few cycles depends on fault clearing time [7].

II. DYNAMIC VOLTAGE RESTORER

Dynamic Voltage Restorer was built in U.S. by Westinghouse in 1996. Dynamic voltage restorer is used to eliminate voltage sag and swell. It is a series connected voltage source converted based device. It is also referred as Static Series Compensator (SSC). Main function of the DVR is to maintain the load voltage constant by injecting required voltage for mitigating sag and swell. DVR is preferred as it controls the active power flow and having higher energy capacity even small in size and cost is less compared to CPD. It is used for harmonic and power factor correction also [4].

Main function of DVR is to inject required voltage for maintaining desired load voltage. For that purpose a reference voltage waveform is created which is similar to that of supply voltage. By comparing the reference and actual voltage form DVR can detect abnormalities in the waveform. DVR is controlled voltage source converter. Compensation capacity of DVR depends on maximum voltage injection ability and real power transfer. That injected voltage is of controlled magnitude and phase angle.

DVR has solid state power electronic switches which are used for pulse width modulated inverter. DC source is connected to the input of the DVR and fed real power to system at the output of DVR. Reactive power is internally generated by the restorer. During undisturbed normal operating condition mode, low voltage side of the injecting transformer is shorted by solid state bypass switch. That means DVR causes only the conduction losses and it must be minimum. Impedance of the injecting transformer must be very low as it causes voltage drop in it and that impedance effects on designing of the filter. Amount of energy fed by the dc source is depends on the load, control strategies applied, deepest sag need to protect.

Circuit of the DVR is as fallow in fig 1.DVR system is consisting of two main parts one is power circuit and other one is control circuit. Injection transformer, an inverter, passive filter and energy source are the components of the power circuit [4].

A.Injection Transformer

Injecting transformer is used in series to connect grid side sensitive load. High voltage side of the transformer is connected to the distribution side and low voltage side is connected to power circuit of the DVR. Coupling of noise and transient energy from primary to secondary side is eliminated by the injecting transformer [6].

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B.Filter

Main function of the filter is to eliminate or minimise the harmonic generated from voltage source converter. These filters can be placed on either side of the inverter or distribution side of injected transformer.

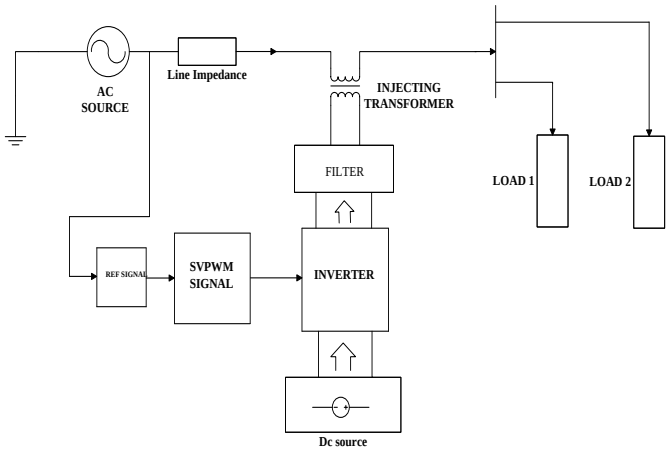

Fig 1. Basic configuration of DVR

C.Voltage Source Converter

Converter is of two types one is voltage and another one is current source converter. Voltage source converter is mostly used for the DVR. VSC is used to generate sinusoidal voltage of required magnitude, frequency and phase angle.

D. Energy Source

Flywheels, lead acid batteries, super conducting magnetic energy storage (SMES), ultra capacitor can be used as the energy storage device for DVR. Main purpose of the energy source is to supply required energy through converter and fed it to injecting transformer during voltage sag.

E. Control Unit

Control system must require for proper operation of the DVR. Load voltage is compared with the reference voltage so that error is generated and that error is used as signal. PI controller uses these signals to generate pulses to control the inverter. PI controller controls system depending on error signal. Park's transformation is used for the calculation of error voltage and pulses are generated by using SVPWM technique to control inverter [3] [5].

III. SPACE VECTOR PULSE WIDTH MODULATION

Three phase voltage source inverter has been used in wide aspects of the power system. PWM technique is used for controlling voltage source inverter. Out of all the control technique Space Vector PWM technique is most famous.

Let the three phase sinusoidal voltages are as fallows,

$$\begin{aligned} V_a &= V_m \sin(\omega t) \\ V_b &= V_m \sin(\omega t - 2\pi/3) \\ V_c &= V_m \sin(\omega t - 4\pi/3) \end{aligned} \quad (1)$$

Space vector is defined as rotating flux in ac machine and that rotating flux in AC machine can be represented in single rotating vector and its magnitude and angle can be determined by Clark's transformation. Representation of rotating vector in stationary frame is as fallow.

$$\bar{V}_s = V\alpha + j\, V\beta = 2/3\,(V_a + a\, V_b + a^2\, V_c) \quad (2)$$

Where,

$$a = e^{j2\pi/3}$$

Three phase two level inverter has eight switching states and these switching states are as shown in table1.

Table1.Switching states for two level inverter

Switching states	[da,db,dc]
1	[1,0,0]
2	[1,1,0]
3	[0,1,0]
4	[0,1,1]
5	[0,0,1]
6	[1,0,1]
7	[1,1,1]
8	[0,0,0]

Above table states that when d = 1 then switch will be on and if d = 0 then switch will be off. Switching of all these states of the inverter is calculated on the basis of the position of reference vector in space vector diagram. Tip of the voltage space vector is move along a circular projector with uniform velocity. For that purpose location of the reference vector need to be decided. Space vector diagram is shown in fig2.

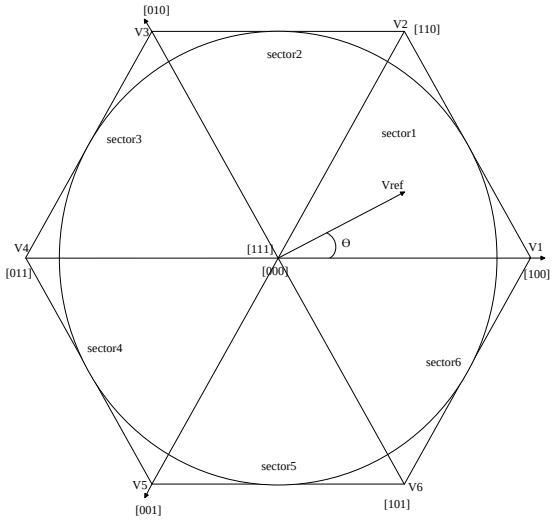

Fig 2. Space vector diagram for inverter switching

In switching of two level inverter, [000] and [111] are zero vector state and all other vectors are as active vectors. These active voltage vectors lie along radius of the hexagon. A three phase vector needed to transform in dq plane for determination of switching time duration that is shown in fig3. Rotating reference space vector is sampled at sampling period.

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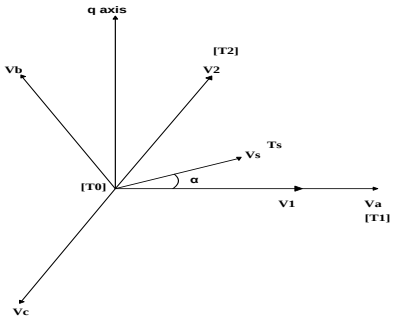

Fig 3. Space vector in dq plane

Along d axis..

$V_d = V_{an} - V_{bn}\cos(60^\circ) - V_{cn}\cos(60^\circ)$

$= V_{an} - 1/2V_{bn} - 1/2V_{cn}$

Along q axis..

$V_q = 0 + V_{bn}\cos(30^\circ) + V_{cn}\cos(30^\circ)$

$= \sqrt{3}/2\ V_{bn} + \sqrt{3}/2\ V_{cn}$

$\alpha = \tan^{-1}(Vd/Vq)$

T0, T1 and T2 can be calculated as fallows.

$T1 = \sqrt{3}\ Ts(\ |Vs|/Vdc\ )\ \sin(n\pi/3-\alpha)$

$T2 = \sqrt{3}\ Ts\ (|Vs|/Vdc)\ \sin[\alpha-(n-1)\pi/3])$

T0=Ts-(T1+T2)
n is sector and it varies from1 to 6.

In this way we can determine the space vector voltage in d and q plane and time widths [2].

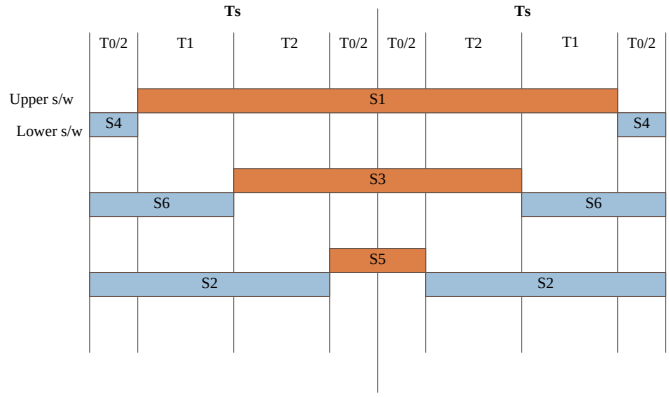

Fig 4. Switching pattern for sector1

Switching pulse pattern for sector 1 is shown in fig4.similarly switching pattern for all other sectors can be calculated. SVPWM technique for controlling two level inverter is can be implemented using MATLAB or PSIM simulation software in application of DVR [2].

IV. FEATURES OF SVPWM

Main aim of the modulation is to obtain variable maximum output and minimum harmonics. SVPWM technique is more popular because of the following features.

- Linear modulation of wide range.
- Less switching loss.
- Low total harmonic distortion.
- SVPWM has lower base band harmonic than other PWM technique.
- More efficient use of DC supplies voltage.
- Advance and computation technique
- 15% more output voltage than convocational technique

V. CONCLUSION

Now a days industrial process are mostly automated and use of computers and controllers are increases. Power quality problems leads to more economical losses in industries. This paper concludes that DVR can be used in simple and efficient way to minimize voltage sag and swell problem using proposed Space vector control technique for inverter. This paper introduces detailed overview of DVR and control technique used for inverter. A simple control technique base on park's transformation is used. With the proposed method, control unit is able to detect quality problem in power system. New sag detection and voltage compensation method is focused.

VI. FUTURE WORK

Voltage sag compensation is to be tested by actual simulation setup in MATLAB/Simulink SimPower System Tool Box. Number of different techniques and loads is to test and have to find out which one is best control technique among all. Future work will be also on the location of DVR. Fuzzy controller and adaptive PI fuzzy controller can be control technique. Instead of two level inverter , multilevel inverter could be the best solution to have low distorted output voltage.

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