Unit.2-Voltage Sag

D. Maharajan Ph.D
Assistant Professor
Department of Electrical and Electronics Engg.,
SRM University,
Chennai-203
Unit-2
-Voltage Sag Mitigation Using Dynamic Voltage Restorer (DVR)
Voltage sag is defined as a sudden reduction of supply (rms) voltage down from 90% to 10% of nominal. According to the standard, a typical duration of sag is 10 ms to 1 minute.
Possible mitigation methods

- Four locations
  - 1,2 cheap not available in market
  - 4 costly
  - 3 widely used
load conditioning- Customer

• The solution to the power quality can be done from customer side or from utility side; first approach is called load conditioning.

• which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion.
Line conditioning-Utility

• The other solution is to install line conditioning systems that suppress or counteract the power system disturbances.
Dynamic voltage Restorer (DVR) static series compensator with transformer injection

• Series compensation devices
  – Protects against
    • Sags
    • Swells
    • unbalance and
    • Distortion

Generates or absorbs Reactive power
Response time less
• Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series.
• Some of the effective and economic measures can be identified as following
  1. Lightning and surge Arresters
  2. Thyristor Based Static Switches
  3. Energy Storage Systems
  4. Electronic tap changing transformer
  5. Harmonic filter
DVR-Introduction

• The DVR is a powerful controller that is commonly used for voltage sags and swells mitigation

• The series voltage controller is connected in series with the protected load.

• It is connected via coupling transformer in series to the ac system.

• The energy storage can be different depending on the needs of compensation
DVR-Introduction

• DVRs are a class of custom power devices for providing reliable distribution power quality.
• Series injection of voltage boost technology using solid state switches for compensating voltage sags and swells.
• The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in the system voltage.
DVR Main components

• 3 phase Voltage Source Converter (VSC)
• coupling transformer
• Passive filter
• Energy storage
• A control system to regulate the output voltage of VSC
Main Stages of DVR control system

– detection of the start and finish of the sag
– voltage reference generation
– injection voltage generation
– protection of sensitive load.
DVR in Distribution system
DVR-Principle of operation

- To inject an appropriate voltage in series with the supply through injection transformer whenever voltage sag or voltage swell is detected.
• The system impedance $Z_{TH}$ depends on the fault level of the load bus. When the system voltage ($V_{TH}$) drops, the DVR injects a series voltage $V_{DVR}$ through the injection transformer so that the desired load voltage magnitude $V_L$ can be maintained.
Schematic Diagram of DVR
Detailed circuit of DVR
Equivalent circuit of DVR
Injected voltage by DVR

From the Equivalent circuit, the series injected voltage of the DVR can be written as

\[ V_{DVR} = V_L + Z_{TH}I_L - V_{TH} \]

Where,

- \( V_L \) is the desired load voltage magnitude.
- \( Z_{TH} \) is the load impedance.
- \( I_L \) is the load current.
- \( V_{TH} \) is the system voltage during fault condition.

The load current \( I_L \) is given by \( I_L = (P_L + jQ_L) / V_L \)
Injected power by DVR

\[ V_{DVR} \angle \alpha = V_L \angle 0 + Z_{TH} I_L \angle (\beta - \theta) - V_{TH} \angle \delta \]

Where \( \alpha, \beta, \delta \) are the angles of \( V_{DVR}, Z_{TH}, V_{TH} \) respectively and \( \theta \) is the load power angle.

\[ \theta = \tan^{-1} \left( \frac{\theta_L}{P_L} \right) \]

The complex power injection of the DVR can be written as

\[ S_{DVR} = V_{DVR} I^* \]
Operating Modes of the DVR

Any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer.

The operating modes of the DVR are:

1. Protection mode
2. Standby mode
3. Injection/Boost mode
Voltage Injection Methods of the DVR

• Voltage injection methods by means of a DVR depend upon the limiting factors:
  – DVR power ratings,
  – various conditions of load,
  – different types of voltage sags and swells.
• Sensitive towards phase angle jump, change in magnitude.
• Therefore the control strategies depend upon the type of load characteristics.
• There are four different methods of DVR voltage injection which are:
  1. Pre-sag compensation method
  2. In-phase compensation method
  3. In-phase advanced compensation method
  4. Voltage tolerance method with minimum energy injection
Voltage source converter (VSC)

• It is a power electronic device, which can generate a three-phase ac output voltage is controllable in phase and magnitude.

• These voltages are injected into the AC distribution system in order to maintain the load voltage at the desired voltage reference.

• The VSC is completely replacing the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual voltage.

• The converter is using some kind of energy storage, which will supply the converter with a dc voltage.
SINUSOIDAL PWM BASED CONTROL

• The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbance.

• The control system only measures the rms voltage at the load point i.e., no reactive power measurements are required.

• The VSC switching strategy is based on sinusoidal PWM technique which offers simplicity and good response.
• The PI controller identifies the error signal and generates the required angle to drive the error to zero, i.e., the load rms voltage is brought back to the reference voltage.

• In the PWM generator, the sinusoidal signal $V_{\text{control}}$ is compared against a triangular signal (carrier) in order to generate the switching signals for the VSC valves.

• The main parameters of the sinusoidal PWM scheme are the amplitude modulation index $M_a$ of signal control and the frequency modulation index $M_f$ of the triangular signal.

• The amplitude index $M_a = \left( V_{\text{control}} / V_{\text{tri}} \right)$ is kept fixed at 1 pu.
PI controller
Dynamic voltage Restorer (DVR)
DVR- switching arrangement:
Voltage Sag mitigated by DVR

Three-phase voltage sag: (a): Source voltages, (b): Injected voltages; (c): Load voltages
Load Voltage without DVR
Load Voltage with DVR
DVR other applications:

- Line voltage harmonics compensation
- Reduction of transients in voltage
- Fault current limitations.
References

• Power Quality Enhancement Using Custom Power Devices by Arindam Ghosh, Gerard Ledwich