Harmonic Analysis of Eddy Current Drive

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ABSTRACT
Many industrial applications require rotating electric drives. These drives are normally capable of speed control and often require an equipment to attain a versatile and smooth speed control and to make the motor to operate on a desired specific speed torque characteristic. The variable speed application of a drive is becoming more and more significant where a wide range of speed is required. Also, it must necessarily have a precise speed control of speed for application to a particular job i.e. for crushing mill in sugar industry.

Keywords
Eddy Current Drive, Output torque, Effect of harmonics, Result

1. INTRODUCTION
This paper describes the actual implementation of eddy current drive for crushing mill machine in sugar cane industry at M.S.S.K (MadhukarSahakariSakharKarkhana)Nhavimarg, Faizpur District: Jalgaon in 1975. Conventionally, eddy current drive is used for varying the speed of cane carriers in sugar plant. Eddy current drive is an electromechanical device, which operates on eddy current principle. In eddy current drive, speed is varied by varying the field of eddy current coupling. The speed is externally controlled and the operating efficiency of eddy current drive is around 80%. A 3 Ø, 440 V, 50 Hz, 1440 rpm,45 kW/60 h.p, and flange mounted squirrel cage induction motor mechanically coupled with eddy current coupling is used in operation for varying the speed of cane carriers.

A growing power quality concern is harmonic distortion that is caused by the non linearity of customers loads. This concern has drawn much attention from many utilities, manufactures of equipment and users[1].Harmonic distorts the waveform shape of voltage and current and increases the current level which results in many disturbances.

IEEE STD 519-1992 is "The IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems". Tables 1(a) and 1(b) define the recommended limits for total harmonic distortion (THD) and individual harmonic distortion for voltage and current at the point-of-common-coupling (PCC) with the utility[1],[2].

Table-1. IEEE Std 519-1992 Voltage Distortion Limits

MAXIMUM VOLTAGE DISTORTION IN %			
	≤ 69 kV	69-161 kV	≥ 161 kV
Maximum For Individual Harmonic	3.0	1.5	1.0
Total Harmonic Distortion (%)	5.0	2.5	1.5

Table –II IEEE 519 Current Distortion Limits for General Distribution Systems (120 V through 69,000 V)

MAXIMUM CURRENT DISTORTION IN PERCENT OF I_L						
	Individual Harmonic Order (Odd Harmonics)					
I_{SC} /I_L	<11	11≤ h ≥17	17 ≤h ≥23	23≤h≥ 35	35≤ h	% TDD
< 20	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0
Where Isc= Maximum short circuit current and IL=maximum load current						

2. 2. EDDY CURRENT DRIVE UNDER STUDY
Electromagnetic drives, or eddy-current couplings, have more in common with mechanical adjustable speed drives than they do with other electrical drives. These drives use a speed adjustment mechanism located between a constant-speed motor and the load rather than an adjustable voltage or frequency power supply controlling the speed of dc or ac motors. Another aspect in common with mechanical drives is that they are inherently single-motor units. The drive unit consists of a constant-speed ac induction motor and a magnetic clutch or eddy-current coupling. The variable-speed output shaft is rotated for the constant-speed ac motor through the action of the eddy-current coupling.

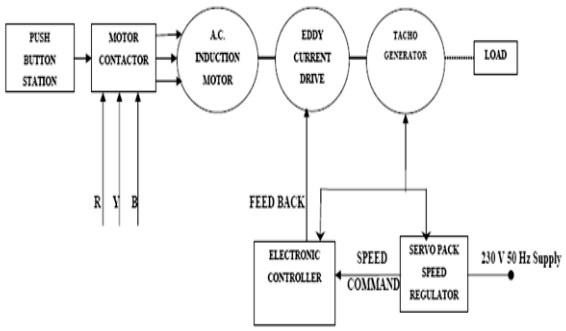


Fig.1 Schematic representation of eddy current drive in M.S.S.K Sugar Industry

Fig.2 Photograph of implemented eddy current drive in M.S.S.KSugar Industry

Table-III. Specification of three phase induction motor

Specification's	Induction Motor (Is325)
Construction Type (IS 2223)	Flange Mounted Induction Motor
Manufacturer	M/S Bharat Bijlee Limited, Mumbai
Output in Kw / H.P.	45 / 60
Rotor Type	Squirrel Cage Type
Power Factor	0.88 (Lag)
Input A.C.Voltage (Volt)	440 ± 10 %
Full Load Current (Amp.)	76.5
Rated Torque in N-M	29.80
Efficiency (%)	93.2
Frequency (Hz)	50
Full Load Speed (R.P.M)	1470
No. Of Poles	4
No. Of Phases	3
Insulation Class	F
Temperature Rise	Class B Limit
Motor Weight In Kg.	362
Rotor Inertia In Kg-M2	1.60
Ratio Of Starting Current To Rated Current	600%
Ratio Of Starting Torque To Rated Torque	250%
Ratio Of Pull Out Torque To Rated Torque	250%
Degree Of Protection (IS 4691)	IP 55
Ambient Temperature (^{0}c)	40
Cooling System (IS6362)	TEFC (Totally Enclosed Fan Cooled)

3. OUTPUT TORQUE OF EDDY CURRENT DRIVE

The output torque is essentially equal to the input torque since friction, windage, and inertial torque are usually negligible. As shown in Fig.3-a, with a fixed amount of excitation applied to the coil, the output speed of the clutch will vary as the load is increased or decreased at points 1 and 2 of the torque speed curve. In Fig.3-b by varying the level of excitation to the coil, the amount of linkage effect and, consequently, the amount of torque transmitted from the ac motor to the output shaft can be varied. (See points 1 and 2 of the torque-speed curve in Figure 3.) Varying the output shaft torque enables the adjustable speed drive to maintain a set speed with a varying load [3]. Torque transmission is accomplished magnetically without physical contact of members. Consequently, there is no wear to require adjustment and replacement of parts.

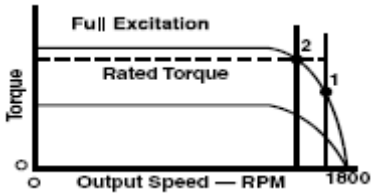


Fig. 3 Torque-speed curve at fixed excitation

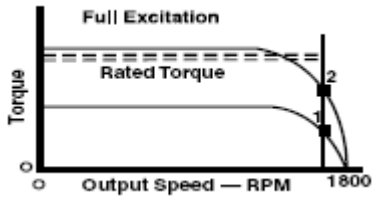


Fig.4 Torque-speed curve at variable excitation

4. EFFECT OF HARMONICS ON EDDY CURRENT DRIVE

Harmonic distortion is a form of electrical pollution that can cause problems if the sum of the harmonic currents increases above certain limits [5]. A harmonic current is one with a frequency at a multiple of the fundamental frequency, for instance a 250 Hz current on a 50 Hz network is the 5th harmonic[6],[7]. The 250 Hz current represents energy that cannot be used by devices on the network. It will therefore convert to heat. According the International Electro technical Commission (IEC), the level of harmonics is described by the total harmonic distortion (THD) and is expressed as a percentage of the total voltage or current.

Harmonics may cause cables to overheat, damaging their insulation. Motors may also overheat or become noisy and torque oscillations in the rotor can lead to mechanical resonance and vibration.

IEEE 519-1981 specified limits for voltage distortion which is referred to as Total Harmonic distortion (THD). This standard stated that the total voltage distortion factor is related to the total notch area. As ASD technology, IEEE 519-1992 maintains the limits for notch area and THD and adds limits for total current distortion. The new standard added current distortion limits because harmonic voltage distortion is afunction of the total injected harmonic current and the systemsimpedance at each of the harmonic frequencies [4].

5. RESULTS OF HARMONIC ANALYSIS

The results obtained from actual measurement ineach mode are given below:

Figure 5shows Table of Voltage produce at nth order of harmonic and harmonic analysis bar graph (Plot between voltage vs harmonic number). It indicates that high voltage is produced at fundamental harmonic number but if you see 3rd, 7th and 11th harmonic order, low voltage is produced. So the percentage of voltage harmonics is produced at 3rd of 2.27 % , 5th of 71 % and 7th of 4.54 %.

Table-IV.Voltage produces at n^{th} order of harmonic

S.N.	Harmonic Order Number	Voltage
1	FUNDAMENTAL	880
2	3^{rd}	20
3	5^{th}	625
4	7^{th}	40
5	9^{th}	350
6	11^{th}	100
7	13^{th}	220
8	15^{th}	250
9	17^{th}	70
10	19^{th}	170
11	21^{st}	90
12	23^{rd}	200
13	25^{th}	30

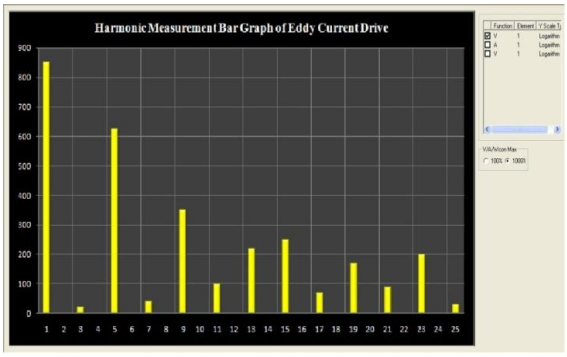
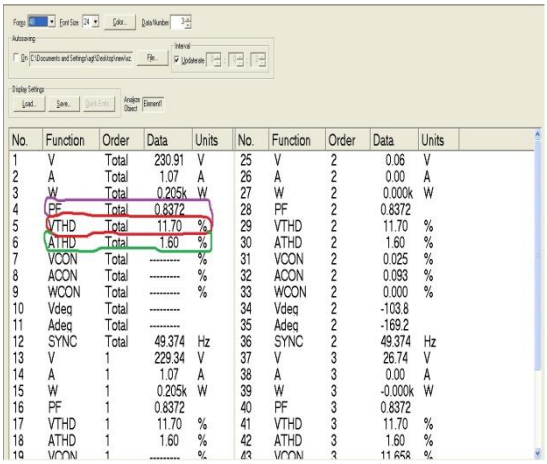


Fig.5 Harmonic analysis bar graph (Voltage v/s harmonic order number)

Figure 6 shows actual harmonic measurement readings of eddy current drive. It indicates how much Total Harmonic Distortion voltage and Total Harmonic Distortion current is produced. Also, it gives load power factor is of 0.8372 (lag).



No.	Function	Order	Data	Units	No.	Function	Order	Data	Units
1	V	Total	230.91	V	25	V	2	0.06	V
2	A	Total	1.07	A	26	A	2	0.00	A
3	W	Total	0.205k	W	27	W	2	0.000k	W
4	PF	Total	0.8372		28	PF	2	0.8372	
5	VTHD	Total	11.70	%	29	VTHD	2	11.70	%
6	ATHD	Total	1.60	%	30	ATHD	2	1.60	%
7	VCON	Total	---------	%	31	VCON	2	0.025	%
8	ACON	Total	---------	%	32	ACON	2	0.093	%
9	WCON	Total	---------	%	33	WCON	2	0.000	%
10	Vdeg	Total	---------		34	Vdeg	2	-103.8	
11	Adeg	Total	---------		35	Adeg	2	-169.2	
12	SYNC	Total	49.374	Hz	36	SYNC	2	49.374	Hz
13	V	1	229.34	V	37	V	3	26.74	V
14	A	1	1.07	A	38	A	3	0.00	A
15	W	1	0.205k	W	39	W	3	-0.000k	W
16	PF	1	0.8372		40	PF	3	0.8372	
17	VTHD	1	11.70	%	41	VTHD	3	11.70	%
18	ATHD	1	1.60	%	42	ATHD	3	1.60	%

Fig.6: Harmonic produced in eddy current drive

Figure 7 and 8 shows output waveform of voltage and current harmonics. This output waveform is distorted. The current harmonics depend on the drive construction and load. Factors that increase current harmonics include: No network choke and higher motor load. Factors that decrease current harmonics include: Greater DC or AC inductance, higher number of pulses in the rectifier and active rectifier. Factors that decrease voltage harmonics caused by the harmonic currents: larger transformer, lower transformer impedance and higher short circuit capacity of supply

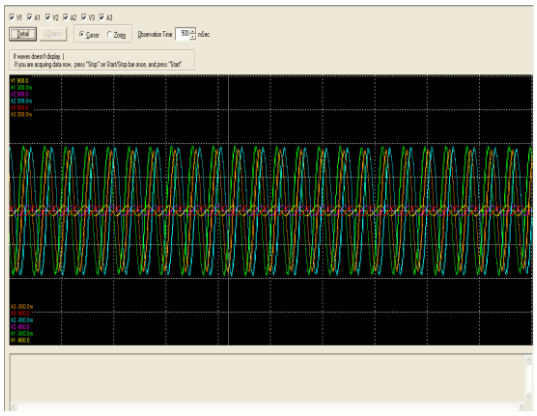


Fig.7 Output waveform of eddy current drive including voltage and current harmonics

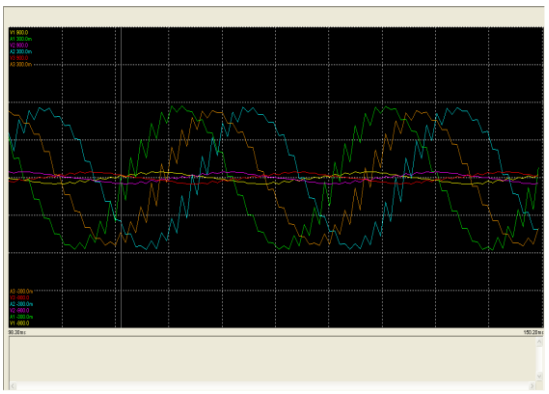


Figure 8: Zooming of Output waveform of eddy current drive including voltage and current harmonics

6. APPLICATIONS OF EDDY CURRENT DRIVE

The major application of Eddy Current Drives is mostly found in the following industries:

1. Sugar Industry for Crusher Machine
2. Asphalt/aggregation material handling
3. Conveyors
4. Paper mill
5. Fans, pumps, and blowers
6. Packaging
7. Cement factory
8. Metal forming/stamping process
9. Winders
10. Processing machines

7. CONCLUSION

In this paper we have shown that the details obtained from actual harmonic measurement on eddy current drive, the line voltage and current signal can indicate notch parameters. An eddy current drive is given a power factor of 0.8372 (lag), Total Harmonic Distortion

of Voltage is 11.70 % and Total Harmonic Distortion of Current is 1.60 %. These technical parameters are carried out by using power analyser Yokogawa make WT-230.IEEE STD 519-1992 is "The IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems". The recommended limits for total harmonic distortion (THD) for voltage and current are 5 % and 1 %.

8. REFERENCES

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