“ I hereby declare that I have read through this report entitle “Voltage Dip Mitigation by Controlling Voltage and Current DQ Components” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)”

Signature	:	....
Supervisor’s Name	:	MOHAMED AZMI BIN SAID
Date	:	18TH JUNE 2014

VOLTAGE DIP MITIGATION BY CONTROLLING VOLTAGE AND CURRENT DQ COMPONENTS

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A report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering

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2014

I declare that this report entitle "*Voltage Dip Mitigation by Controlling Voltage and Current DQ Components*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : SYARIFAH SYAKILA BINTI SYED WAHAB

Date : 18TH JUNE 2014

Specially dedicated:

To my beloved mother Muziah binti Ahmad,

My beloved sisters,

My supervisor and all my lecturers

And all my friends

For their encouragement, support and motivation

Through my journey of education.

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Alhamdulillah, I am greatly indebted to Allah SWT on His mercy and blessing for making this project successful.

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ABSTRACT

Power quality problems, especially voltage dip contribute a major negative impact on industrial productivity. There is much available method to compensate voltage dip. This report briefly examines the method voltage dip mitigation by controlling voltage and current DQ components, and compares performance attributes of uncompensated system and compensated system. Important comparison points include performance of time response and efficiency of controller. The method of mitigation voltage is simulated by using PSCAD software.

ABSTRAK

Masalah kualiti kuasa, terutama voltan susut menyumbang kesan negatif yang besar kepada produktiviti industri. Terdapat banyak kaedah yang ada untuk memperbaiki voltan susut. Laporan ini secara ringkas mengkaji mitigasi voltan susut dengan kaedah mengawal voltan dan komponen DQ, dan membandingkan sifat-sifat persembahan sistem sebelum pembaikan dan selepas pembaikan. Antara perkara perbandingan yang penting ialah persembahan tindak balas masa dan kecekapan pengawal. Kaedah voltan mitigasi ini disimulasikan dengan menggunakan perisian PSCAD.

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CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

Consumer of large electrical power such as industrial is concern about power quality problem. The common power quality problem happen is voltage dip, voltage swell and interruptions. Among of this power quality problem, voltage dip is the most common disturbance occurred. Generally, voltage dip is the decreasing of voltage in short period.

Nowadays, the high technology industry will likely use sensitive equipments in their industry in order to apply energy saving concept. However, the sensitive equipment cannot withstand the sudden fluctuation of voltage like voltage dip. As the voltage dip is happen, this sensitive equipment will be malfunction. The breakdown of sensitive electronic equipment can cause significant financial losses. This is because in many production processes, loss of some equipment can cause to a full shut down of production. From [1], the losses in industry in the United States, due to voltage dips are over $20 annually. Instead of repair or buy the new equipment, the money can used to produce more products. Therefore, it is important to mitigate voltage dip to increase the productivity of operational, economical and quality of services of industrial area.

1.2 PROBLEM STATEMENT

In power system, the voltage dip usually happens in transmission line and distribution system. Voltage dips is caused by different event that can occur in the power system such as transformer energizing, high starting current and sudden high current that lead to ground fault (current leakage to the earth). One of the situations that caused voltage dip to be produced is, as in industrial application, starting large motor yields a very high current. Based on Ohm's law, high current is affected on the decreasing of voltage. The decreasing of voltage in this situation is called as voltage dip.

Ideally, power distribution system should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in real life, power systems have numerous non linear signals, which significantly affect the quality of power supplies [2]. Therefore, the source of voltage dips problems is unavoidable. So it is important to find a way to overcome voltage dips. Power system analysis is needed to gain some knowledge about how to maintain the level of voltage even there is fault occur.

1.3 OBJECTIVES

There are three main objectives of this project which are:

1. To design a method of mitigating power line voltage dip by using current and voltage DQ components through transforming three phase reference frames to rotating reference frame.
2. To simulate voltage dip mitigation system by using PSCAD software.
3. To analyze the performance of the uncompensated and compensated system by using simulation software (PSCAD, MATLAB, etc).

1.4 SCOPE OF RESEARCH

The power quality problem can be categorized into nine which is voltage dips, voltage swells, harmonics, frequency deviations, transients, unbalance, flicker, interruptions and waveform distortion. Amongst of all this power quality problem, the voltage dips is the only power quality problem that will be focused on.

There are two types of three phase system which is balanced system and unbalanced system. The balanced three phase system is chosen to be the type of system to be tested by voltage dips.

To analyze and simplify the three phase system, there are several method can be used. The method that will be used in this project is DQ transformation.

To mitigate voltage dips, one of the solutions is by injecting reactive power into transmission line. There are several methods to inject reactive power into transmission line. The proposed method is by controlling shunt current DQ component. To controlling shunt current DQ component, the custom power devices used is current source. Current source can be injected in two ways which is series connection and shunt connection. This study will focus on mitigate voltage dips by injecting shunt current source.

As the definition of voltage dips is power voltage drops to a level below 90% of standard voltage for no longer than a minute, this project is about to design the controller to mitigate voltage dips for situation of 10% voltage dips [3].

This project will cover simulation part only.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND OF PROJECT

2.1.1 Voltage Dip Definition

Voltage dip is the decreasing between 0.1 to 0.9 pu in the RMS voltage at the power frequency with duration from 0.5 cycles to 1 minute [4]. For more understanding, voltage dip is visualized as Figure 2.1.

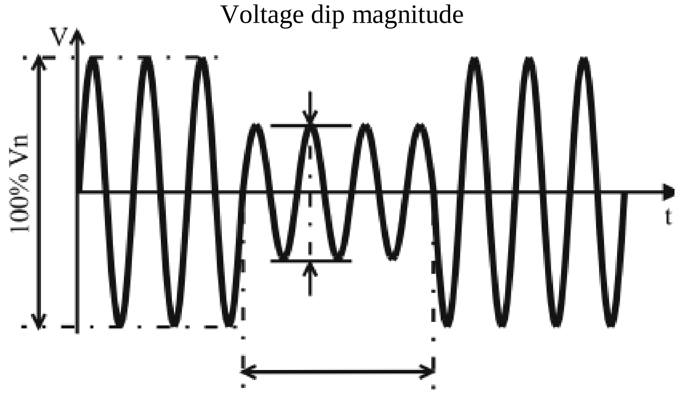

Figure 2.1: Waveform of voltage dip

2.1.2 Transformation Of Three Phase Reference Frames To Rotating Reference Frame

Three phase reference frame signal can be transformed into rotating reference frame signal [5]. One of the method signal transformation can be used is Clarke's and Park's transformation. Clarke's and Park's transformation is mathematical transformation that rotates the reference frame of three-phase systems in order to simplify the analysis of three-phase circuits. Clarke's and Park's transformation transform signal by cascade as

Figure 2.2. In other word, to transform three phase reference frame signal into rotating reference signal, the Clarke's and Park's transformation is work in separate way.

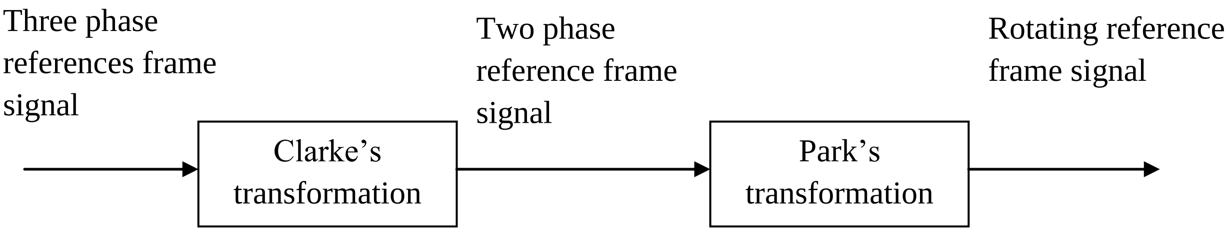

Figure 2.2: Block diagram of Clarke's and Park's transform

Clarke's transform is transformation three phase stationary parameter from a-b-c system into two phase stationary reference frame as Figure 2.3. The variable of two phase stationary reference frame is called as α and β.

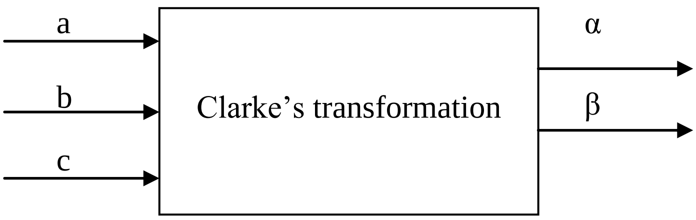

Figure 2.3: Clarke's transformation

The three phase stationary parameter from a-b-c system is transform into two phase stationary reference frame based on the equation below:

$$F = T_{\alpha \beta o} \cdot [F_{abc}] \quad (2.1)$$

Where;

F : Parameter such as voltage, current, line leakage.

F_{abc} : Parameter such as voltage, current, line leakage in abc form.

$T_{\alpha\beta o}$ from equation (2.1) is obtained as below:

$$T_{\alpha\beta o} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \tag{2.2}$$

After simplify the equation (2.1), the equation of two phase stationary reference frame is as below:

$$V_\alpha = \frac{2}{3}V_a - \frac{1}{3}(V_b - V_c) \tag{2.3}$$

$$V_\beta = \frac{2\,V_b - V_c}{\sqrt{3}} \tag{2.4}$$

$$V_0 = \frac{1\,(V_a + V_b + V_c)}{3} \tag{2.5}$$

The equation of inverse Clark's transformation is as below:

$$V_a = V_\alpha \tag{2.6}$$

$$V_b = \frac{-V_\alpha + \sqrt{3}\,V_{\beta_c}}{2} \tag{2.7}$$

$$V_c = \frac{-V_\alpha - \sqrt{3}\,V_{\beta_c}}{2} \tag{2.8}$$

Park's transform is transformation of three phase stationary parameters into two phase orthogonal rotary reference frame as Figure 2.4. The variable of two phase orthogonal rotary reference frame is called as d and q (DQ components).

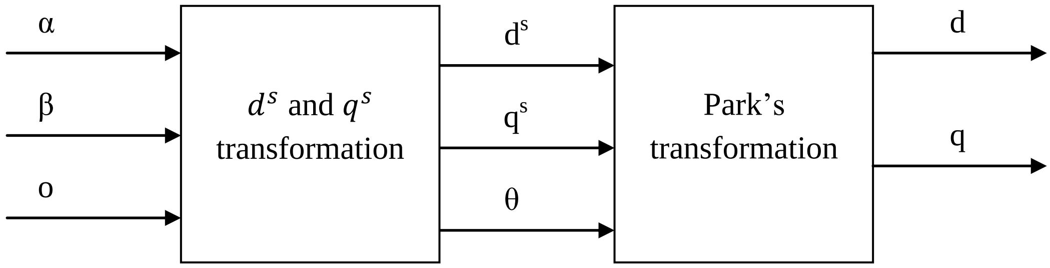

Figure 2.4: Park's transformation

The three phase stationary parameters is transform into two phase orthogonal stationary reference frame based on the equation below:

$$V_{dqo}(\theta) = T_{dqo}(\theta) \cdot [V_{\alpha\beta o}] \tag{2.9}$$

V : Parameter such as voltage, current, line leakage.

T_{dqo} from equation (2.9) is obtained as below:

$$T_{dqo} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{2.10}$$

To transform three phase stationary parameters into two phase orthogonal rotary reference frame, the equations involve are:

$$V_d = V_\alpha \cos\theta + V_\beta \sin\theta \tag{2.11}$$

$$V_q = -V_\alpha \sin\theta + V_\beta \cos\theta \tag{2.12}$$

The equation of inverse Park's transformation are as below:

$$V_\alpha = V_d \cos\theta - V_q \sin\theta \qquad (2.13)$$

$$V_\beta = V_d \sin\theta + V_q \cos\theta \qquad (2.14)$$

The difference between three phase reference, two phase reference and rotating reference frame that produced from Clarke's and Parks transform is demonstrated in Figure 2.5.

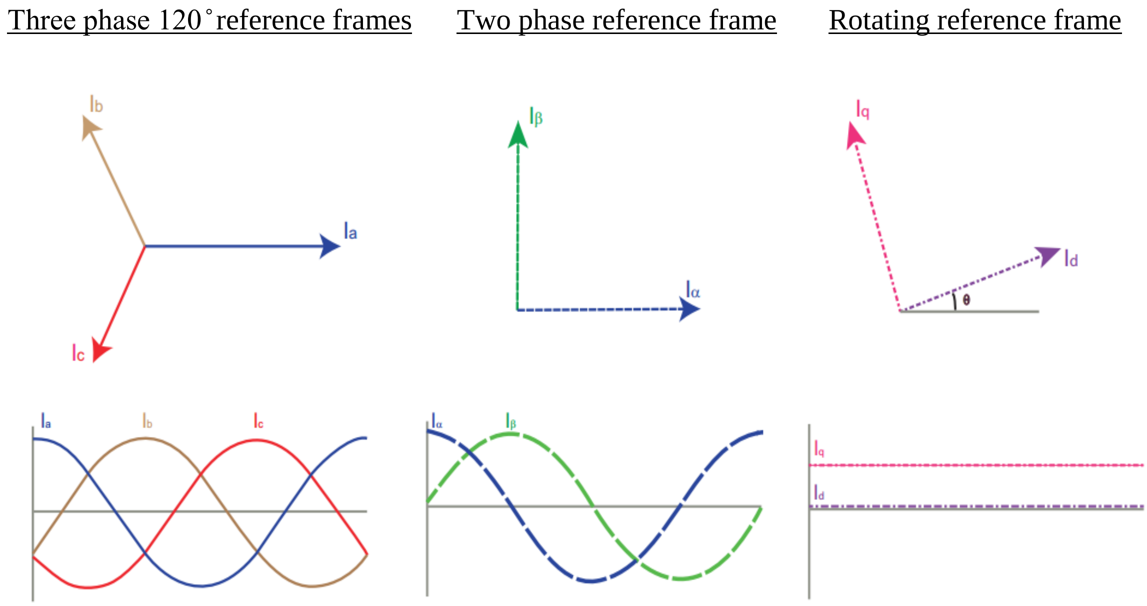

Figure 2.5: Graph and polar form of three phase reference frames signal, two phase reference signal and rotating reference frame signal

2.1.3 Control System

To gain better understanding on the project, the control system of power system should be studied. Figure 2.6 show the basic closed loop control system. In this project, the block plant represents the power system. The power system is consists of generator, transmission line or distribution system. The disturbance represents the fault (voltage dip). The block controller is a feedback controller, such as P controller, PI controller, PD controller or PID controller.

The process in closed loop control system is as follows. When the plant is experience fault, the sensor will sense the amount of output signal is not equal to the desired output signal. Then the output signal will be compared to the reference signal by controller. The controller will process the signal and compensate the signal.

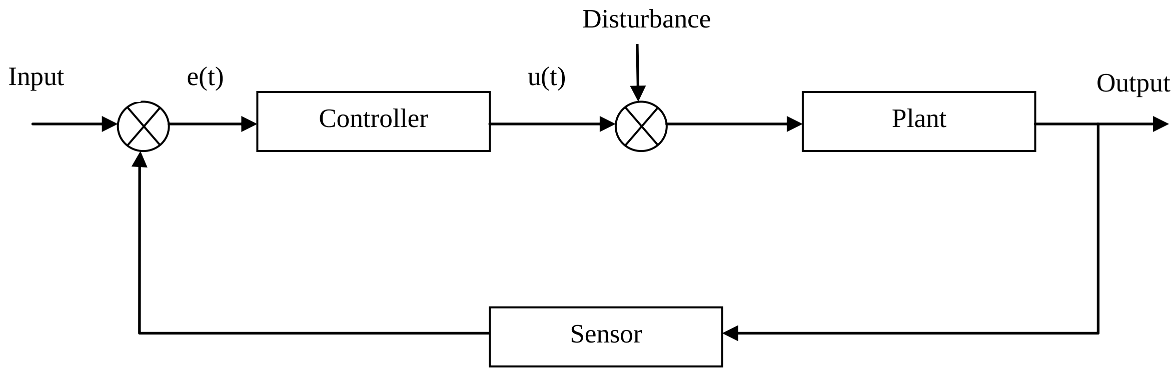

Figure 2.6: Basic closed loop control system

2.1.4 PI Controller

The combination of proportional gain and integral gain is called as PI-controller. The PI-controller is expressed in the equation that contains proportional gain and integral gain as Equation 2.15:

$$u(t) = Kp\, e(t) + Ki \int e\,(t)\, dt \tag{2.15}$$

Kp: Proportional gain
Ki: Integral gain

From the Equation 2.15, Kp and Ki are the tuning knobs. To obtain the desired output, this tuning knob is adjusted. The function of Kp is to increase the speed of response. The function of Ki is to eliminate the steady state error.

2.1.5 Advantage Of PSCAD Software

PSCAD software can be used to simulate the circuit of power system. PSCAD software is chosen to simulate the circuit of power system because PSCAD software is software that makes use of intelligent techniques to computerize the power quality evaluations for improved accuracy and efficiency since manual analysis takes considerable time and would require special knowledge [6]. Another advantage of PSCAD is ability to interface with MATLAB/SIMULINK software.

2.2 RELATED PREVIOUS WORKS

2.2.1 Solutions To Voltage Dip

To improve voltage dip in industrial plant, first action is find which process in the plant is sensitive to voltage dip [7]. Then understand the product manufacturing process and operation of the equipment. Next step is identifying which equipment is critical to the other machine operation and will be adversely affected by voltage dip. The example of equipment is Adjustable Speed Drive (ADS) and control and logic circuit. The methods to repair the voltage dip on ADS are reprogramming the response of ADS and restart the motor after a user-defined time delay. While the methods to improve voltage dip on control and logic circuit are use Semi F47 compliant power source, change the trip setting of control circuit and install a coil hold-in device.

Phase of power is categorized into two, which is single phase power and three phase power. To mitigate voltage dip that happens in single phase power and three phase power, consumer should use power conditioning devices. The example of single phase power conditioning devices that available in market is Uninterruptible Power Supply (UPS), Constant Voltage Transformer (CVT), Dip Proofing Inverter, Voltage Dip Compensator (VDC), Dynamic Compensator (Dynacom) and Dynamic Sag Corrector (DySC). The example of three phase power conditioning devices that available in market is Active Voltage Conditioner (AVC), Datawave, Flywheel, Dynamic Voltage Restorer (DVR), three phases Dynamic Compensator (Dynacom), Dynamic Sag Corrector (ProDysc) and Dynamic Sag Corrector (MegaDysc).

2.2.2 Shunt-Connected Voltage Source Converter (VSC)

One of the methods to mitigate voltage dip is by set shunt-connected VSC [8]. The control system of shunt connected VSC is consists of two controllers which is vector current controller and vector voltage controller. The vector current controller generates a reference signal proportional to the VSC output voltage in order to track the reference VSC output current. While voltage controller generate a reference signal proportional to the output voltage VSC current. The purpose is to maintain the voltage above the capacitor constant to the desired value.

The three phase system can be expressed by two-phase system by obtain the DQ components. The block diagram of the transformation is as Figure 2.7. The purpose of transformation of three phase system into two-phase system is because to facilitate the PI controller to sense the amount of fault in the line voltage. To get the DQ components, voltage and current will be converted to fixed coordinate $\alpha\ \beta$ and then to DQ components. To calculate DQ components, it is important to carry out the calculation of transformation angle θ(t). The transformation angle θ(t) will be calculated by Phase-Locked Loop (PLL).

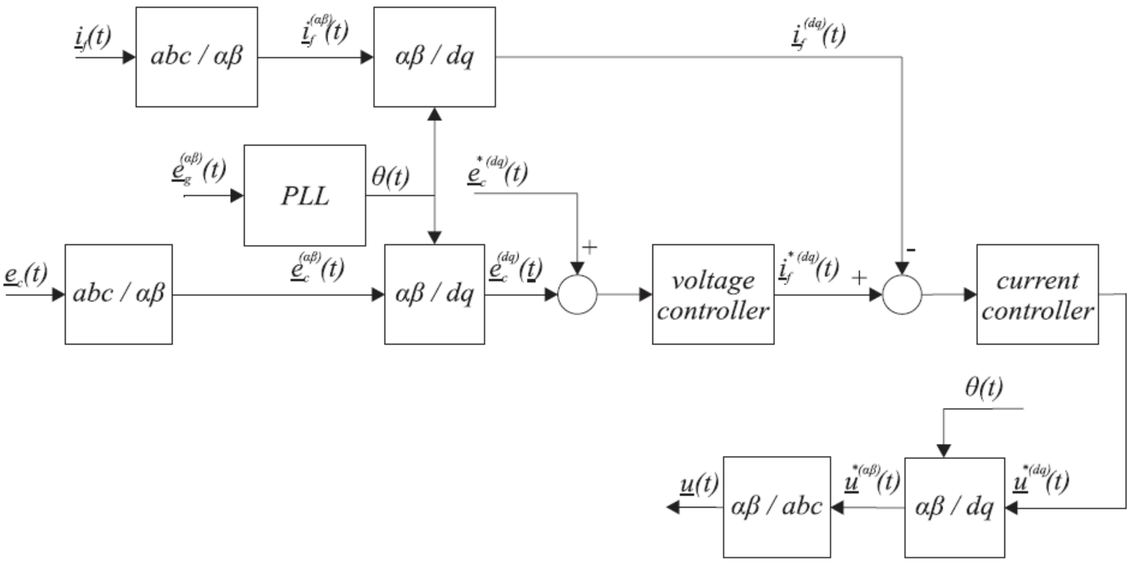

Figure 2.7: Block diagram of the implemented control system

2.2.3 Phase-Locked Loop

Phase-Locked Loop (PLL) is one of the controllers that used to sense the difference (error) between phase of reference signal and phase of line voltage with fault [9]. PLL is consisting of variable frequency oscillator and phase detector. The function of oscillator is to generate a periodic signal. The function of phase detector is to compares the phase of output signal with the phase of the input signal and adjust the oscillator to keep the phases matched. The output signal is bring back toward the input signal for comparison is called a feedback loop since the output is ‘feed back’ toward the input forming a loop.