Minimization of Harmonic Distortion of Industrial Motor Drives with Active Power Filter in Paper Mill - a Case Study

Y.Kusumalatha, Ch.Saibabu, and Y.P.Obulesu

***Abstract*—With the increasing of non-linear loads in electric power system, power quality distortion has become a serious issue in recent years. In paper and pulp industries, due to presence of concentrated high power non-linear loads such as electric drives, this problem is a greater concern. In this paper, the impacts of harmonic distortions on the electric drives in Delta paper mill, Vendra, West Godavari(Dist),Andhra Pradesh, India is investigated. The harmonic measurement is done with Fluke 434 power quality analyzer. Different solutions exist to reduce the harmonic emission of Adjustable Speed Drives in order to fulfill the requirements of the international harmonic standards. In recently active power filters gained an increased attention due to their effective harmonic reduction. In this paper an active power filter has been designed for minimization of the harmonics, which is implemented in matlab/simulink based on real time measurement of the harmonic data.**

***Index Terms*— Variable Speed Drives, Harmonics, Delta Paper Mill (DPM), Power Quality, power quality analyzer, minimization of harmonics and active power filter**

I. Introduction

In modern power systems, due to increase of non-linear loads, power quality has become a great concern. Non-linear loads, which were only 15% of total loads in 1987, have increased to 50% in 2000[1,2,8,9]. In the paper industry, the main production line needs high quality electric power because it consists of several coupled motors working simultaneously together with precise speed. These power quality disturbances cause paper breaks that require a long time to clean the machinery and resume production. They may also blow the rectifier fuses in the DC drives because of higher transient current [1-3]. In the Delta paper mill plant, there are 15 DC drives on the paper machine working together. Tripping the paper machine, usually, causes other areas of the paper mill such as wood handling and pulp preparation to stop [4]. The latest investigations show that the cost of poor power quality for industry is about $US12 billion per year [5,6]. The transient voltage variations are caused by lightning strikes, switching of power lines and capacitor banks, system faults, and large motor start-ups. Therefore, a good power quality monitoring system is essential for the paper mills in order to decrease the downtime and increase the efficiency. Although, electric drives are sensitive to voltage distortions, they are also one of the major sources of current harmonics generation and power quality problems [9]. Electric drives draw non sinusoidal currents from the electrical power system[10,11]. The current harmonics passing through the impedance of the power system create non-linear voltage drops and cause voltage distortions. Therefore, the input voltage provided to the distribution transformers is not pure sinusoidal. One of the major effects of harmonic distortions is increasing transformer losses. In presence of harmonics, the load loss, eddy current loss, and other stray losses are increased. Possible problems include transformer overheating, motor failures, fuse blowing, capacitor failures, and mal-operation of controls [12]. In addition, they increase the hot spot temperature of the transformer which results in loss of life. Furthermore, if voltage harmonics level is more than standard, audio noise and no load loss will also be increased in transformers.

In this paper, the impacts of harmonic distortions on the electric drives in Delta paper mill, Vendra, West Godavari(Dist), Andhra Pradesh, India, which is major supplier of different kinds of paper to most of the industries/organizations in south India, is investigated. The harmonic measurement is done with Fluke 434 power quality analyzer. A large diversity of solutions exists to reduce the harmonic emission of Adjustable Speed Drives in order to fulfill the requirements of the international harmonic standards. In recently active power filters gained an increased attention due to their good harmonic reduction. In this paper an active power filter has been designed for minimization of the harmonics and results are presented in terms of % THD without and with active power filter, which is implemented in Matlab/Simulink based on real time measurement of the harmonic data.

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II. OVERVIEW OF PAPER MILL

Delta Paper Mill is one of the paper manufacturers in South India with capacity of 51100MT/annum of quality writing and printing papers. It has three paper machines.

A part of single line diagram is shown in Fig. 1. The 415V incoming line is fed by a 500MVA 415V/240V transformer. From the power quality point of view, the paper machine section is the most important part because of its continuous process. Most of the variable speed drives of the plant are used in the paper machine section and work continuously with multi drive control strategy. AC and DC drives are more sensitive to the voltage sag because of the power electronic switches. There are 10 DC drives for DPM.NO-1 manufacturing section. Each DC drive has microcontroller processor board and its speed is regulated with static accuracy lower than 0.01% and dynamic accuracy lower than 0.1% with pulse transducer.

III. HARMONIC MEASUREMENT

Fluke-434 power quality analyzer was used to monitor the power quality parameters. This is installed on the 440V (230V phase to ground) paper machine drive incoming feeder. There were 4 potential transformers (PT) for voltage measurement; therefore, three phase voltages could be monitored. It sampled all three voltages and three currents of the system. Using a Fluke-434 three phase power quality analyzer serial data transfer, and with Fluke view software, the recorded data was transferred to a computer. The quantities such as power factor, Total Harmonic Distortion (THD), harmonic order magnitude, active and reactive power, sag and swell were transferred to the personal computer through the software. In the case of under voltage, over voltage, and over current, 20 cycles waveform (10 cycles before and 10 cycles after event) were saved in the analyzer for later analysis. The under voltage threshold was set to 18 KV for the fixed analyzer, and 210 V for the portable one. The over voltage threshold was set to 22 KV for the fixed and 250 V for the portable analyzer phase to ground voltage. The over current thresholds were set to 3000A and 500A for the fixed and portable analyzers, respectively.

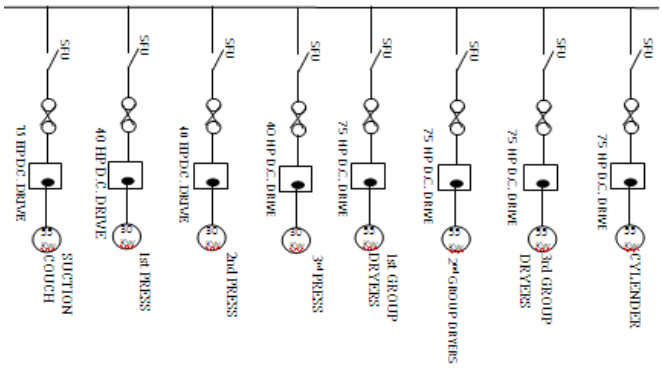

Fig. 1. part of single line diagram of in paper mill

IV. ANALYSIS OF MEASURED HARMONIC DATA

Large DC motor drives are extensively utilized in Delta paper mill. The most used front-end topology for the ASD's is 6-pulse thyristor rectifiers, due to well-known advantages such as, high efficiency, robustness and reliability. Nevertheless, the major drawback of this type of ASD is the emission of the harmonic currents. Fig. 2 to Fig. 10 showed the harmonic spectrum of voltage and currents for different motor drives and summarized in Table I for all the motor drives in Delta paper mill. From the Table I, it is observed that %THD of certain electric drives is very high and beyond the International standards. Hence, harmonics need to be reduced, for which different solutions are available such as adding line reactors, passive harmonic filters but Active power filter is most preferred for effective harmonic reduction, i.e, even in non-ideal supply voltage (e.g. unbalance, voltage pre-distortion) these types of harmonic filters ensure effective minimization of Total Harmonic Distortion (THD). Therefore, many applications currently in use can replace the common line reactors with an advanced active power filters if the cost performance balance leans to a positive investment.

V. HARMONIC PROFILE WITHOUT FILTER

4.1.1 Suction-couch drive

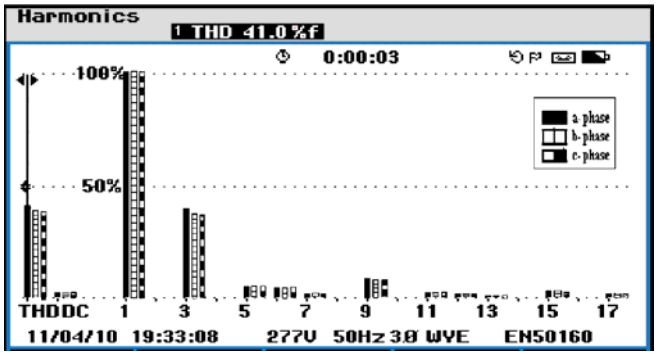

Fig. 2(a): Voltage of suction couch drive

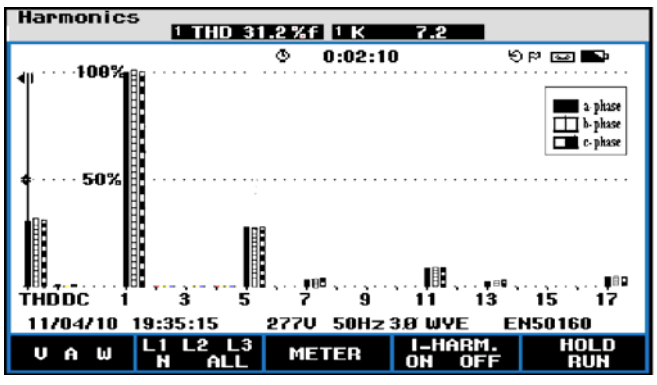

Fig. 2(b): Current of suction couch drive

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4.1 HARMONIC PROFILE WITHOUT FILTER

4.1.2. 40 hp 1st press drive

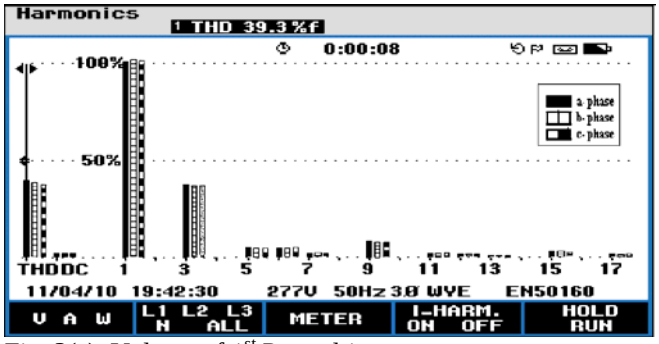

Fig. 3(a). Voltage of 1st Press drive

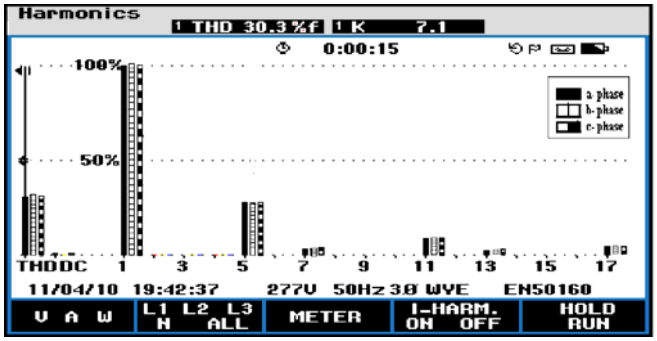

Fig. 3(b).Current of 1st Press drive

4.1.3. 40 hp 2nd press drive

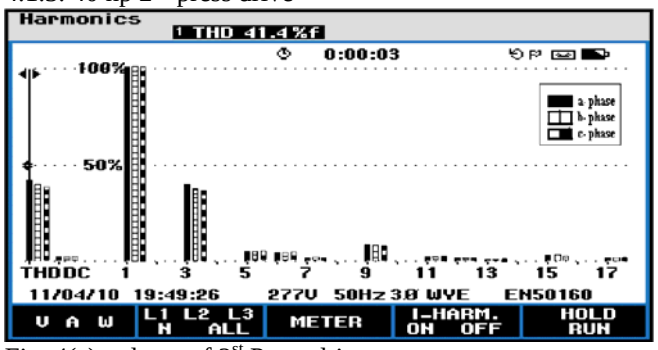

Fig. 4(a).voltage of 2st Press drive

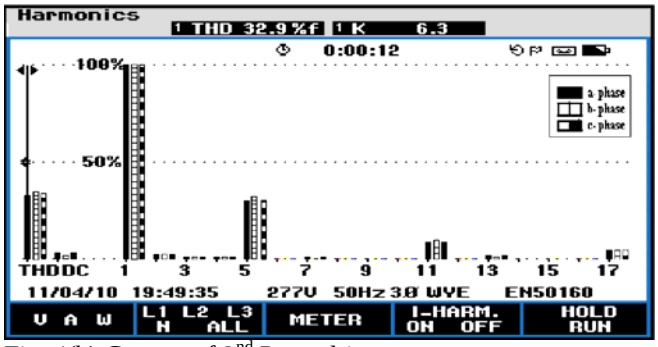

Fig. 4(b).Current of 2nd Press drive

4.1.4 40 hp 3rd Press Drive

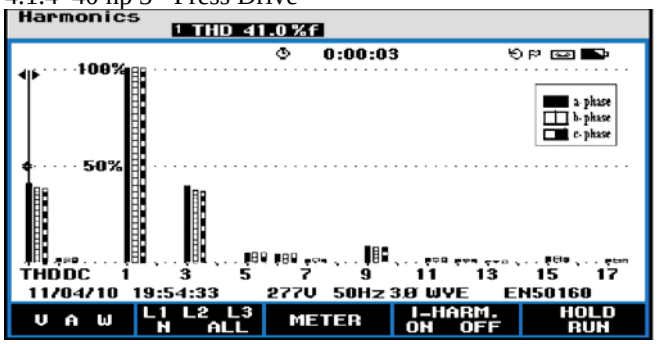

Fig. 5(a).voltage of 3rd Press drive

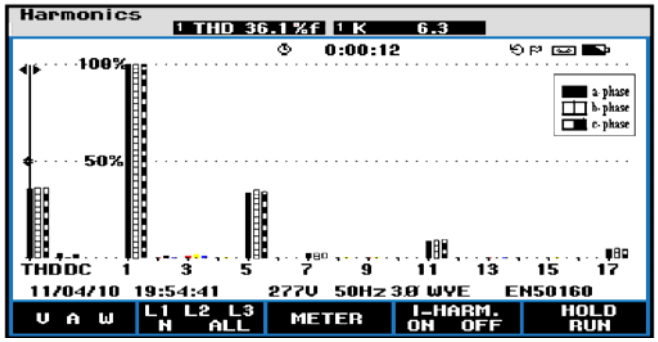

Fig. 5(b).Current of 3rd Press drive

4.1.5. 75 hp 1st Group Dryer

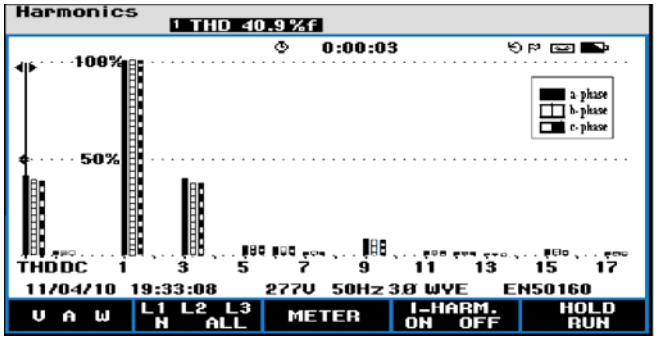

Fig. 6(a).voltage of 1st Group dryer drive

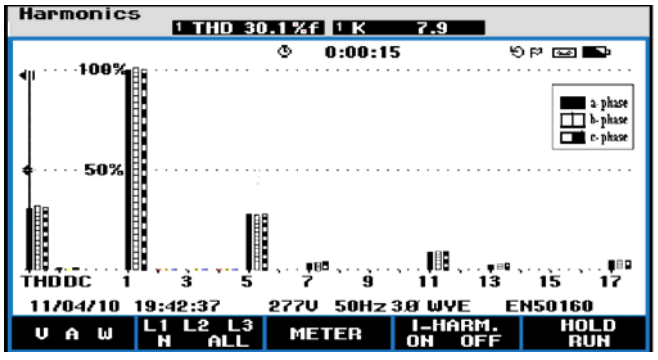

Fig. 6(b).Current of 1st Group dryer

4.1.6. 75 hp 2nd Group Dryer

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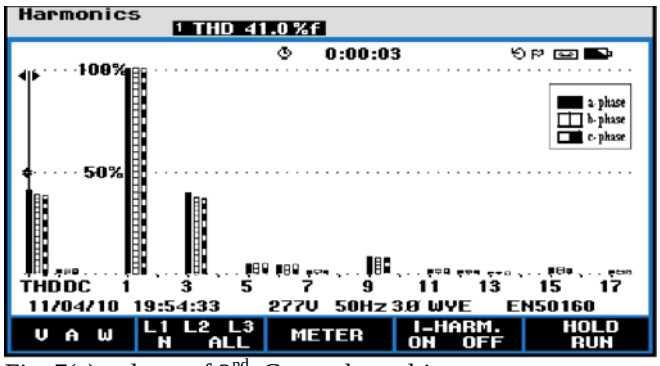

Fig. 7(a).voltage of 2nd Group dryer drive

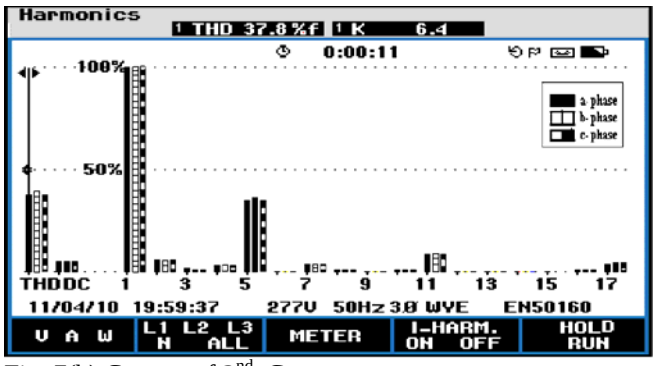

Fig. 7(b).Current of 2nd Group dryer drive

4.1.7. 75 hp 3rd Group Dryer

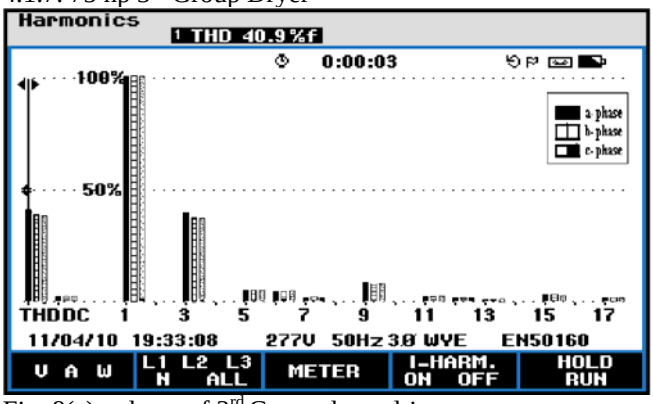

Fig. 8(a).voltage of 3rd Group dryer drive

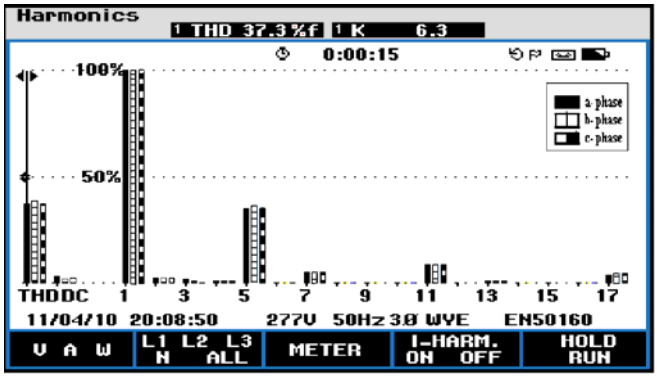

Fig. 8(b).Current of 3rd Group dryer

4.1.8. 25 hp Pope Reel Drive

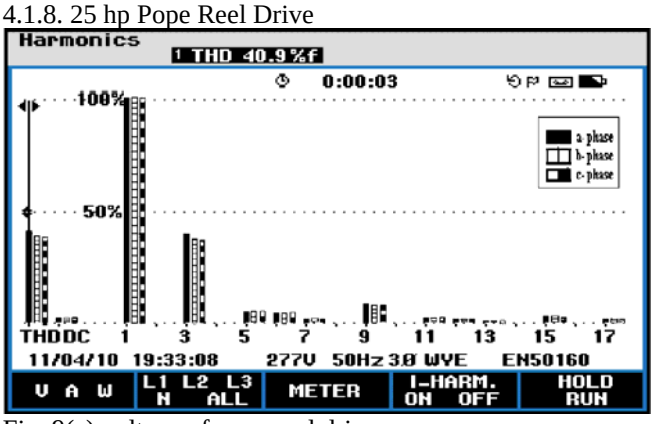

Fig. 9(a).voltage of pope reel drive

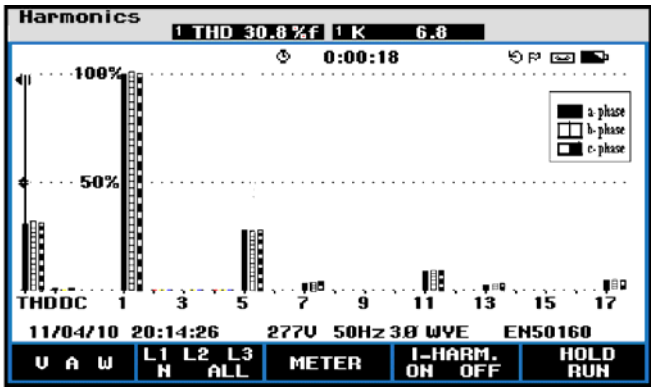

Fig. 9(b).Current of pope reel drive

4.1.9. 75hp Calendar Drive

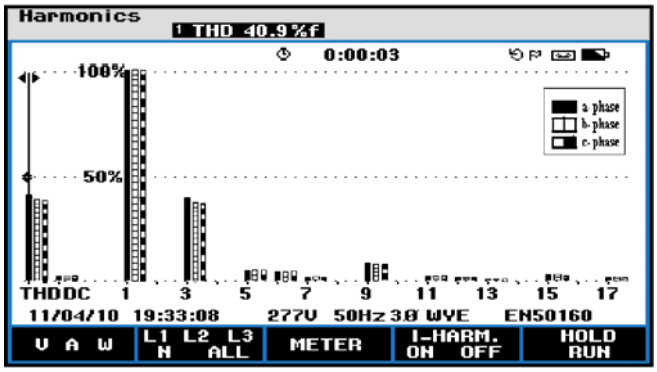

Fig. 10(a).voltage of Calendar drive

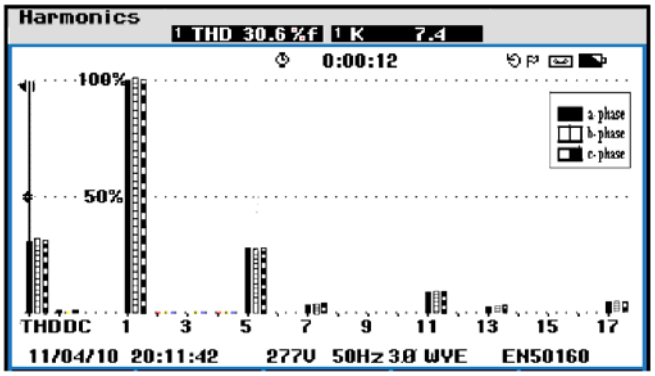

Fig. 10(b).current of calendar drive

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Table I: Harmonic content of various motor drives

S. no	Name of drive	Voltage %THDv	Current %THDi	Remarks
1	Suction-couch drive	41.0%	31.2%	Above normal level
2	40 hp 1st press drive	39.3%	30.3%	Above normal level
3	40 hp 2nd press drive	41.1%	32.9%	Above normal level
4	40 hp 3rd Press Drive:	41.0%	36.1%	Above normal level
5	75 hp 1st Group Dryer	40.9%	30.1%	Above normal level
6	75 hp 2nd Group Dryer	41.0%	37.8%	Above normal level
7	75 hp 3rd Group Dryer	40.9%	37.3%	Above normal level
8	25 hp Pope Reel Drive	40.8%	30.8%	Above normal level
9	75hp Calendar Drive	40.8%	30.6%	Above normal level

VI. HARMONIC MINIMIZATION WITH ACTIVE POWER FILTER

From Table I, it is observed that the considerable amount of harmonic distortion is present in both voltage and current waveforms of all the motor drives. In order to reduce the harmonic content of the motor drives an active power filter has been designed for 75 hp 2nd Group Dryer which is having highest THD in voltage and current and it is implemented using Matlab/Simulink. The block diagram of a dc drive control is shown in Fig.11. The same can be implemented for other drives also. Results are obtained for harmonic profile with active power filter and shown in Fig. 12 and Fig.13.

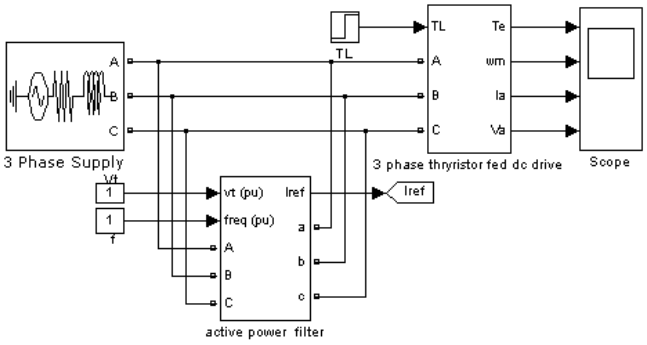

Fig 11. Simulink model of DC motor drive with active filter

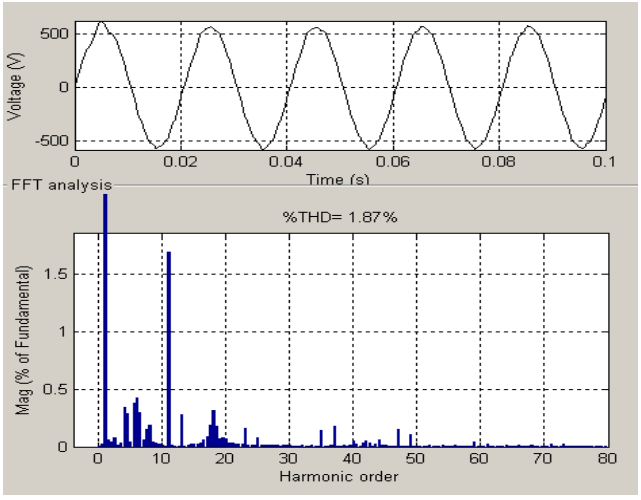

Fig 12. line side voltage with filter

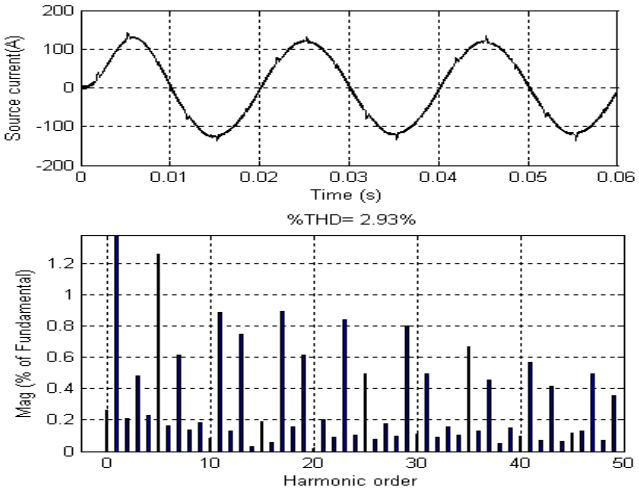

Fig. 13. Line side current with filter

Table II. Comparison of %THD For 75hp group dryer drive

	%THD Without filter	%THD With filter
Voltage	37.07	1.87
Current	26.54	2.93

VII. CONCLUSION

Both voltage and current harmonics at supply side have been measured practically at 75 hp dc motor drive using fluke 434 power harmonic analyzer and results are presented. The results of the harmonic measurements of voltage and current showed that there is large amount of harmonic content (%THD) presented in the supply voltage and current. These investigations reveal that filtering is required for the drives in the paper mill to reduce the

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harmonic content in electrical supply system. Hence, active filter has been designed for the dc motor drives. By simulation of a DC drive system with Matlab/simulink software, effects of different kinds of harmonics on speed, torque, and armature current of the motor have been analyzed and from the results, From the Table II, it is very clear that the harmonic content has been reduced to a great extent with active power filter. The speed of the motor is not affected significantly due to high moment of inertia of the load

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