Development of active power filter using rectifier boost technique

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Article Info	ABSTRACT
Article history: Received Aug 27, 2018 Revised Jan 25, 2019 Accepted Mar 15, 2019	The development of active power filter (APF) using rectifier boost technique has been identified to compensate for the pulsating nature of the distorted supply current waveform of non-linear load. In this work, investigation is carried out on the operation of rectifier without any filters function. This is then extended to operate the rectifier converter with an active power filter function. APF function is implemented by enabling the closed-loop control
<i>Keywords:</i> Active power filter Boost rectifier Non-linear load Rectifier	using standard proportional integral control to rectify the distorted supply current to become continuous, sinusoidal and in-phase with the supply voltage waveform. Consequently, the total harmonic distortion (THD) level was reduced to meet the acceptable limit defined in the standard of IEEE-519 1992. The selected simulation results obtained from MATLAB/Simulink are presented to justify the proposed filter structure. <i>Copyright</i> © 2019 Institute of Advanced Engineering and Science. <i>All rights reserved.</i>
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1. INTRODUCTION

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The demand for high power quality, power supply system has shown an increase in recent years. This trend reflects in the increase use of active power filter to provide high power factor operation with low total harmonic distortion (THD) level of input current waveform, resulting in power quality problems [1-12]. It is a variation of voltage, frequency and waveform. A significant phase difference between current and voltage waveform leads to low power factor.

Currently, there are various methods to mitigate power quality problems such as STATCOM, hybrid filters, passive power filter, and active power filter. In comparison to other filters, passive power filter would be seen as a common industrial technique to resolve power quality problems. However, the use of passive power filter during design stage tend to cause dissatisfaction due to its main drawback which is the limitation of frequencies reduction [8]. Besides, in many situations, the requirement of reactive power at fundamental frequency would be lower and the design of passive filters could be very challenging to reduce *rms* current of the supply where the dominance is of the harmonic currents [13-19].

On the other hand, active power filter has been identified to overcome the passive power filter drawbacks with consideration to input and output loading. The main purpose of the active power filters is the capability to form continuous sinusoidal line current to reduce semiconductor components, and coupling transformers. The usage of active power filter is less common in industry field compared to passive power filter due its higher cost. However, the unknown advantage of active power filter is proven to be more beneficial where it can filter the harmonic simultaneously, less design stage as harmonic study not compulsory, and filter power is easier [8].

In recent years, various active power filter (APF) configurations have been proposed to solve power quality problem such as harmonic problems. It have been classified into series, shunt and hybrid active power filters. There were many studies regarding the control strategies, configuration and application of active power filter including the voltage source inverter (VSI) or current source inverter (CSI) operation. The methods introduced on these converter topologies are boost rectifier circuit in which one of the simplest technique and form that contains adjustment of a basic bridge-diode circuit by insertion of boost switch and inductor. Based on analysis observation on these conceptual studies, this converter offers more benefits such as sinusoidal input current, unity power factor on the source side and a simpler power circuit compared to other circuit topologies [11].

The proposed ac-dc converter will be able to provide almost unity power factor during wide variations of the rectifier load. Fundamentally, boost rectifier produces higher DC output voltage from an input of AC voltage. Thus, inductor will be used at the input to provide an additional voltage source in series with the supply [9].

Typically, this method is widely used in various applications due to its respective features like high switching rates, and high power rating. In addition to that, boost rectifiers are also commonly used in electric drives, Switching-Mode Power Supply (SMPS), Uninterruptible Power Supply (UPS) and power factor corrector devices [20-25] Therefore, in this paper, an attempt is made to review the circuit topology and simulation modeling performed on active power filter (APF) using boost rectifier simulated in MATLAB/Simulink.

2. RESEARCH METHOD

The step-by-step procedure for the study is shown in Figure 1. The flowchart begins with the research and study about various types of power quality and its problems. Harmonic distortion has been identified as the main cause of power quality problems. Next, one of the techniques or methods to rectify power quality problems was identified, which is with active power filter using rectifier boost technique. Then, the design analysis of the proposed filter which is APF to obtain the desired low value of THD level is simulated using MATLAB/Simulink. However, after the circuit execution, the THD level without filter appeared to be exceeding the limit of harmonic based on IEEE519 standard. Thus, the design of active power filter using rectifier boost technique was developed to ensure the harmonic level is comply with the IEEE 519 standard.



Figure 1. Overall flowchart of project

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3. PROPOSED APF WITH RECTIFIER BOOST TECHNIQUE

In this paper, APF with boost rectifier technique has been proposed. The main objective of this technique is to filter out harmonics in the power system while correcting the supply current waveform of the non-linear load.

The circuit topology of APF implemented with boost rectifier circuit is shown in Figure 2. The configuration consists of inductors, capacitors, resistor, diode-bridge, power switching device, and current control loop (CCL). Meanwhile, the components inside CCL are subtractor, reference current, Proportional-Integral (PI) controller, comparator and carrier signal.



Figure 2. APF using boost rectifier topology

4. COMPUTER SIMULATION MODEL

The computer simulation model of the proposed converter starts with the design of the rectifier interconnection with power supply and a capacitive load. This circuit was implemented without any filter. The proposed configuration technique model is shown in Figure 3. Initially, the supply current passes through the subtractor that acts to create an error signal. Next, the signal passes through the PI controller to eliminate an error signal. Finally, a comparator was used to produce an active pulse width modulation (APWM) by comparing the modulating signal with the carrier signal. The modeling of a step response as shown in Figures 4 and 5 were also developed to investigate that the supply current will track the variation value of reference current, thus verify the proposed APF function. The Circuit specifications detail is shown in Table 1.

Table 1. Circuit specifications		
System Parameters	Values	
Input voltage, V_s	$40 V_{rms}$	
Line inductor, L_s	1 mH	
Output capacitor, Co	1000 µF	
Resistive load, R	300 Ω	
Switching frequency, fs	50 kHz	
Proportional gain, K_p	20	
Integral gain, Ki	1000	

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Figure 3. APF circuit with Boost rectifier technique







Figure 5. Step Response Controller

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5. RESULTS AND DISCUSSION

Figure 6 shows the pulsating supply current waveform which contains a rich of harmonics while Figure 7 shows the comparison of the THD level without filter from the pulsating supply current with the IEEE 519 standard regulation. Since the pulsating supply current violated the IEEE 519 standard regulation, an APF configuration circuit is integrated to the boost rectifier to mitigate the harmonic distortion.

Figure 8 shows the sinusoidal supply current waveform of the proposed APF function, whilst Figure 9 shows that the supply current follows the sinusoidal waveform of reference current when APF is applied. Figure 10 shows that the supply current and voltage waveforms are in-phase, thus increase the power factor.

The comparison result of the THD level without any filter function and with the proposed APF function is as tabulated in Table 2. It shows that the THD value without any filter function is 152.56%, whilst, with the proposed APF function, the THD level was reduces to 1.62%. Thus, it shows that the corrective waveforms was achieved and it complies with IEEE 519 standard as shown in Figure 11.

Figure 12 shows the step response signal with I_{ref} that represents both current and two different amplitudes for two cycles from 0s to 0.04s and 0.04s to 0.08s. Technically, it proves that the input line current will entirely follow the sinusoidal reference current.



Figure 6. The pulsating supply current from supply current and supply voltage



Figure 7. Comparison value for THD level between Simulation and IEEE 519 Standard without filter

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Figure 8. The input supply current waveform



Figure 9. The input supply current with sinusoidal reference current



Figure 10. The input supply current and input supply voltage waveforms



Figure 11. Comparison value for THD level between Simulation and IEEE 519 Standard with filter



Figure 12. The step response signal with $I_{ref} = 1.5$ A at 0.04s and $I_{ref} = 3$ at 0.08s

6. CONCLUSION

In this paper, the proposed APF using boost rectifier technique has been presented. From the evaluation via MATLAB/Simulink, it was found that the THD level of the rectifier converter without filter is higher compared with APF. By using the proposed APF function, we can reduce the THD level, thus, complying with the IEEE 519 standard. Finally, the use of APF circuit configuration can further improve the power quality problems.

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