Design and Simulation of Dynamic Voltage Restorer (DVR)

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Abstract

This paper gives a systematic technique of the design and simulation of Dynamic Voltage Restorer (DVR) the use of Sinusoidal Pulse Width Modulation (SPWM). though electricity great associated problems like voltage sags/swells arise both at the transmission aspect as well as the distribution side, the terminology used for the compensation devices is exclusive. DVR is a series linked tool used for compensating voltage sags and swells at the distribution side. on this work, a step by step technique is given to determine out the additives which can be required for the layout and simulation of DVR. The detection of sags/swells is completed with the assist of d-q-o concept, whereas the manager of the voltage source inverter is achieved with the assist of SPWM. The VSI has been applied with the assist of both Bipolar SPWM in addition to Unipolar SPWM and the results were compared. The simulation becomes achieved with the help of SIMULINK & MATLAB and the consequences have been located to be in accordance with concept.

Keywords: Dynamic Voltage Restorer (DVR), d-q-o theory, Sinusoidal Pulse Width Modulation (SPWM), Voltage sag

I. INTRODUCTION

With the speedy era improvements in industrial manage techniques; electric powered utilities are experiencing extra disturbing necessities at the energy best from the massive business electricity customers. Such energy best issues were higher preferred whilst the price paid, because of the economic losses as a result of them, is big. These issues are contemplated inside the newer versions of power great standards, together with IEEE 1159-1995 (IEEE, 1995) and IEC61000-30 (IEC, 2003). among the diverse energy best troubles, the voltage sag, normally as a consequence of the faults on parallel transmission/distribution feeders, is attracting quite a large amount of attention from researchers of both enterprise and academia. A definitive solution to this hassle at huge energy levels has been commonly known as dynamic voltage restorer (DVR), below the rubric of the custom power concept brought by way of EPRI (Hingorani, 1999). The principle feature of DVR is to mitigate the voltage sag, despite the fact that once in a while, extra capabilities such as harmonic compensation and reactive energy compensation also are integrated to the tool.

Strength satisfactory standards for connection of an inverter to the grid are nevertheless beneath improvement, because previously, there have been a few similar high power applications. In (IEEE, 1992) it’s far said that the energy great is decided by means of the voltage quality, whilst the voltage is a controlled o variable. Voltage sags in an electrical grid are famous phenomenon due to the finite clearing time of the faults and the propagation of sags from the transmission and/or distribution device to the low voltage hundreds. The principle of voltage sags and interruptions for electric networks is thoroughly described inside the paintings of Bollen (1999).

Dynamic voltage restorer (DVR) has been diagnosed as a fee powerful solution for the safety of sensitive Hundreds from voltage sags (Fitzer et al., 2004). DVR is by and large used for the distribution system through injecting compensating voltage in series with the delivery network when an upstream fault is detected (Zhan et al., 2001; Kara et al., 1998; Nielsen et al., 2004). Hundreds linked downstream of the DVR are thus included from any voltage sags because of faults elsewhere at the community. With a view to deliver awesome ac energy, the controlled pulse width modulation (PWM) inverter and L-C output filter ought to convert a dc voltage source (for instance, batteries) to a sinusoidal ac voltage with low voltage THD and speedy transient response beneath load disturbances.

Another vital thing of energy nice is harmonic distortion. Widespread requirements for harmonic distortion May be determined in fashionable as seen inside the paintings of Casadei et al. (2005) and specifically for connection of dispersed resources to grid in Iqbal et al. (2006). PWM control is the most effective method that offers a easy technique for manipulate of analogy structures with the processor’s digital output (Grandi et al., 2006). With the supply of low price, excessive overall performance DSP chips, characterised by the execution of most instructions in one guidance cycle, complicated manage algorithms may be completed with rapid speed, making very high sampling fee viable for digitally-managed inverters (Hadiouche et al., 2006).

Lately, strategies to supply an output voltage with low total harmonic distortion (THD) in a 3-section pulse width modulation (PWM) inverter have been proposed (Maria et al., 2007). in this paper, the implementation of a virtual signal processor (DSP) the usage of an improved d-q-0 primarily based controller became done for you to manage inverter pulses, and then the output of the inverter turned into injected thru the injection transformer of the DVR. The improvement of the controller is easy to design and

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II. THE CONCEPT OF THE DVR IN THE DISTRIBUTION SYSTEM

A. DVR Operation and Additives:
A electricity electronic converter based collection compensator that may protect crucial loads from all deliver side disturbances aside from outages is called a dynamic Omar and Rahim 1097 voltage restorer (Blaabjerg et al., 2004; Ojo et al., 2005). Discern 1 suggests the configuration of the DVR such as an inverter, collection or injection transformer, inverter manage gadget and electricity storage. The principle feature of a DVR is the protection of touchy load from any disturbances coming from community.

B. Injection Transformers:
In a 3-phase gadget, both three single-segment transformer units and one 3 section transformer unit can be used for voltage injection cause (Zhan et al., 2000)

C. Capacitor Bank
DVR has a big DC capacitor to make certain stiff DC voltage input to inverter.

D. Inverter
An Inverter machine is used to transform dc storage into ac form (Ravi et al., 2007). Voltage supply inverter (VSI) of low voltage and excessive modern with step up injection transformer is used for this reason in the DVR repayment approach (Perera et al., 2006)

E. Passive Filters
To transform the inverted PWM waveform into a sinusoidal waveform Passive filters are used. This is done by means of doing away with the unwanted harmonic components generated VSI movement. Higher orders harmonic additives distort the compensated output voltage (Zhan et al., 2000).

F. Storage unit
It’s far chargeable for power storage in DC shape. Flywheels, batteries, superconducting magnetic electricity storage (SMES) and extraordinary capacitors may be used as strength garage devices. It resources the real energy necessities of the gadget whilst DVR is used for repayment (Banaei et al., 2006). The fundamental concept of a DVR is to inject the missing voltage cycles into the gadget thru series injection transformer on every occasion voltage sags are gift in the device deliver voltage.

III. DYNAMIC VOLTAGE RESTORERS
A DVR is a tool that injects a dynamically controlled voltage V (t) collection to the bus voltage through a booster transformer as depicted in parent L There are three single segment booster transformers related to a three section converter with energy storage device and manipulate circuit [8]. The amplitudes of the 3 injected phase voltages are managed including to put off any destructive consequences of a bus fault to the weight voltage V1. Because of this any differential voltage because of temporary disturbances in the ac feeder may be compensated with the aid of an equivalent voltage generated by the converter and injected at the medium voltage level through the booster transformer.

The DVR works independently of the sort of fault or any occasion that occurs within the machine, furnished that the entire machine remains connected to the deliver grid, i.e. the road breaker does now not trip. For most realistic cases, a greater good value layout can be carried out through simplest compensating the high quality- and poor collection components of the voltage disturbance seen on the input of the DVR, this feature is affordable because for a regular distribution bus conjugation, the zero collection a part of a disturbance will now not bypass through the step down transformers because of countless impedance for this thing. For maximum of the time the DVR has, truly, "nothing to do," besides tracking the bus voltage. This indicates it does no longer inject any voltage (V(t)=zero) based of the burden cutting-edge. Therefore, it’s miles advised to in particular recognition on the losses of a DVR at some stage in ordinary operation. Specific capabilities addressing this loss difficulty were implemented in its layout, which are a transformer design with low impedance and the semiconductor gadgets used for switching. An equal circuit diagram of the DVR and the principle of collection injection for sag repayment is depicted in figure 2.
IV. D-Q-0 TRANSFORMATION

Direct–quadrature–zero (d-q-0) transformation additionally referred to as Park’s transformation is a mathematical transformation used to simplify the evaluation of 3-phase circuits. Within the case of balanced 3-phase circuits, software of the d-q-0 transformation reduces the three AC portions to 2 DC quantities. Simplified calculations can then be performed on those imaginary DC quantities before acting the inverse rework to get better the real three-section AC outcomes.

The dq0 approach offers the sag depth information with start and end instances. The quantities are expressed as the immediate area vectors. Firstly convert the voltage from a–b–c reference frame to d–q–0 reference with the aid of using following equation

\[
\begin{bmatrix}
    v_d \\
v_q \\
v_0
\end{bmatrix} = [T] \begin{bmatrix}
v_a \\
v_b \\
v_c
\end{bmatrix}
\]

…… (3)

Where,

\[
[T] = \begin{bmatrix}
    \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & 1 \\
    -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\
    \frac{1}{2} & \frac{1}{2} & \frac{1}{2}
\end{bmatrix}
\]

…… (4)

\[
\begin{bmatrix}
    v_d \\
v_q \\
v_0
\end{bmatrix} = \begin{bmatrix}
    \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & 1 \\
    -\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & 1 \\
    \frac{1}{2} & \frac{1}{2} & \frac{1}{2}
\end{bmatrix} \begin{bmatrix}
v_a \\
v_b \\
v_c
\end{bmatrix}
\]

…… (5)

Where,

T is the transformation metrics V_a,V_b V_c, , are instantaneous supply voltage of segment A, B and C respectively and V_d ,V_q ,V_0 are d-axis ,q-axis, zero-axis factor of reference body respectively.

The theta (θ) is described by means of the attitude among phase A to the d-axis [17]. Above equation defines the transformation from three section gadget a, b, c to dq0 desk bound frame. In this modification, segment A is aligned to the d-axis that is in quadrature with the q-axis.

The manipulate is based totally on the contrast of a voltage reference and the measured terminal voltage (V_a ,V_b ,V_c ). The voltage sags is detected when the deliver drops below 90% of the reference value. Both the voltages want to be transformed to dq body and the difference in voltage in dq body gives injected voltage in same body of reference. Then the dq frame signal to be transformed to abc body of reference the usage of inverse transformation given as follows:

\[
\begin{bmatrix}
    v_a \\
v_b \\
v_c
\end{bmatrix} = [T]^{-1} \begin{bmatrix}
v_d \\
v_q \\
v_0
\end{bmatrix}
\]

…… (5)
These injected voltage in abc frame of reference act as the control signal for the voltage source inverter. The pulses to the switches are generated using sinusoidal PWM technique (SPWM)

V. SIMULATION RESULTS

A MATLAB simulation is carried out to discover the performance of DVR for repayment of voltage sag the usage of d-q principle. A three-φ energy device with the parameters given in table 2 is simulated using simpered device block set. An RL load is considered for the observe. A voltage supply inverter is designed the use of MOSFET because the switching devices and DC voltage for the inverter calculated as 800V

Table - 1 System parameter and constant valve

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source voltage per phase</td>
<td>200V</td>
</tr>
<tr>
<td>DC Bus Voltage</td>
<td>800V</td>
</tr>
<tr>
<td>Filter Inductance</td>
<td>0.17µH</td>
</tr>
<tr>
<td>Filter Capacitance</td>
<td>26µF</td>
</tr>
<tr>
<td>Load Resistance</td>
<td>40 Ω</td>
</tr>
<tr>
<td>Load Inductance</td>
<td>60mH</td>
</tr>
</tbody>
</table>

Fig. 3: shows the d-q transformation in MATLAB/SIMULINK for generation of reference voltage
Three phase programmable voltage source has been used for generating 50% voltage sag for the period of 0.2s and twitch time of sag is 0.15s and finish time is 0.35s as shown in Fig.8 (a). Fig.8 (b) shows d constituent which gives the depth of sag.

The recompense voltage is generated by associating the orientation voltage in d-q frame with d-q position frame voltage of the definite power system voltage. The alteration in these voltages is to be inoculated by the voltage source inverter. This voltage will act as the reference recompensing voltage for the inverter. This is shown in Fig. 6

A sine triangular PWM Technique is used to generate pulses to the switches of three phase inverter. The output of the three phase inverter is connected in series with the transmission line with the help of series transformers as shown in Fig. 10 PLL block is used to synchronize the supply voltage and the injected voltage
Fig. 8: Simulink diagram showing the DVR in the distribution system

VI. CONCLUSION

This paper has proposed and modeled the Dynamic Voltage Restorer (DVR) based totally on sinusoidal PWM technique the use of MATLAB/SIMULINK. The reference voltage generated primarily based on d-q reference theory. The principle blessings of this DVR is low value and it’s control is easy. The DVR can mitigate lengthy period sag also. The validity of proposed method is permitted by using consequences to the simulated in MATLAB/SIMULINK.

REFERENCES