Investigation of Various Levels of Cascade Multi-Level Inverter DVR for Improve Power Quality of Induction Motor

Presented By
T.Manokaran.,M.E,
Dept of EEE,
SSCET,Palani.
OBJECTIVES

Main objectives of work is to improve the power quality factors in induction motor drives.

The Power quality factors such that Sags, Swells, Interruptions, Under voltage, Overvoltage, and Harmonics.

The ‘Behavior’ of an Induction Motor is examined and using ‘Dynamic Voltage Restorer(DVR)’ improve the power quality factors in induction motor drives.
Voltage disturbances are the most common power quality (PQ) problem in low voltage distribution systems. The voltage disturbances mainly encompass the voltage sags, swells, harmonics, unbalances, and flickers [2].

These voltage disturbances can cause the malfunction of voltage-sensitive loads in factories, buildings, hospitals and severe process disruptions resulting in substantial economic and/or data losses [3].

Voltage sag is normally caused by the startup of large ratings induction motors, short-circuit faults, such as a single-line-to-ground (SLG) fault in a power system and [4-6].

Voltage swell is defined as a short duration increase in rms supply with an increase in voltage ranging from 1.1 p.u. to 1.8 p.u. of nominal supply. The main reasons for voltage swells are switching large capacitors or the removal of large loads [7],[8].

The basic operation of DVR is to inject a voltage of required magnitude, phase angle, and frequency in series with a supply line to maintain the desired amplitude and waveform for load voltage even when the voltage is unbalanced or distorted [9], [10].
Power Quality Problems

• It include all possible situations in which the waveforms of the supply voltage or load current deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three phases of a three-phase system.

• According to the summary of *P1159 Terms* Power quality disturbance covers transients, short-duration variations, long-duration variations, voltage imbalance, waveform distortion, voltage fluctuations and power frequency variations.
IEEE Standard 1159-1995

Event Magnitude

- Voltage swell
- Normal Operation Voltage
- Voltage Sag
- Over Voltage
- Under Voltage
- Sustained Interruption

Event Duration
- 0.5 Cycle
- 30 Cycle
- 3 Sec
- 1 Min
Effect of voltage SAG&SWELL on Induction Motor

- Supply voltage to the induction motor decreases, the motor speed also decreases. If Fail to recover the normal voltage amplitude motor may stall.

- Due to ‘SAG’, Reduce the motor torque proportional to the square of the motor terminal voltage. ($T\alpha V^2$).

- Due to ‘SWELL’ and ‘SAG’ condition motor may accelerate and slows down the speed.
# Effects of Power Quality Problems in Induction Motor

<table>
<thead>
<tr>
<th>Power quality Issue</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over Voltage</td>
<td>Overstress insulation (Expected life shortening)</td>
</tr>
<tr>
<td>Under Voltage</td>
<td>Excessive $I_m$ (low speed &amp; Over Heating)</td>
</tr>
<tr>
<td>Unbalance</td>
<td>Motor Heating (Core losses)</td>
</tr>
<tr>
<td>Impulse Surges</td>
<td>Insulation Damages</td>
</tr>
<tr>
<td>Short Interruptions</td>
<td>Mechanical Shock &amp; Possible to stall</td>
</tr>
<tr>
<td>Voltage ‘SAG’</td>
<td>Torque, power, Speed and possible to stall</td>
</tr>
<tr>
<td>Voltage ’SWELL’</td>
<td>Insulation Damages</td>
</tr>
<tr>
<td>Harmonics</td>
<td>Core loss &amp; Insulation Damages</td>
</tr>
</tbody>
</table>
## Solution of Power Quality Problems

<table>
<thead>
<tr>
<th>Mitigation of Voltage Dips and Short Interruption</th>
<th>Flicker Mitigation</th>
<th>Harmonic Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Voltage Restorer (DVR)</td>
<td>Static Var Compensator</td>
<td>Active Filter</td>
</tr>
<tr>
<td>Static Series Compensator</td>
<td>D-Statcom</td>
<td>Passive Filter</td>
</tr>
<tr>
<td>Motor-Generator set</td>
<td></td>
<td>Multi-Pulse Configuration</td>
</tr>
</tbody>
</table>
Behavior of an ‘Induction Motor’
About DVR (Dynamic Voltage Restorer)

- The Dynamic Voltage Restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage ‘SAG’ and ‘SWELL’.
- The control of the compensation voltages in DVR based on dqo algorithm is discussed.
- The effects of power quality as well as enhancing this power quality in distribution network, using FACTS (Flexible AC Transmission System) Devices.
- DVR is a powerful custom power device for short-duration voltage compensation, which is connected in series with the load & hence it possesses some advantages.
Flow Chart for DVR Control Technique

1. Input Vref
2. Convert to d,q,o coordinate system
3. Vsupply V<sub>a</sub>, V<sub>b</sub>, V<sub>c</sub>
4. Convert to d,q,o
5. PLL
6. Compare
7. Convert to V<sub>a</sub>b<sub>c</sub> coordinate system
8. Generate signal for PWM
Main Elements in DVR

- An Injection / Series Transformer.
- Harmonic Filter.
- Voltage Source Converter (VSC).
- Energy Storage.
- Control Systems.
DVR - Block Diagram

AC SOURCE -> IMPEDANCE -> VDVR -> FILTER -> VSC -> ENERGY STORAGE

DVR

SENSITIVE LOAD

V_s -> V_load
DVR Equivalent Circuit Diagram

• $V_{DVR} = V_L + Z_{TH}I_L - V_{TH}$
• $V_L =$ The Desired Load Voltage Magnitude.
• $Z_{TH} =$ The load impedance.
• $I_L =$ The load current.
• $V_{TH} =$ The system voltage during load condition.
DVR Modes of Operation

**STAND BY MODE OF OPERATION**
- Source
- Ib windings
- Booster transformer
- By pass switches
- Filter Unit

**PROTECTION MODE**
- (Creating another path for current)
- S1
- S2
- S3
- Source
- Sensitive Load
- Booster Transformer
- By Pass switches
DVR Modes of Operation...

- In **Standby Mode** \((V_{DVR}=0)\), the booster transformer’s low voltage winding is shorted through the converter.

- In **Boost Mode (Or Injection Mode)** \((V_{DVR}>0)\), the DVR is injecting a compensation voltage through the booster transformer due to a detection of a supply voltage disturbances.
DVR Control Systems
DTC based IMD phase voltage \((V_{as})\), line current \((I_{as})\), rotor speed \((N_r)\), electromagnetic torque \((T_e)\).
Source current and harmonic spectrum for DTC based IMD with a simple diode bridge rectifier at rated load.
Dynamics of a DTC based IMD with a simple diode bridge rectifier and Multi-Level DVR at the front end.
AC mains current and harmonic spectrum for DTC based IMD with Multi Level DVR at the front of DTC.
Harmonics in ‘LOAD VOLTAGE’
Harmonics in ‘LOAD CURRENT’
Harmonics in S/M During ‘SLG’ Fault
DVR Injects Voltage During ‘SLG’ Fault & Harmonics Range
Reference


Thank you...