DESIGN AND SIMULATION VOLTAGE DYNAMIC RESTORER (DVR)

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"I declare that this work as the product of my own effort with the exception of excerpts cited from other works of which the sources were duly noted"

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ABSTRAK

Tesis ini menghuraikan tentang permasalahan voltan jatuh, voltan membengkak dan kesan yang teruk pada beban tidak linear atau beban sensitif. Pemulih voltan dinamik (DVR) telah menjadi penyelesaian kos yang efektif untuk perlindungan beban sensitif dari voltan jatuh dan voltan membengkak. Kawalan voltan pampasan dalam DVR berdasarkan algoritma dqo dibincangkan. Pertamanya rangkaian kekuatan sistem DVR dianalisa untuk menghasilkan keterbatasan kawalan yang tepat dan sasaran kawalan untuk kawalan voltan pampasan. Keputusan simulasi yang dihasilkan oleh Matlab / Simulink mengesahkan prestasi kaedah yang dicadangkan

ABSTRACT

This thesis describes the problem of voltage sags and swells and its severe impact on non linear loads or sensitive loads. The dynamic voltage restorer (DVR) has become popular as a cost effective solution for the protection of sensitive loads from voltage sags and swells. The control of the compensation voltages in DVR based on dqo algorithm is discussed. It first analyzes the power circuit of a DVR system in order to come up with appropriate control limitations and control targets for the compensation voltage control. Simulation results carried out by Matlab/Simulink verify the performance of the proposed method.

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LIST OF ABBREVIATIONS

DVR	-	Dynamic Voltage Restorer
SCADA	-	Supervisory Control and Data Acquisition
IEEE	-	Institute of Electrical and Electronics Engineers
CBEMA	-	Computer and Business Equipment Manufacturers' Association
SEMI	-	Semiconductor Equipment and Materials International
PWM	-	Pulse Width Modulator
FACTS	-	Flexible AC Transmission Systems
APF	-	Active Power Filters
BESS	-	Battery Energy Storage Systems
DSTATCOM	-	Distribution Static synchronous COMpensators
DSC	-	Distribution Series Capacitors
SMES	-	Super conducting Magnetic Energy Systems
SETC	-	Static Electronic Tap Changers

LIST OF SIMBOLS

V_L	-	The desired load voltage magnitude
Z_{TH}	-	The load impedance
I_L	-	The load current
V_{TH}	-	The system voltage during fault condition
V_{VDR}	-	V inject
$\propto$, β, δ-		Angle of V_{VDR}, Z_{TH}, V_{TH} respectively
θ	-	Load power angle

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

1.2 Sources and effects of power quality problems

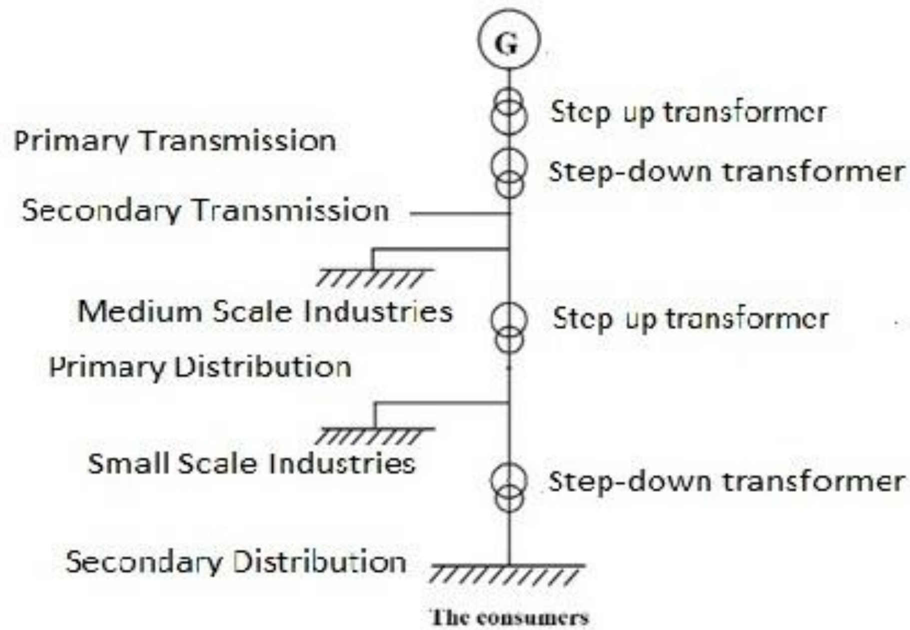

Figure 1.2 Single line diagram of power [8]

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.

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.

- Voltage dip: A voltage dip is used to refer to short-term reduction in voltage of less than half a second.

- 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.

- 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.

- Voltage 'spikes', 'impulses' or 'surges': These are terms used to describe abrupt, very brief increases in voltage value.

- Voltage transients: 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.

- 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.

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

1.2.1 Causes of dips, sags and surges:

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

1.2.2 Causes of transients and spikes:

1. Lightening.
2. Arc welding.
3. Switching on heavy or reactive equipments such as motors, transformers, motor drives.
4. Electric grade switching.

1.3 Standards Associated with Voltage Sags

Standards associated with voltage sags are intended to be used as reference documents describing single components and systems in a power system. Both the manufacturers and the buyers use these standards to meet better power quality requirements. Manufactures develop products meeting the requirements of a standard, and buyers demand from the manufactures that the product comply with the standard. The most common standards dealing with power quality are the ones issued by IEEE, IEC, CBEMA, and SEMI.

1.3.1 IEEE Standard [6]

The Technical Committees of the IEEE societies and the Standards Coordinating Committees of IEEE Standards Board develop IEEE standards. The IEEE standards associated with voltage sags are given below.

IEEE 446-1995, “IEEE recommended practice for emergency and standby power systems for industrial and commercial applications range of sensibility loads”.

The standard discusses the effect of voltage sags on sensitive equipment, motor starting, etc. It shows principles and examples on how systems shall be designed to avoid voltage sags and other power quality problems when backup system operates. IEEE 493-1990, “Recommended practice for the design of reliable industrial and commercial power systems”

The standard proposes different techniques to predict voltage sag characteristics, magnitude, duration and frequency. There are mainly three areas of interest for voltage sags. The different areas can be summarized as follows:

- Calculating voltage sag magnitude by calculating voltage drop at critical load with knowledge of the network impedance, fault impedance and location of fault.

- By studying protection equipment and fault clearing time it is possible to estimate the duration of the voltage sag.

- Based on reliable data for the neighborhood and knowledge of the system Parameters an estimation of frequency of occurrence can be made. IEEE 1100-1999, “IEEE recommended practice for powering and grounding Electronic equipment”.

This standard presents different monitoring criteria for voltage sags and has a chapter explaining the basics of voltage sags. It also explains the background and application of the CBEMA (ITI) curves. It is in some parts very similar to Std. 1159 but not as specific in defining different types of disturbances.

IEEE 1159-1995, “IEEE recommended practice for monitoring electric power quality” The purpose of this standard is to describe how to interpret and monitor electromagnetic phenomena properly. It provides unique definitions for each type of disturbance. IEEE 1250-1995, “IEEE guide for service to equipment sensitive to momentary voltage disturbances”.

This standard describes the effect of voltage sags on computers and sensitive equipment using solid-state power conversion. The primary purpose is to help identify potential problems. It also aims to suggest methods for voltage sag sensitive devices to operate safely during disturbances. It tries to categorize the voltage-related problems that can be fixed by the utility and those which have to be addressed by the user or equipment designer. The second goal is to help designers of equipment to better understand the environment in which their devices will operate. The standard explains different causes of sags, lists of examples of sensitive loads, and offers solutions to the problems.

1.3.2 SEMI International Standards

The SEMI International Standards Program is a service offered by Semiconductor Equipment and Materials International (SEMI). Its purpose is to provide the semiconductor and flat panel display industries with standards and recommendations to improve productivity and business. SEMI standards are written documents in the form of specifications, guides, test methods, terminology, and practices.

The standards are voluntary technical agreements between equipment manufacturer and end-user. The standards ensure compatibility and interoperability of goods and services. Considering voltage sags, two standards address the problem for the equipment.

SEMI F47-0200,“Specification for semiconductor processing equipment voltage sag immunity”. The standard addresses specifications for semiconductor processing equipment voltage sag immunity. It only specifies voltage sags with duration from 50ms up to 1s. It is also limited to phase-to-phase and phase-to-neutral voltage incidents, and presents a voltage-duration graph, shown in Figure 2.2. SEMI F42-0999, “Test method for semiconductor processing equipment voltage sag immunity”.

This standard defines a test methodology used to determine the susceptibility of semiconductor processing equipment and how to qualify it against the specifications. It further describes test apparatus, test set-up, test procedure to determine the susceptibility of semiconductor processing equipment, and finally how to report and interpret the results.

1.4 Solutions to power quality problems:

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. Both schemes are implemented preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor. However, with the restructuring of power sector and with shifting trend towards distributed and dispersed generation, the line conditioning systems or utility side solutions will play a major role in improving the inherent supply quality; some of the effective and economic measures can be identified as following: