FACULTY OF ELECTRICAL ENGINEERING

FINAL YEAR PROJECT REPORT

CONTROL STRATEGY OF THREE PHASE OF SERIES ACTIVE FILTER FOR VOLTAGE DISTURBANCES IN ELECTRICAL DISTRIBUTION SYSTEM

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CONTROL STRATEGY OF THREE PHASE OF SERIES ACTIVE FILTER FOR VOLTAGE DISTURBANCES IN ELECTRICAL DISTRIBUTION SYSTEM

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor in Electrical Engineering (Industrial Power) with Honours

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2016

"I hereby declare that I have read through this report entitle "**Control Strategy of Three Phase of Series Active Power Filter for Voltage Disturbances in Electrical Distribution System**" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature :

Supervisor's Name : Associate Professor Ir. Dr. Rosli Bin Omar

Date : 3rd June 2016

"I hereby declare that I have read through this report entitle "**Control Strategy of Three Phase of Series Active Power Filter for Voltage Disturbances in Electrical Distribution System**" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature :

Student's Name : Siti Nordiana Binti Yunos

Date : 3rd June 2016

Especially To My Family

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

In the name of Allah, the Most Gracious, the most Merciful.

All Praise is due to Allah S.W.T for His mercy and grace. I am so thankful for all the chances that given to me. Finally, I manage to complete my report for Final Year Project entitle “Control Strategy of Three Phase of Series Active Power Filters for Voltage Disturbances in Electrical Distribution System”.

I would like to express my deepest appreciation to my supervisor, Associate Professor Ir. Dr. Rosli bin Omar who always guiding me through this project. It is a great chance for me to learn and get guidance from him until this project finally completed. Not to forget, I would like to express millions of thanks to both of my supportive parents, which never stop give support and courage me to give my best. Not to forget, all my friends, that always give their hands and always support each other through completing our study.

I also would like to forward a special thanks to Universiti Teknikal Malaysia Melaka (UTeM) and also people who have help me and give support until I able complete this project. There are a lot of things that I have learnt through this journey. From this project, I have better knowledge regard voltage disturbances in electrical distribution system. I hope this report can give us a better knowledge regard voltage sags and voltage swells.

ABSTRACT

The main objective of this project is to study control strategy of three phase of series active power filters for voltage disturbances in electrical distribution system. Generally, there are many types of voltage disturbances, but this project only focusing on voltage sags and voltage swells. As we know, voltage sags is happen when voltage level drop temporary 10% to 90% from its nominal value. Meanwhile, voltage swells occurs when voltage increase suddenly from 110% up to 180% from its nominal value. Voltage disturbances in source voltage may affect voltage load and lead to many severe damages. Therefore, a grid voltage must be free from voltage distortion in order to make sure load voltage maintain at its nominal value. Thus, a method or technique to mitigate the voltage disturbance in electrical distribution system, series active power filter (SAPF) will be study through this project. This project is carry out by using MATLAB Simulink. The circuit configuration is simulate in MATLAB Simulink. Result obtained from the simulation are collected and analysed.

ABSTRAK

Objektif utama projek ini adalah untuk mengkaji strategi kawalan siri penapis kuasa aktif tiga fasa untuk gangguan voltan dalam sistem pengagihan elektrik. Secara umumnya, terdapat banyak jenis gangguan voltan, tetapi projek ini hanya memberi tumpuan kepada sags voltan dan pengembangan voltan. Seperti yang kita tahu, sags voltan berlaku apabila tahap voltan jatuh sementara 10% kepada 90% daripada nilai nominalnya. Sementara itu, pengembangan voltan berlaku apabila peningkatan voltan secara tiba-tiba dari 110% sehingga 180% daripada nilai nominalnya. Gangguan voltan pada voltan sumber boleh mengganggu beban voltan dan seterusnya membawa kepada pelbagai kerosakan teruk dalam system pengagihan elektrik. Oleh itu, voltan grid mestilah bebas daripada gangguan voltan supaya voltan beban terus kekal pada nilai nominal. Oleh itu, kaedah atau teknik untuk mengurangkan gangguan voltan dalam sistem pengagihan elektrik, siri penapis kuasa aktif (SAPF) akan dikaji melalui projek ini. Projek ini dijalankan dengan menggunakan MATLAB Simulink. Konfigurasi litar akan disimulasikan dalam MATLAB Simulink. Keputusan yang diperolehi daripada simulasi akan dikumpulkan dan dianalisis.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Customers now days are interested in guaranteeing the quality and reliability of power supplies. This is because many economic activities are depends on the power quality and their efficiency. Power quality actually is referring to the quality of the voltage. Therefore, the voltage magnitude for perfect power quality must at a specified value, both RMS and peak. [1]

Unfortunately, due to many factors, perfect waveform of supply voltage is difficult to achieve. [2] This problem is due to voltage distortions such as voltage sags, swells and harmonics in electrical distribution network. This problems can cause failure or malfunction of sensitive equipment such as personal computers, programmable logic controllers (PLC) and contactors. [3]

Failure or malfunction of sensitive equipment in electrical distribution system may lead to various impacts such as power loss, disturbances, measurement errors, and control malfunctions, increase damage rate of components, cause undesirable tripping of sensitive devices and worse, may contribute to the degradation of the power quality in distribution network. All this effects will lead to industrial production losses because its operation is dependent on the functionality of mentioned sensitive equipment. [3] This occurrences just not have major economic impact but also impact on the quality services and products.

To mitigate the voltage disturbances in distribution system, there are a lot of methods can be used. One of methods is by using series active filters. Series active power filter (SAPF) is regarded as controlled voltage source (CVS) since it is able compensating voltage sags and swells by inject a voltage component in series with supply voltage. [3] Therefore, the SAPF are able to improve quality of power supply.

Hence, the proposed of this project is to design, develop and analyse a three phase of SAPF using MATLAB/SIMULINK for voltage compensation in electrical distribution system.

1.2 Problem Statement

Voltage disturbances that happened caused by fault in electrical distribution can reduce quality of power supply. This may lead to failure and damage of sensitive electrical equipment and lead to losses. [3] [4] Therefore, the ultimate goal of this project is to maintain perfect waveform of voltage supply.

1.3 Objectives

The objectives of this project are:-

1. To study the impact of voltage disturbances focusing on voltage sags and swells in electrical distribution system.
2. To propose efficient method that able to compensate voltage disturbances (sag and swell) in supply voltage.
3. To design, develop and analyse of a three phase of series active power filter configuration using MATLAB/SIMULINK system.

1.4 Scope

There are many methods has been used in order to mitigate voltage disturbances in electrical distribution system. The most popular method for mitigating voltage disturbances is by using series active power filter. The scope of this study is to design, develop and analysis of a series active power filter parameters for voltage disturbances by using MATLAB/SIMULINK software. The voltage disturbances had occur is only focusing on voltage sags and swells in electrical distribution system.

CHAPTER 2

LITERATURE REVIEW

2.1 Voltage disturbances in electrical systems

Voltage disturbances can be defined as any problem in voltage drop or voltage increase from its nominal value. This phenomena can lead to failure or malfunction of electrical equipment. [5][6] This problem then will give impact on quality and reliability of power supply. Voltage distortion is classified based on how the voltage are distorted as shown in table 2.1. [7]

Table 2.1: Types of voltage disturbances in electrical network

Disturbances	Voltage	Duration
Dip	0.1 – 0.9 pu	0.5 – 30 cycle
Surge (Swell)	1.1 – 1.8 pu	0.5 – 30 cycle
Flicker ($\boldsymbol{P_{It}}$)	0 – 1%	Steady state
Imbalance	0.5 – 3%	Steady state
Interruption	<0.1 pu	0.5 cycle

2.1.1 Voltage Sags

Voltage Sag is happen when voltage level is distorted temporary to 10%-90% of it nominal value. It happen for 0.5 cycles to 1 minute. Therefore, it is classified as a short duration voltage decrease phenomena. [8]

2.1.2 Voltage Swells

Voltage swells is defined as increasing of voltage to 110%-180% of nominal value. It is happen for duration of 0.5 cycles to 1 minute. It is classified as a short duration voltage increase. Basically, voltage swell is opposite of a voltage sag. [9]

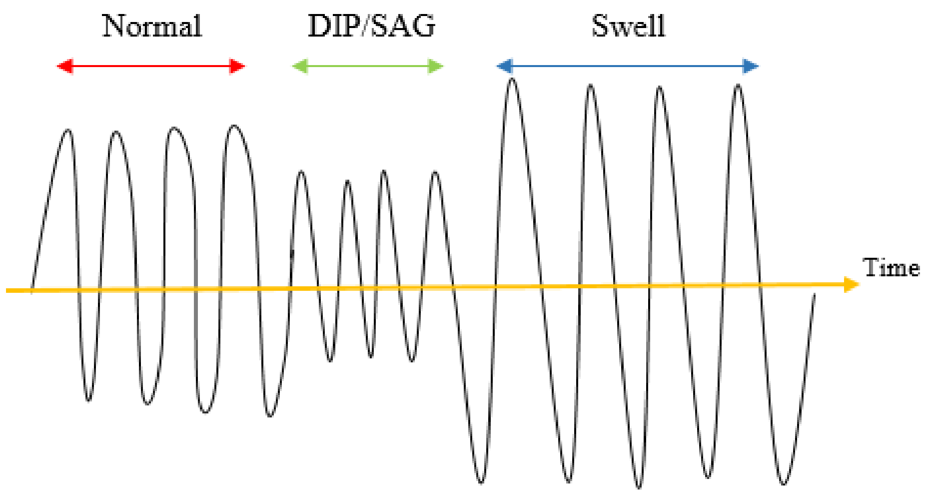

Figure 2.1: Voltage sags and voltage swells [10]

2.1.3 Causes of Voltage Sags and Voltage Swells

2.1.3.1 Sags Causes [11]

The causes of voltage sags can be divided into three areas of occurrence which are the transmission system (usually above 65kV); distribution systems (65kV to 12 kV); and, point-of utilization (120-480V). Meanwhile, voltage swells are classes under a single category. [11] A common, basically cause of sags and swells in all three areas is an unexpected change of current flow through the source impedance.

A sag, the unexpected, large increase in the current required from a source will cause a larger voltage to be developed across the source impedance. This will cause in a reduction in the voltage, as seen by the load. Similarly with a surge. A sudden reduction in the current flow will effect an increase in voltage in inductive/capacitive impedances, which the load may experience.

Voltage sags have be connected to the most common cause of power-related computer system failure. This was proved in 1976 by study in Northern Virginia [12], where there were an average of 40 thunderstorms/year. The consequence in high-incidence areas of lightning strikes, such as Florida, is even more obvious. Table 2.2 shows the results from that study.

Table 2.2: Cause of sags on distribution system

Cause	No. Of Occurrences	Percentage (%)
Wind and lightning	37	46
Utility equipment failure	8	10
Construction or traffic accident	8	10
Animals	5	6
Tree limbs	1	1
Unknown	21	26
Total	80	

2.1.3.2 Sag Causes- Distribution Systems

Same like the transmission system causes, motor vehicle accidents, weather (lightning, wind), construction accidents, animal contact, contamination of insulators, falling or contact with tree limbs can result in voltage sags. Faults may happen in 3- phase, line-to-line, or single line-to-ground. But, the 3-phase faults are the most severe, but are relatively infrequent. "In an industrial plant, single line-to-ground faults on the utility system are the most common cause of voltage sags". [13] [14]

Based from previous study indicate that most important cause of momentary voltage sags is lightning strikes. In the common of sags, the voltage drops to about 80% of nominal value on the parallel feeders, while the faulted feeder may have a lower sag value, or may result in an outage if the fault cannot be mitigate.

Distribution system sags tend to cluster around several duration ranges, based on the fault protection schemes: 6-20 cycles (typical distribution fault clearing times, 30-60 cycles (the instantaneous reclosing time for breakers) or 120-600 cycles (the delayed reclosing time for breakers).

2.1.3.3 Swell Causes [15]

Swells are less common than voltage sags, but also usually related with system fault conditions. A swell can occur due to a single line-to ground fault on the system, which can also effect in a temporary voltage rise on the unfaulted phases. This is specifically true in ungrounded or floating ground delta systems, where the sudden change in ground reference result in a voltage rise on the ungrounded phases. Usually, close to the substation on a grounded system, there will be no voltage rise on unfaulted phases because the substation transformer is usually connected delta-wye, providing a low impedance path for the fault current.

2.1.4 Impact of Voltage Sags and Voltage Swells [16]

Voltage sags may lead to following impacts:-

i. Equipment does not operate correctly
ii. Variable speed drives close down to prevent damage
iii. Production rates fluctuates
iv. Unreliable data in equipment test
v. Relays and contactors drop out
vi. Dimming of lighting systems

Voltage swells may cause:-

i. Failure of system
ii. Data corruption
iii. Damage of electronic devices

2.2 Monitoring and Testing

As with other technology-driven products, the power quality monitoring products have quickly developed in the last fifteen years. [17] Increased complexity and performance of VLSI components, particularly microprocessor, digital signal processors, programmable logic, and analogue/digital converters, have allowed the manufacturers of power quality monitoring instruments to include more capability in the similar size package for the equivalent or lower price. Different types of monitoring equipment is offered, depending on the user's knowledge base and necessities.

The four basic types of power quality monitors (also known as power line disturbance monitors) are: [18]

- Event indicators,
- Text monitors,
- Solid state recording volt/ammeters
- Graphical monitors.

Even though all of these devices can be used to measure or monitor sags and swells, the efficiency of each depends on what information the user wants to gain. Usually, the indicators are on the lower price end of the market. They indicate to the user that a sag or swell has occurred through visual means, such as indicator lights or illuminated bar graphs.

Meanwhile, some products will collect the worst case amplitudes of such and/or the number of occurrences of the type of event. Most such device do not provide an indication of the time of occurrence or the duration. Basically, the voltage limit detectors may be pre-set or programmable, with the accuracy being in the 2-5% range.

Textual-based monitors were actually the first dedicated power quality monitors, produced back in 1976. The function of these instruments is similar to the event indicators, except the output is in alphanumeric format. Additional information, such as duration and time-of-occupancy is often provided.

Besides, some of these products allow for the correlation of other information (such as environmental parameters and system status levels) to help the user in determining the cause of the event. Solid state recording volt/ammeters have replaced the older pen-and-ink chart recorders as a means of providing a graphical history of an event. These devices typically does not have the resolution necessary for monitoring fault-clearing sags. Sampling techniques range from average of several cycles to samples over 2-30 cycles. The averaging over several cycles may mask the sag or swell, as well as result in less accurate amplitudes. Sampling over multiple cycles will not properly represent the event either.

Graphical monitors offer the most information regard a sag or swell. Most graphical monitors provide a cycle-by-cycle picture of the disturbance, as well as recording minimum/maximum values, duration, and time-of-occurrence. The three-phase voltage graphs, combined with graphs of neutral to ground voltage, phase currents, neutral current (in wye), and ground currents, will usually provide the user with enough information to determine if the fault occurred upstream or downstream. The timing and magnitude information can frequently recognize the source of the fault. For example, if the phase current levels of the load same with to the voltage sag, the fault is more likely upstream. If the magnitude of the sag is down to 20% of nominal, it is likely that the fault was close by.

The location of the monitor, power supply wiring, measurement input wiring, and immunization from RFI/EMI is exclusively serious with the higher performance graphical monitors. The monitor itself must also be able of riding through the sag and surviving extended duration swells. Therefore, the functionality of the monitor should be thoroughly evaluated in the laboratory, under simulated disturbances, before placing out in the field. It is cannot be simply assumed it did not happen just because it have not be recorded. Unless there is equivalent information pointing to the cause of the disturbance before the monitoring begins, it is common practice to begin at the point of common coupling with the utility service as the initial monitoring point.

Current developments in artificial intelligence tools, especially fuzzy logic, have allow software vendors to develop products that allow knowledge and reasoning patterns to be stored in the software program. [19] Thus, continuous sags that return to nominal for an adequate time for the power supply capacitors to recharge may not be as severe as a longer duration sag of a higher amplitude.

2.3 Solution

2.3.1 Series Active Power Filters (SAPF)

Series active power filters are operated mainly as a voltage regulator and as a harmonic isolator between the non-linear load and the utility system. It can protects the consumer from distorted supply voltage. SAPF will injects a voltage components in series with the supply voltage to compensate voltage sags and swells on the load side as shown in Figure 2.3. This method is recommended for compensated of voltage distortions from the AC supply and for low power applications. [20]

The main stages of the control system of a SAPF are as follows: detection of the start and finish of the sag, voltage reference generation, injection voltage generation, and protection of the system. If voltage sag/swell occurs, the detection block generates the reference load voltage. The sag detection strategy is based on Root Means Square (rms) for the error vector which can be used for symmetrical and non-symmetrical sags with any associated phase jump. Load voltage feedback is also added, and it is implemented in the odq frame to minimize any steady state error in the fundamental component. The injected voltage is also generated according to difference between the reference load voltage and supply voltage and it is applied to the VSC to produce the preferred voltage using hysteresis voltage control.

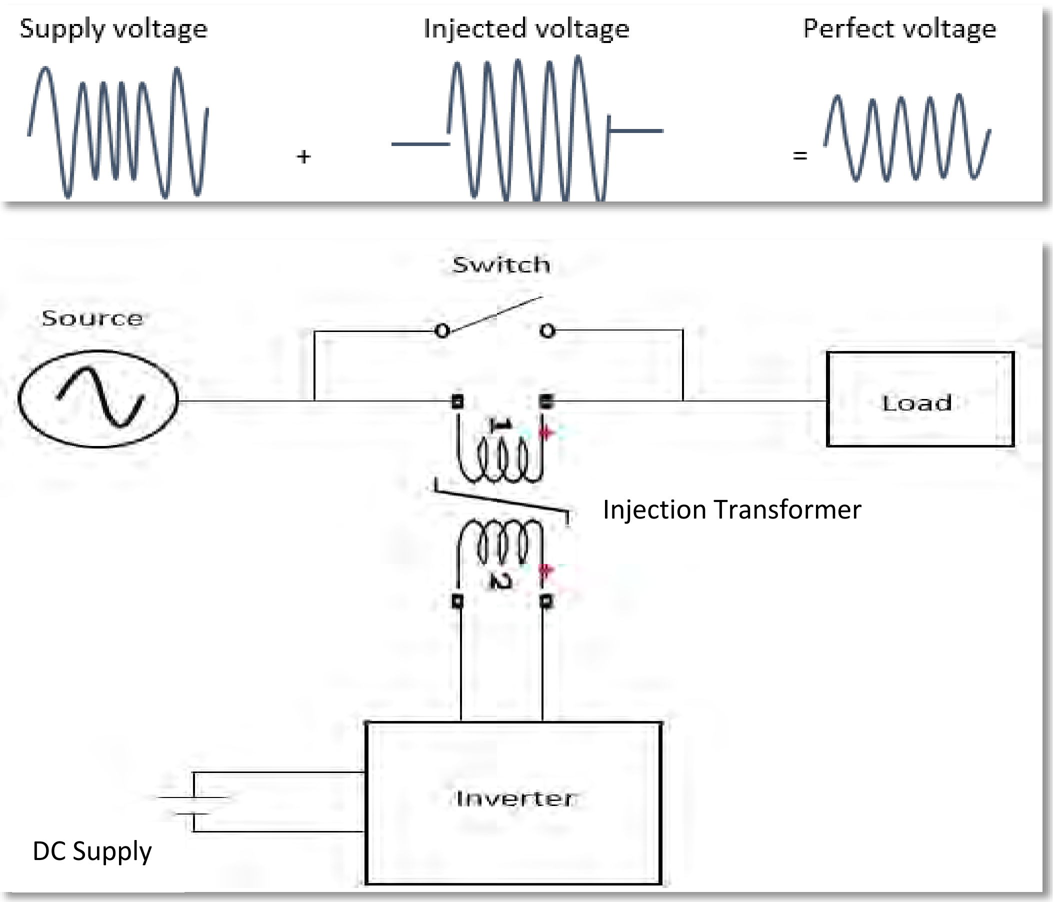

Figure 2.3: Series active power filter