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Power Factor Improvement of AC-DC Converter Based on Separately Excited DC Motor Using Passive Filter

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Abstract

In industries DC motor drives are very essential due to their high performance applications such as its reliability, ease of control, low cost and simplicity. And speed control of these motors is very easy due to power electronic AC-DC converters. These power electronic converters are with prominent low power factor and higher Total Harmonic Distortion (THD). These converters operate only for short time resulting non-sinusoidal waveform. This problem of harmonic distortion can be mitigated by reshaping the non-sinusoidal waveform to pure sine wave. Different wave shaping techniques have been developed by using different filters among which one is tuned passive filter. This paper proposed power factor improvement and harmonic mitigation of AC-DC converters based on separately excited DC motor using tuned passive filter. In this context experimental model is designed and results are analyzed by power quality analyzer.

Keywords

DC Motors, AC-DC Converters, Power Factor, Total Harmonic Distortion, Passive Filters

1. Introduction

DC (Direct Current) power supplies are important and extensively used in many electrical and electronics applications such as computers and telecommunication equipment. Because of the friendly technology electrical ve-

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hicle is rapidly increasing; thus DC power is becoming the heart of these systems [1] [2]. To achieve this DC recently a large number of different AC-DC converters have been developed and due to their low cost, high efficiency and fast switching actions these converters are used in DC motors on a large scale. DC motor drives have very essential industrial applications and are widely used because of its high performance. Speed control of DC motor is very easy by power electronic converters. And due to its favorable cost, reliability, simplicity and ease of applications DC motors have long been the backbone of industrial application [3]. AC-DC converters are playing a vital role in power electronics. In these power electronic converters, the AC supplies can be converted to DC. The non-linear natures of power electronic devices are of prominent harmonic distortion and low power factor which are of great concern [4]. It is also well known fact that AC-DC supplies suffer from two drawbacks *i.e.* current distortion and low power factor [5].

According to IEEE standards 519-1992, the harmonic distortions produced by power electronic devices should be under specific value that any individual harmonic should not be exceed more than 3% and total harmonic distortion should not be more than 5% [6].

Therefore, it is evidence that THD should not exceed more than 8% when load applied is varying and continuously changing and should be 5% when full-load is applied [7].

2. AC-DC Converters

A power electronic device which converts main AC voltage to DC voltage is called AC-DC converters. AC-DC converters are used in many applications such as in DC Motor speed control, Power supplies, Converters at the input end of DC transmission line, Portable hand tool drives and Solid state switch applications [8].

Effects of AC-DC Converters

- Voltage drops at the buses.
- Causes blown of fuses on power factor correction capacitors due to flow of high current and high voltage.
- Electromagnetic interference with the communication circuits.
- Heating of transformers, generators.
- Increase losses in the equipment connected to the utility such as transformers and motors.

3. Harmonics

The harmonics are defined as "a wave whose frequency is an integer multiple of the fundamental frequency" it can be odd harmonics or even harmonics. As power system is designed to operate with pure sinusoidal voltage and current with a constant frequency which is also known as fundamental frequency but by connecting the non-linear power electronics loads like diode and thyristors to the system causes excessive harmonics current which causes distortion of voltage and current. This in turns results power quality problems [9].

Main Problem of Harmonics

- Additional losses in supply generators and transformers.
- Neutral conductor overloading.
- Interference to communication.
- Over loading of power factor correcting capacitors supply voltage distortion.
- Error in energy meters.
- Malfunction of sensitive equipment.
- Reduced power factor to low values.

4. Single Tuned Passive Filters

By using passive elements like inductor, capacitor and resistor passive filters are designed so Passive filter consists of a certain combination of inductor capacitor and resistor as shown in **Figure 1**, which used to reduce the harmonic current [9] [10].

Many topologies for harmonic mitigation and active filter are used to control the harmonic. But power more than 1 MW passive filters are the best choice because some of the advantages such as low cost, simple design and high reliability. A single installation of passive filter can service many purposes *i.e.* reactive power compensation, power factor improvement, total harmonic distortion to acceptable limits. A well designed passive filter can be implemented in large sizes of MVAr ratings and provide almost maintenance free service [11].

5. Research Objectives

The objective of this research work is to develop an experimental model of single phase AC-DC converters based separately excited dc motor to analyze the harmonics caused by nonlinear nature of power electronics AC-DC converters and using single tuned passive filter to reduce harmonics according to IEEE standards 519-1992 and power factor improvement.

6. Research Methodology

This research work is based on experimental setup and the methodology used for this research work is given as

- Development of experimental setup of dc motor with rectifier.
- Power factor and harmonic analysis of experimental models.
- Power factor improvement by using passive tuned filter.

7. Experimental Setup

Figure 2 shows the experimental setup of rectifier based separately excited dc motor it can be seen from the **Figure 2** that the input supply is AC. To convert this AC into DC AC-DC converter is used. Power quality analyzer is used to measure the harmonic distortion and the power factor before and after installation of filter. Single tuned passive filter is used to improve the power factor and reduce the THD caused by AC-DC converter according to IEEE standard 519-1992. **Figure 3** shows the developed experimental model of the research work.

8. Harmonics and Power Factor before and after Installation of Filter At-Load

Figure 4 and **Figure 5** show the wave spectrum of AC-DC converter at-load without and with installation of

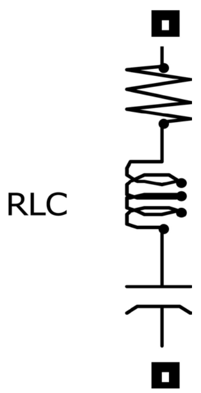

Figure 1. Tuned passive filter.

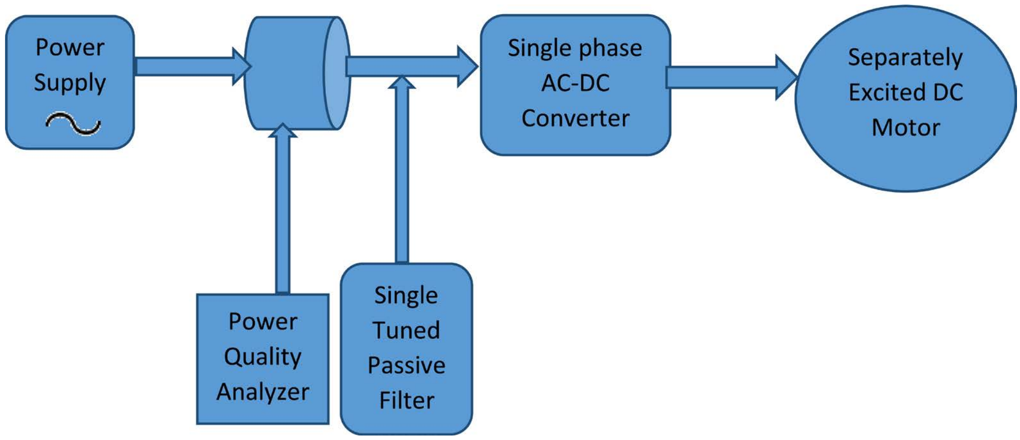

Figure 2. Experimental setup of rectifier based separately excited DC motor.

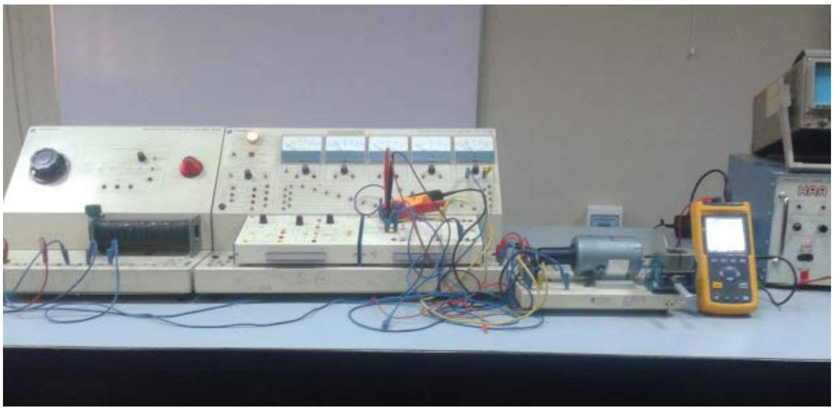

Figure 3. Experimental model of research work.

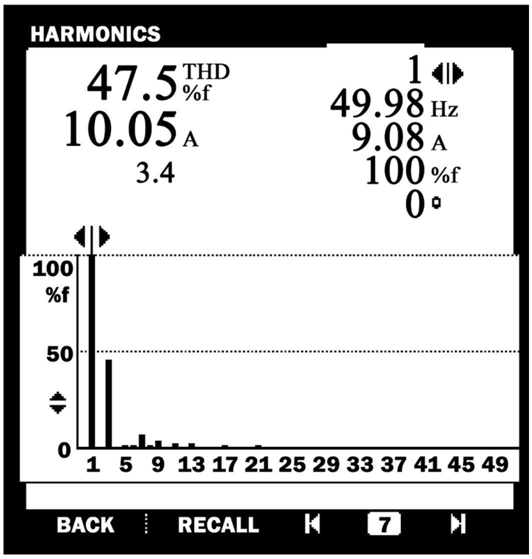

Figure 4. Wave spectrum of THD without filter.

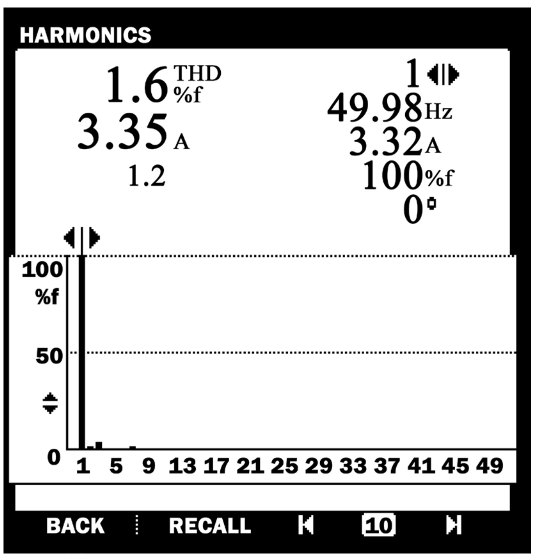

Figure 5. Wave spectrum of THD with filter.

passive filter. It can be seen from the wave spectrum in **Figure 4** that without installation of filter the THD measured is 47.5% which is very high to reduce the high THD passive filter is used and it can be seen from **Figure 5** that after installation of passive filter the THD reduced from 45.5% to 1.6% at-load.

Similar to THD the power factor without filter is 0.67 as shown in **Figure 6** which is very low but **Figure 7** shows that after installing filter the low power factor has been improved from 0.67 to 0.99.

Table 1 shows a comparison of power factor and THD with and without filter at-load. It can be seen from

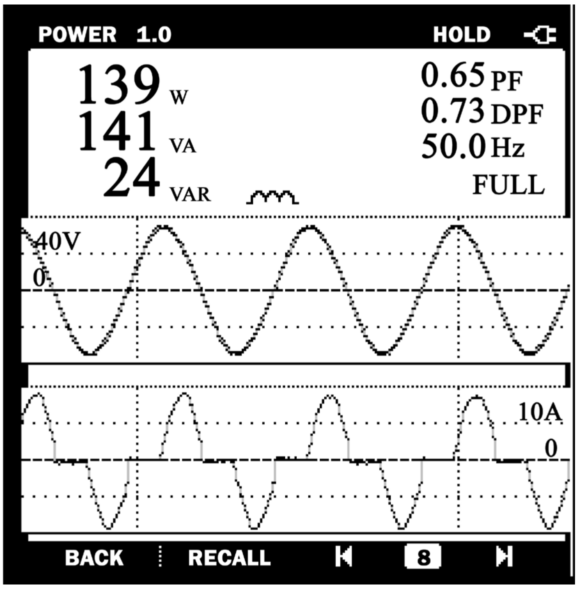

Figure 6. Power factor without filter.

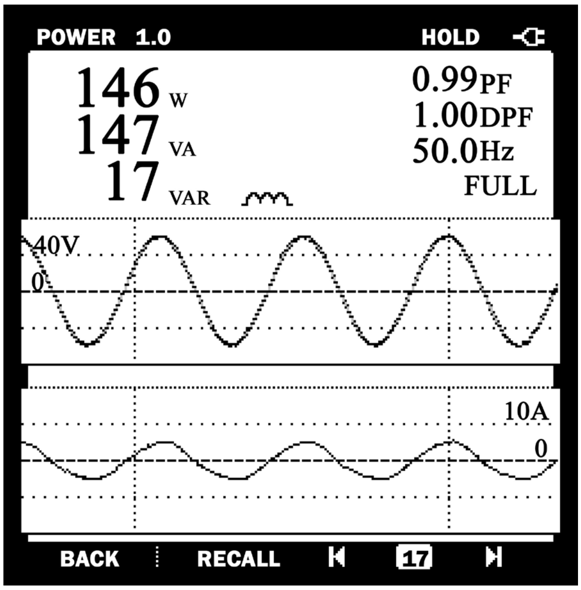

Figure 7. Power factor with filter.

Table 1. Power factor and total harmonic distortion with and without filter at-load.

S.No	Conditions	Power Factor (PF)		Total Harmonic Distortion (THDi) %	
		Without Filter	With Filter	Without Filter	With Filter
1.	**At load**	0.65	0.99	47.5	1.6

the **Table 1** that without filter the power factor at-load is very low *i.e.* 0.65. To improve this power factor single tuned passive filter is used. After installation of filter the power factor has been improved up to 0.99. Similarly without filter the total harmonic distortion was very high *i.e.* 47.5% but after installation filter it has been reduced to 1.6%.

9. Graphical Representation of PF and THD with and without Filter

Figure 8 and **Figure 9** show the comparison of power factor and THD by graphical representation. It can be

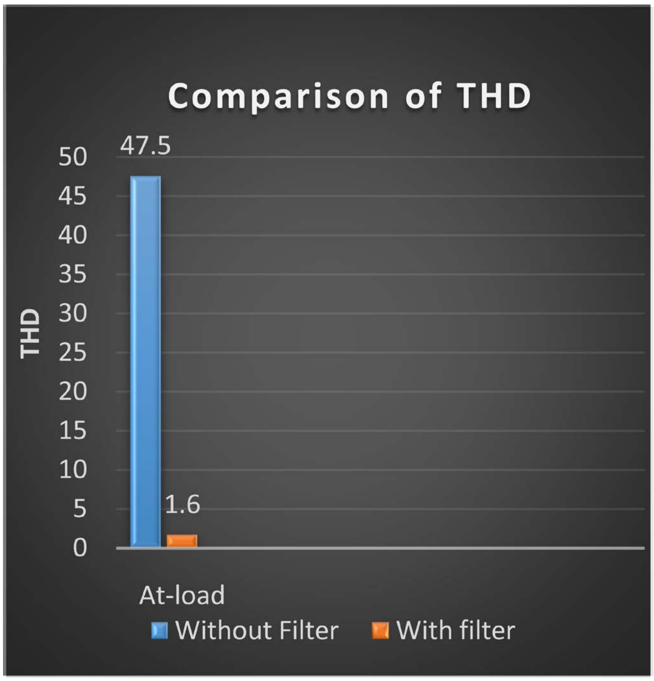

Figure 8. Graphical representation for the comparison of THD with and without filter.

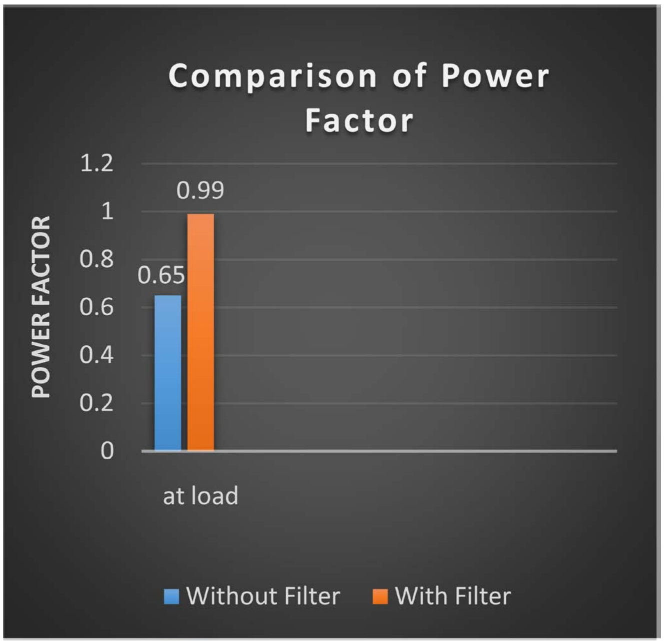

Figure 9. Graphical representation for the comparison of power factor with and without filter.

seen from the comparison that without installation of filter the power factor is very low and total harmonic distortion is very high but after installation tuned passive filter the power factor improved to unity and total harmonic distortion reduced according to IEEE standard 519-1992.

10. Conclusion

In this research work power factor and total harmonic distortion of separately excited DC motor controlled with AC-DC converter has been analyzed at-load. The tuned passive filter is also designed in this research work. From the experimental results, it is concluded that the total harmonic distortion (at-load) has reduced within the range of IEEE Standards 519-1992. It has been seen that without filter the power factor of DC motor was very low *i.e.* 0.65 at-load and total harmonic distortion was very high 47.5%. After development of single tuned filter, it is clear from experimental results that THD reduced within the range of IEEE standards 519-1992 and the power factor is improved near to unity at-load.

Future Work/Suggestions

As this research work was done on single phase converter using single tuned passive filter the same work can be extended on three phase AC-DC converter based DC drives. This research work can be extended to implement passive filters in field control methods of DC drives. Instead of single tuned passive filter we can also use parallel input resonant filter, series input resonant filter.

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