Improvement in Voltage Sag using FACTS Device

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Abstract— Sags and swells are the most common types of power quality disturbances. Millions of dollars are lost in productivity each year in the United States due to these disturbances. A simple understanding of the causes will allow for effective solutions to mitigating these disturbances in most applications. The definitions of sags and swells have evolved over the past fifteen years, as have the power quality instruments that measure them. Sags, or dips as they are referred to in the European communities, were initially any reduction in voltage below a user- defined low limit for between one cycle and 2.55 seconds. Swells, originally referred to as surges, were similar to sags, except that the voltage exceeded a user-defined high limit.
Key words: Sag, FACTS Device

I. Introduction

Over the last fifteen years, based on how the power quality instruments measure voltage sags and swells the definitions have been developed. Power system communities state sags or dips as a reduction in voltage below a user- defined low limit for between one cycle and 2.55 seconds. Surges are now called as swells, except that the voltage exceeds a particular user-defined high limit. While different definitions pertaining to the amplitude and duration are still in use, the IEEE 1159-1995 Recommended Practice on Monitoring Electric Power Quality has defined them as follows:

Sag (dip) can be defined as, "*A decrease to between 0.1 and 0.9pu in rms voltage or current at the power frequency for durations of 0.5 cycles to 1 minute*."

Swell can be defined as, "*An increase to between 1.1pu and 1.8pu in rms voltage or current at the power frequency durations from 0.5 to 1 minute*."

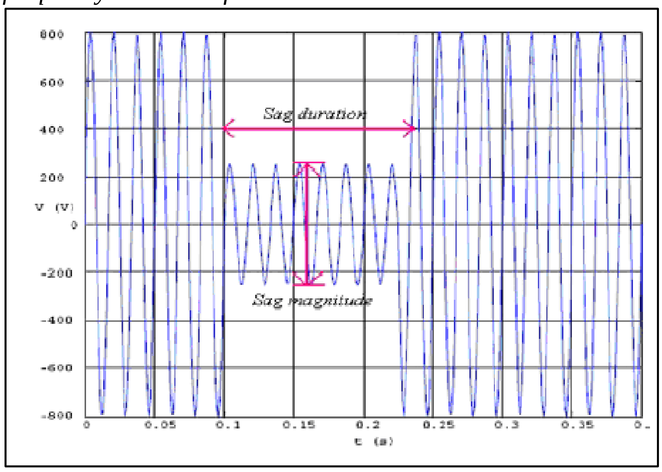


Fig. 1: Sag and Swell Detection by the Magnitude Separation from Filters

With respect to an outage or interruption, sag is differentiated by the amplitude being greater than or equal to 0.1 per unit (of nominal voltage). The IEEE 1159 document further categorizes the duration values into: Instantaneous, momentary, and temporary, as illustrated in the following table2.

According to the IEEE Std. 1995-2009 a voltage sag is "*A decrease in rms voltage or current at the power frequency for duration of 0.5 cycle to 1 minute*".

IEC has the following definition for a dip (IEC 61000-2-1, 1990) "*A voltage dip is a sudden reduction of the voltage at a point in the electrical system, followed by a voltage recovery after a short period of time, from half a cycle to a few seconds*".

II. General Causes and Effects of Voltage Sags

A. Voltage sags can be caused by

- Lightning faults on the transmission or distribution system or
- by switching of loads with large amounts of initial starting or inrush current such as motors, transformers, and large dc power supply.
- Voltage Sags Due to Faults

The magnitudes of the voltage sags can be equal in each phase or unequal depending on the types of the fault such as symmetrical or unsymmetrical, respectively

B. Multi-Phase Sags and Single Phase Sags

- Single Phase Sags: which are basically due to a phase to ground fault occurring somewhere on the system.
- Typical causes are lightning strikes, tree branches, animal contact etc.
- It is common to see single phase voltage sags to 30% of nominal voltage or less in industrial plants.

C. Phase to Phase Sags

- The 2 Phase or Phase to phase sags may be caused by tree branches, adverse weather, animals or vehicle collision with utility poles.
- These types of sags typically appear on other feeders from the same substation.

III. Three phase sags

These are caused by switching or tripping of a 3 phase circuit breaker, switch or recloser which will create three phase voltage sag on other lines fed from the same substation

A. Three Phase Sags

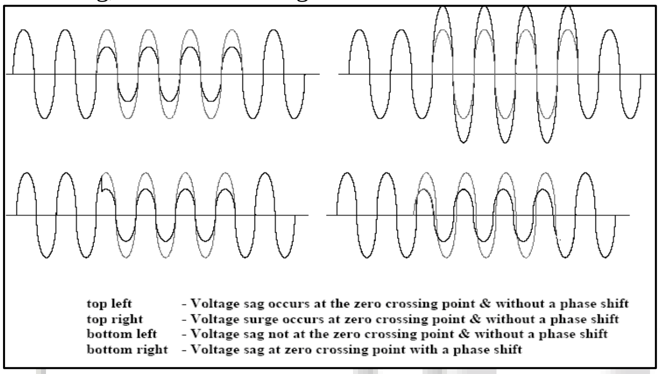
These are caused by switching or tripping of a 3 phase circuit breaker, switch or recloser which will create three phase voltage sag on other lines fed from the same substation. Symmetrical 3 phase sags arise from starting large motors and they account for less than 20% of all sag events and are usually confined to an industrial plant or its immediate neighbors.

B. Effects of Voltage Sag

- The prime interest about voltage sags is their effect on sensitive electrical devices, such as personal computers, adjustable speed drives, programmable logic controllers, and other power electronic equipment.
- The least sensitive loads failed when the voltage dropped to 30 % of the specified voltage.
- On the other hand, the most sensitive components failed when the voltage dropped to 80-86 % of rated value. From the test results, the calculated sag threshold to affect production at the utility PCC.

Type of Sag	Duration	Magnitude
Instantaneous	0.5 – 30 cycles	0.10 – 0.90pu
Momentary	30 cycle – 3 s	0.10 – 0.90pu
Temporary	3 s – 1 min	0.10 – 0.90pu

Table 1: Voltage Sag Classification Based on the type of Sag, duration and magnitude as shown in Table.

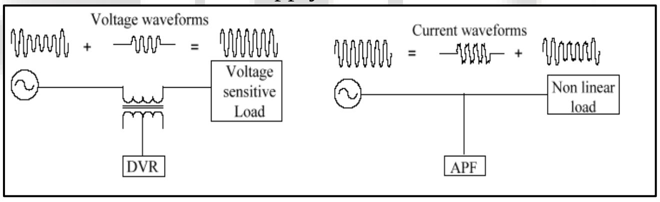


C. Classification of Equipment's used for Voltage Sag Mitigations

- A greater awareness of voltage quality has been created with the recent growth in the use of digital computers and PWM adjustable speed drives.
- Voltage dips and its associated phase angle jumps can cause equipment to fail or malfunction which in turn can lead to production downtime.
- Since a very long time interval is needed to restart industrial processes, these effects can be greatly expensive for the clients/customers who are continuously seeking for cost effective sag mitigation techniques.
- These interests have resulted in the development of power electronics based devices with sag mitigation capability.
- Flexible AC Transmission Systems (FACTS), the term custom power devices relates to the use of power electronics controllers in a distribution system, to deal with various power quality problems.
- FACTS improves the power transfer capabilities and stability margins, custom power devices ascertain that customers get pre-specified quality and reliability of supply.

D. There are many types of Custom power devices like those listed below:

- Active Power filters(APF)
- Distributed Static Compensators(DSTATCOM)
- Dynamic Voltage Restorer(DVR)
- Static VAR Compensators(SVC)
- Thyristor Switched Capacitors(TSC)
- Distribution series Capacitors(DSC)
- Uninterruptible Power Supplies (UPS), Dynamic Voltage Restorers (DVR) and Active Power Filters (APF) with voltage sag compensation facility are the most common custom power devices to compensate for the voltage sags and swells.
- UPS is ubiquitous whereas DVR and APF are less popular due to the fact that they are still in the developing stage, even though they are highly efficient and cost effective than UPSs.
- Due to the rapid ongoing development in the power electronic industry, low cost power devices like DVR and APF will become much popular among the industries in the near future.
- DVR and APF are normally used to eliminate two different types of abnormalities that affect the power quality.
- When the supply voltage/current consists of abnormalities, with a linear load
- A reliable device that can be used for the above case for voltage abnormalities is the DVR.
- It compensates for voltage sags/swells either by injecting or absorbing real and reactive power.
- When the Power supplied is in normal condition with a non linear load
- In this case, when non-linear loads are connected to the system, the supply current also becomes non-linear and this will cause harmonic problems in the supply waveform. In such a situation, a shunt APF is connected to inject/absorb the current to make the supply current sinusoidal. So, the supply treats both the non-linear load

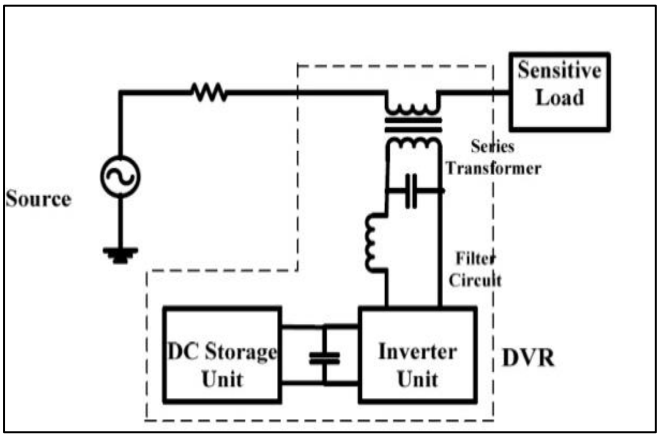


- It is clear from Figure above that the DVR is series connected to the power line, while APF is shunt connected. Among the custom power devices, UPS and DVR can be qualified as the devices that inject a voltage waveform to the distribution line.
- The UPS is always supplying the full voltage to the load irrespective of whether the wave form is distorted or not unlike DVR. This property of the UPS leaves it always operating at its full power whereas the DVR injects only the difference between the pre-sag and the sagged voltage and that also only during the sagged period.
- Therefore as compared to UPS, DVR operating losses and the required power rating are very low.
- Hence DVR is considered as a power efficient device compared to the UPS.

IV. DVR

- The DVR is a series power electronic device used to inject voltage of required magnitude and frequency.

A. Basic Structure:



B. COMPONENTS

- VOLTAGE SOURCE INVERTER
- DC STORAGE UNIT
- FILTER CKT
- SERIES T/F

C. Voltage Source Inverter

- A VSI is a power electronic system consists of switching devices (IGCTs, IGBTs, GTOs), which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle.
- In the DVR application, the VSI is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing

D. DC Energy Storage Device

- The DC energy storage device provides the real power requirement of the DVR during compensation
- . Various storage technologies have been proposed including flywheel energy storage , super-conducting magnetic energy storage (SMES) and Super capacitors .
- These have the advantage of fast response. An alternative is the use of lead-acid battery.

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E. Output Filter

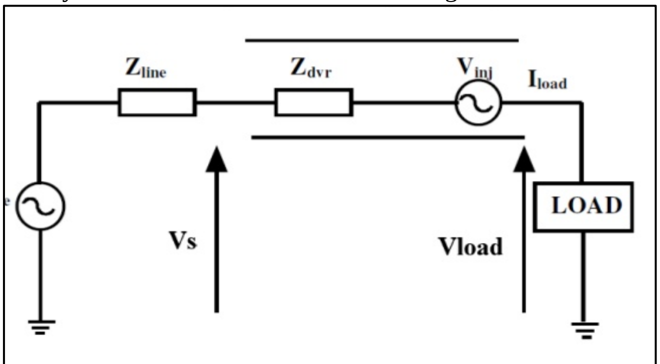
- The main task of the output filter is to keep the harmonic voltage content generated by the voltage source inverter to the permissible level (i.e. eliminate high frequency switching harmonics).It has a small rating approximately 2% of the load VA

F. Voltage Injection Transformer

- The basic function of this transformer is to connect the DVR to the distribution network via the HV-windings and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage
- The design of this transformer is very crucial because, it faces saturation, overrating, overheating, cost and performance. The injected voltage may consist of fundamental, desired harmonics, switching harmonics and dc voltage components.
- If the transformer is not designed properly, the injected voltage may saturate the transformer and result in improper operation of the DVR

G. DVR Operation

- The nominal or rated voltage is compared with the voltage variation and DVR injects the difference voltage that is required by the load.
- Here Vs is the supply voltage Vin is the injected voltage by the DVR and V1 is the load voltage.



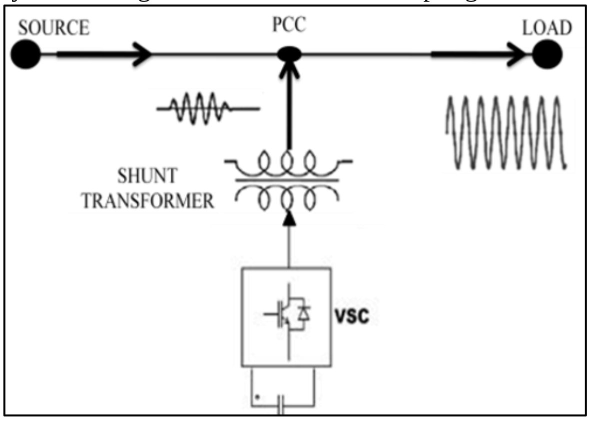
Equivalent Circuit Diagram of DVR

V. DSTATCOM

DSTATCOM is a shunt connected device designed to regulate the voltage either by generating or absorbing reactive power.

figure1, consists of a filter, Voltage source converter, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer.

The voltage source converters the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer.



Adjustment of the phase and magnitude of the DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system

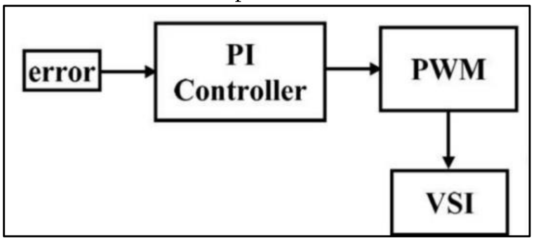
Such configuration allows the device to absorb or generate controllable active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1) Voltage regulation and compensation of reactive power
2) Correction of power factor
3) Eliminating of current harmonics.

VI. CONTROL STRATEGY

- The aim of the control strategy implemented to control a DSTATCOM used for voltage mitigation is to control the amount of reactive power



- when the PCC voltage is less than reference value then DSTATCOM generates reactive power and
- when PCC voltage more than rated value the DSTATCOM absorbs reactive power.
- To achieve desired value the firing pulses to PWM VSI are controlled The actual bus voltage is compared with the reference value and error is passed through a pi controller .
- the controller generates a signal which is given as an input to the PWM generator. the generator finally generates triggering pulses such that the voltage imbalance is corrected

VII. CONCLUSION

Among the different methods to mitigate the voltage sag, the use of fact device is best method

The fact devices like DVR DSTATCOM are helpful in overcoming the voltage unbalance problems in the power system

These devices are connect to the power network at a point of interest protect the loads

These devices have other advantages like harmonic reduction power factor correction.

REFERENCES

[1] Optimal Location of STATCOM and SVC Based on Contingency Voltage Stability by Using Continuation Power Flow: Case Studies of Khouzestan Power Networks in Iran.

[2] Hingorani, N.G.”Flexible AC Transmission”, IEEE Spectrum, Vol.30, pp.40-45, April 1993 ”.

[3] Lof P: A et al, Voltage dependent reactive power limit for voltage stability studies, IEEE Transactions on power system. Vol .10, No. 1, Feb 1995, pp. 220-226

[4] L., T .Coli,(2007).Numerical Modeling and simulation variant for pollutants spatial Dispersion ,proceeding of International conference CSCS-16 Bucharest .

[5] Anaya-Lara , O., Ach, E. 2002. Modeling and Analysis of custom power systems by PSCAD/EMTDC .IEEE Transaction on power Delivery , 17(1), pp. 266-272.

[6] Padiyar, R.K. 2007. FACTS Controllers in Power transmission and Distribution . 1st Edition ,Anshan Publishers ,India .

[7] Chi-Jen Huang ; shyh –Jier Huang ; Fu sheng Pai 2003.Design if dynamic voltage restorer with disturbance-filtering enhancement ,IEEE transaction on power electronics , 18(5) ,pp. 1202-1210.

[8] L., Zhang, “Three Phase Unbalance of Voltage dips”. Licentiate thesis ,Chalmers University of technology ,Sweden ,1999

[9] M.H.J. Bollen , “Understanding power quality problem –Voltage dips and Interruptions”New York ;IEEE Press ,1999.

[10] ^a b Remus Teodorescu; Marco Liserre; Pedro Rodriguez (2011) .Grid Converters for Photovoltaic and Wind power system .Wiley –IEEE Press .ISBN 978-1-119-95720-1.

[11] ^ “Industrial Voltage Regulator Power Conditioner” Utility System Technologies. Retrieved 25 September 2013.

[12] IEEE Transactions on industry Application , “Voltage Sag in Industrial System ”,March/April 1993.

[13] IEEE P1195/D5 Recommended Practice on Monitoring Electric power Quality ,May2, 1994 revision

[14] Lamoree, Jeff, Electrical World, “How Utility Faults Sensitive Customer Loads ”April 1992 ,Pg 60-63.

[15] Statcom for arc Furnace and flicker Compensation , CIGRE Technical Brochure 237,2003

[16] Yanushkevich, A .; Using STATCOM for Active Power Compensation : Power Quality Improvement in Distribution System ,poster 2011 , praha CVUT v praze ,FEL, p.1-4., ISBN 978-80-01-04806-1