Voltage Sag Mitigation by Parasitic Boost Circuit

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Abstract— Many customer power devices have been proposed to mitigate such voltage sags for sensitive loads. The most studied voltage regulator topologies can generally categorized into two groups: the inverter-based regulator and direct ac–ac converters. Series-connected devices (SD) are voltage-source inverter-based regulators and an SD compensate for voltage sags by injecting a missing voltage in series with the grid. There are lots of SD topologies, and key features related to the evaluation of a certain SD topology are the cost, complexity, and compensation ability. Dynamic voltage restorer (DVR) is a commonly used SD and has been widely studied. Different types of DVRs are discussed. Four typical DVR system topologies are investigated and experimentally compared. The overall evaluation has shown that DVR with no storage and load-side-connected shunt converter ranks the highest as it can compensate for long-duration deep sags at a relatively low complexity and cost.

Key words: DySC, Parasitic Boost Circuit

I. Introduction

However, the for mentioned DVR topology is still not a cost-effective solution for long duration deep sags as it regularly contains a series transformer that is heavy, bulky, and costly operating at the line frequency. This drawback is obviously no ignorable especially in low-power applications. Soa type of transformer less SD topology known as dynamic sag corrector (DySC) is proposed, and it is a low-cost, small size, light weight, and highly effective system for sag mitigation as the series transformer is no longer needed. There are several circuit structures of the Dy-SC including one given in and Fig. illustrates another possible configuration. When the grid voltage differs from its desired waveform, a missing voltage will be injected and filtered by the DySC through its half-bridge series converter (V1, V2) and output filter (Lf, Cf) to maintain the load voltage at its rated value. During this period of time, the energy needed for the compensation is provided by the residual supply via a passive shunt converter (D1, D2, L1) and stored in the dc-link capacitors (C1, C2). So, the dc-link voltage should always be lower than the peak value of the supply voltage, and it means that the DySC can only compensate for voltage sags no deeper than 50% since the largest injection voltage of the DySC is solely determined by its dc-link voltage. As mentioned in and the ride-through time of the DySC in deeper voltage sags is limited by the dc-link energy storage, and it is inadequate to provide reliable protection for sensitive loads.

Although the DySC is an excellent solution for sags in many cases, it is invalid for long-duration deep sags as its compensation ability is limited by the passive rectifier. In order to increase the energy provided during voltage sags either PWM rectifier or backup grid is adopted. But the compensation ability is greatly enhanced at the expense of significantly increasing the complexity and cost. In this paper, position of the shunt converter and series converter in the DySC is changed according to the structure differences between the DVR with the load-side-connected shunt converter and the DVR with the supply-side-connected shunt converter. As a result, the shunt converter together with the series converter formed a boost charging circuit and the dc-link voltage will be charged to exceed the peak value of the supply voltage. This obtained novel topology is called the transformer less active voltage quality regulator with the parasitic boost circuit (PB-AVQR), and it is capable of mitigating long duration deep voltage sags without increasing the cost, volume, and complexity compared with the traditional DySC topology.

The dc-link voltage adaptive control method proposed in is also applied in the PB-AVQR to improve its operation efficiency. In this project introduction of the operating mode and working principles of the proposed configuration. Then, the parasitic boost circuit model is provided followed by the theoretical analysis to calculate its dc-link voltage. At last, the simulation results using MATLAB are given to verify the feasibility and effectiveness of the PB-AVQR topology. Modern electric power systems are complex networks with hundreds of generating stations and thousands of load centres are interconnected through long power transmission and distribution networks. Power quality is major concern in industries today because of enormous losses in energy and money. With the advent of myriad sophisticated electrical and electronic equipment, such as computers, programmable logic controllers and variable speed drives which are very sensitive to disturbances and non-linear loads at distribution systems produces many power quality problems like voltage sags, swells and harmonics and the purity of sine waveform is lost. Voltage sags are considered to be one of the most severe disturbances to the industrial equipment's.

Modern industrial processes are based a large amount of electronic devices such as programmable logic controllers and adjustable speed drives. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, harmonics, flickers, interruptions, and notches.

II. Power Quality Problems

A. *Sources and Effects of Power Quality Problems*

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems.

Power quality problems are associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault conditions or energies of large loads that require high starting currents. Depending on the electrical distance related to impedance type of grounding and connection of transformers between the faulted/load location and the node, there can be a temporary loss of voltage or temporary voltage reduction (sag) or voltage rise (swell) at different nodes of the system. Among them, two power quality problems have been identified to be of major concern to the customers are voltage sags and swells, but this project will be focusing on voltage sags/swells, as well as interruptions. Voltage dips are considered one of the most severe disturbances to the industrial equipment. A paper machine can be affected by disturbances of 10% voltage drop lasting for 100ms. A voltage dip of 75% (of the nominal voltage) with duration shorter than 100ms can result in material loss in the range of thousands of US dollars for the semiconductors industry. Swells and over voltages can cause over heating tripping or even destruction of industrial equipment such as motor drives.

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

1) Voltage Dip

A voltage dip is used to refer to short-term reduction in voltage of less than half a second. A voltage dip may be caused by switching operations associated with a temporary disconnection of supply, the flow of heavy current associated with the starting of a large electric motors or the flow of fault currents or the transfer of load from one power source to another. These events may emanate from customers systems or from the public supply network. The main cause of momentary voltage dips is probably the lightning strike. Each of these cases may cause sag with a special characteristics (magnitude and duration).

2) Voltage Sag

Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.

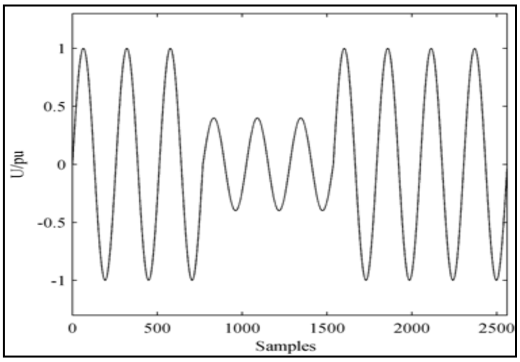

Fig. 1: Voltage Dip (Sag) Waveform

3) Voltage Swell

Voltage swell is defined as an increase in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

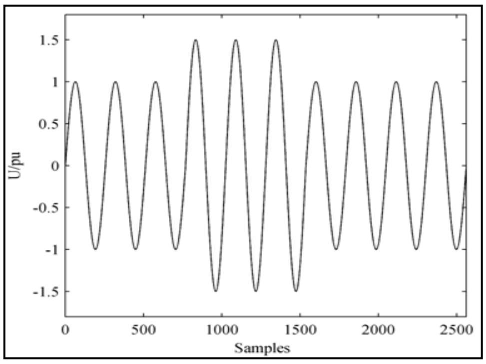

Fig. 2: Voltage Swell Waveform

Swells can upset electric controls and electric motor drives, particularly common adjustable-speed drives, which can trip because of their built in protective circuitry. Swells can also put stress on delicate computer components and shorten their life span.

4) Voltage spikes, impulses or surges

These are the RMS used to describe abrupt, very brief increases in voltage value.

5) Voltage transient

They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.

6) Harmonics

The fundamental frequency of the AC electric power distribution system is 50 Hz. A harmonic frequency is any sinusoidal frequency, which is a multiple of the fundamental frequency. Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.

7) Flickers

Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

B. Causes of Dips, Sags and Surges

- Rural location remote from power source
- Unbalanced load on a three phase system
- Switching of heavy loads
- Long distance from a distribution transformer with interposed loads
- Unreliable grid systems
- Equipments not suitable for local supply

C. Causes of Transients and Spikes

- Lightening
- Arc welding
- Switching on heavy or reactive equipments such as motors, transformers, motor drives
- Electric grade switching

D. Effects of Voltage Sag and Swell

- Unplanned shutdowns at plant side
- Interrupted Communication
- Equipment failure
- Scrambled data

- Create a large current unbalance that could blow fuses or trip breakers at plant location.
- Huge losses of money of order of Rs. 15 lakhs / event for DC drives

E. Solutions to Power Quality Problems

Power quality is certainly a major concern in the present era; it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Modern industrial processes are based a large amount of electronic devices such as programmable logic controllers and adjustable speed drives. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, and harmonics. Voltage dips are considered one of the most severe disturbances to the industrial equipment. Swells and over voltages can cause over heating tripping or even destruction of industrial equipment such as motor drives. Electronic equipments are very sensitive loads against harmonics because their control depends on either the peak value or the zero crossing of the supplied voltage, which are all influenced by the harmonic distortion. This project analyzes the key issues in the power quality problems.

As one of the prominent power quality problems, origin consequences and mitigation techniques of voltage sag/swells and interruptions problem will be discussed in detail. The study describes the techniques of correcting the problems in a distribution system by a strong power electronics based devices called Reference vector generation with the help of Wavelet Transformation. And this method is studied for the power quality problems to be viewed.

There are two approaches to the mitigation of power quality problems. 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. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source.

III. DVR TECHNOLOGY

The strategy of the operation of the DVR has attracted a great attention on the last few years. According to J. Nielsen and F. Blaabjerg, four different system topologies for DVRs are analyzed and tested, with particular focus on the methods used to acquire the necessary energy during voltage sag. Comparisons are made between two topologies that can be realized with a minimum amount of energy storage, with energy taken from the grid during the voltage sag, and two topologies that take energy from stored energy devices during the voltage sag. Experimental tests using a 10-kVA DVR show that the no-energy storage concept is feasible, but an improved performance can be achieved for certain voltage sag using stored energy topologies. The results of this comparison rank the no-storage topology with a passive shunt converter on the load side first, followed by the stored energy topology with a constant dc-link voltage.

It consist of

- Energy Storage Unit
- Voltage Source Inverter
- Passive Filter
- By-Pass Switch
- Voltage Injection Transformer

DVR topology is still not cost effective solution for long duration deep sag because it regularly contain series transformer. Series connected transformer is heavy, bulky and costly operating at line frequency. This drawback can no be ignorable for low applications. So a type of transformer less SD topology known as Dynamic Sag Corrector is proposed.

IV. DYSC TOPOLOGY

There are several structure of DYSC available one of them given below it is transformer less topology hence having less cost and complexity. When the grid voltage differs from desire waveform, missing voltage will be injected and filter by DySC

It consist of

- Half bridge series converter (V1,V2)
- Output filter (Lf,Cf)
- Passive shunt converter (D1,D2,L1)
- Dc link capacitor (C1,C2)

DySC is changed according to the structural differences between the DVR with load-connected shunt converter and the one with supply-connected shunt converter. As a result, the shunt converter together with the series converter forms a boost charging circuit and the DC-link voltage will be charged to exceed the peak value of supply voltage. Thus obtained novel topology is called the transformer-less active voltage quality regulator with the parasitic boost circuit (PB-AVQR), and it is capable of mitigating long-duration deep voltage sags without increasing the cost, volume and complexity compared with the traditional DySC topology. The DC-link voltage adaptive control method proposed and is also applied in the PB-AVQR to improve its efficiency.

V. PB-AVQR TOPOLOGY

The PB-AVQR topology is mainly consists of five parts

- Static bypass switch (VT1, VT2
- Half-bridge inverter (V1, V2),
- Shunt converter (VT3, VT4),
- Storage module (C1,C2),
- Low Pass Filter (Lf,Cf)

Operating mode and applied control strategies is simple as shown in fig under normal operating conditions, the static bypass switch is controlled to switch on and the normal grid voltage is delivered directly to the load side via this bypass switch. When an abnormal condition is detected, the static bypass switch will be switched OFF and the inverter will be controlled to inject a desired missing voltage in series with the supply voltage to ensure the power supply of sensitive loads. There are totally two different kinds of control strategies in the proposed PB-AVQR system. When the grid voltage is lower than the rated voltage, an in-phase control strategy will be adopted and a phase-shift control strategy will be applied when the supply voltage is higher than the nominal voltage.

So, the compensation ability of the PB-AVQR is theoretically unlimited as long as the grid is strong enough to provide the needed power. However, as the boost circuit is parasitic on the series inverter, and the two switches are actually controlled according to the missing voltage, there still exist some restrictions.

VI. Conclusion

The proposed topology is derived from DySC circuit and compensation ability highly improved without increasing cost, weight, complexity and volume. For long duration deep sag PB-AVQR is cost effective solution compared with traditional DVR with load side connected shunt converter as series transformer no longer needed. The PB-AVQRis considered to be an efficient solution due to its relatively low cost and small size, also it has a fast dynamic response Principle of working of PB-AVQR and circuit equations are given through theoretical analysis. To verify feasibility and effectiveness of proposed topology for the compensation of long duration deep sag that are lower than half of its rated voltage simulation result are presented by using the Dc link voltage adaptive control technique the operating efficiency of PB-AVQR system also remain at high level. Hence the PB-AVQR topology provides novel solution with great reliability and compensation performance for deep voltage sag

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