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Experimental Study on Energy Consumption of Wound Rotor Induction Motor in Mine Applications

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Abstract:* With increase in the power demand there is immense pressure on technology and engineers to cater to it with the enhancement in electrical energy conservation. Electrical power is the basic need for all the industries and developing sectors. The present situation is such that demand of power is large & power generation is limited, considering the mining industry which is the backbone of development in any country requires a huge amount of electric power. In order to equalize the demand and generation there is a need to conserve electrical energy in mines. The main objective in consumption of electrical energy in mines includes replacement of conventional systems with the present technology system which leads to reduction in energy consumption per annum for about 10-15%. In this paper lab experimental setup for conventional method and static are presented with mechanical reduction gear system and rope drum, tube with rail arrangement. The experiments are conducted for conventional and static method control technique with different loading condition and results are presented. Electrical equipment consumes huge amount of electrical energy due the rheostatic nature. These have been replaced by the static device to control the speed of the induction motor and the electrical energy conservation can be reduced. Rotor chopper control (static method) is a simple and effective drive method for induction motor. The experimental results of conventional and static method which compare the different parameters of wound rotor induction motor. Controlling duty cycle of IGBT and control the speed of the slip ring induction motor.

Key words: **Consumption of Electrical Energy, Slip Ring Induction Motor, Mine Haulers, Rheostatic, Static Control.**

I. INTRODUCTION

Induction motors consume 80% of the electrical energy in industries, for applications like pumping, compressing, prime movers etc. It has been observed that many of these motors are loaded to the extent of 50% or even less. Hence under-loading of motors leads to poor power factor and lower efficiency. As per an estimate by increasing the motor efficiency by 2 % will reduce additional capacity of 1100MW with less capital investment. Use of proper size motors and application of variable speed drives for variable loading applications particularly in case of compressors, fans, pumps and blowers are found to be economical propositions. One feature of the latter is that the slip power becomes easily available from the slip rings, which can be either mechanically or electronically controlled for motor speed adjustment [1]. With increase in the power demand there is immense pressure on technology and engineers to cater to it with the enhancement in electrical energy conservation. The main objective in conservation of electrical energy in mines includes replacement of conventional systems with the present technology system which leads to reduction in energy consumption per annum for about 10-15%.

The components used in mine electrical power systems often exhibit shorter service lives than their counterparts used in other industrial applications. This reduced reliability is due to the harsh mine environment, severe service, and sometimes inadequate maintenance practices. Induction motors are one of the most common electrical components on mining and mineral processing equipment, and motor failures can contribute significantly to maintenance related downtime. One large U.S. coal producer, for example, reported that ***49*** electric motors required replacement during a one year period in an underground coal mine operating three continuous miner sections (Schmidt, J. F., et al. *1988***)** More than half of industrial motor failures are due to breakdown of winding insulation [2].

The simplest speed control scheme for wound rotor induction motors is achieved by changing the rotor resistance. It has been established that this rotor resistance control method can provide high starting torque and low starting current and variation of speed over a wide range below the synchronous speed of the motor [3]. *(*

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Mine haulers play a vital role in underground mining operations. Substantial power is consumed by these haulage machines. The conventional haulers work on linear resistance control method. It requires frequent maintenance of various parts and sometimes replacement besides high power consumption. Around 10% of power is wasted in rheostatic control of slip ring induction motor.

II .SPEED CONTROL TECHNIQUE AND EXPERIMETAL SETUP:

1. Conventional of speed control method: The experimental setups for conventional method are as shown in figure 1. The technical specification of Slip Ring Induction Motor are as follows : 415 V, 4.0 A ,2.25 KW , 1500 RPM , 50Hz and mechanical specification are reduction gear ratio 1:20 . The simplest speed control scheme for wound rotor induction motors is achieved by changing the rotor resistance. It has been established that this rotor resistance control method can provide high starting torque and low starting current and variation of speed over a wide range below the synchronous speed of the motor.

The conventional haulers work on linear resistance control method. This type rotor is provided with 3-phase, double layer, and distributed windings consisting of coils as used in alternators. The phases are stared internally. The other 3 winding terminals are brought out and connected to 3 insulator slip rings mounted on the shafts with brushes resting on them. These 3 brushes are further externally connected to a 3 phase star connected rheostat (liquid starter)[4].

Therefore, increasing the rotor resistance will at a constant torque causes a proportionate increase in the motor slip with a result decrease in rotor speed. Thus, the speed for a given load torque may be varied by varying the rotor resistance. Function of this resistance is to introduce voltage at rotor frequency, which opposes the voltage induced in rotor winding.

Fig1. Experimental Setup for Conventional speed control Method

2. Static speed control technique (chopper controlled method)[5]

The experimental setup for IGBT methods of speed control is shown in figure 2. The technical specifications are as follows IGBT chopper Control unit with mechanical arrangement .The experiments are conducted as per the procedure. The experimental results are tabulated for different loading conditions.

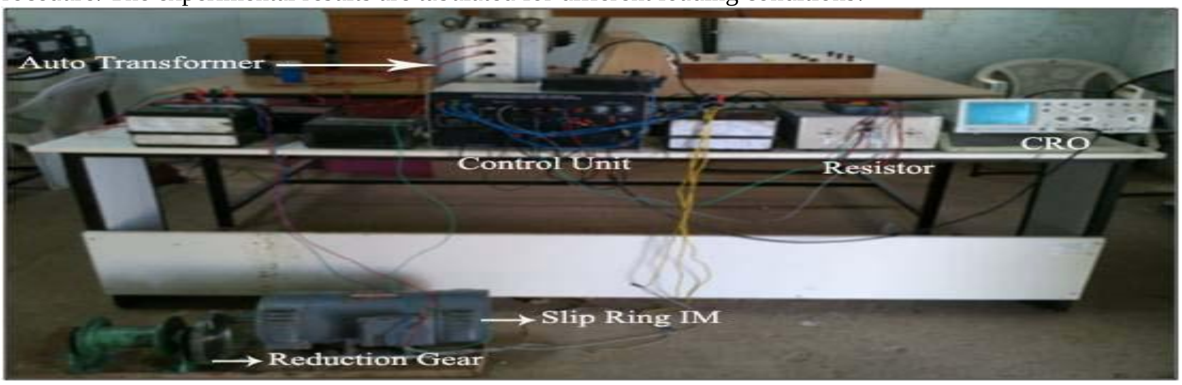

Fig 2. Experimental Setup for chopper controlled method

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III. EXPERIMENTAL DATA AND RESULT ANALYSIS FOR ENERGY CONSUMPTION STUDY

Case 1: Conventional method of speed control: The Experimental results for case 1 are given in table I, II and III for various loading condition and tub weight is also taken for calculation. The graphs are plotted for speed, and efficiency verses output powers for various loads are as shown in figure.3, 4 and 5.

Table .I Experimental results for 7.5 Kg load.

Sl.N0	V1 Volts	I1 Amps	W1 Watts	V2 volts	I2 Amps	N1 RPM	N2 RPM	Time Sec	O/P watts	η%
1	220	1.5	120	75	0.4	600	60	14	88.04	73.36
2	320	3.4	160	80	0.3	700	70	18	102.68	64.17
3	360	4.4	248	90	0.2	1000	100	20	146.73	59.16
4	400	6.0	352	95	0.1	1350	135	10	198.07	56.27

Table.II Experimental results for 12.5 Kg load.

Sl.N0	V1 Volts	I1 Amps	W1 Watts	V2 volts	I2 Amps	N1 RPM	N2 RPM	Time Sec	O/P watts	η%
1	220	1.9	180	60	1	450	45	13	110.03	61.13
2	310	3.5	208	80	0.9	500	50	19	122.27	58.78
3	360	4.3	240	90	0.8	550	55	22	134.50	56.04
4	400	5.4	520	94	0.7	1100	110	25	268.97	51.73

Table III. Experimental results for 15 Kg load.

Sl.N0	V1 Volts	I1 Amps	W1 Watts	V2 volts	I2 Amps	N1 RPM	N2 RPM	Time Sec	O/P watts	η%
1	220	2.0	80	70	1.5	500	50	20	146.65	45.82
2	320	2.5	88	90	1.2	450	45	22	131.95	37.49
3	360	4.5	96	92	1.0	400	40	24	117.3	30.50
4	400	5.7	104	96	0.8	350	35	26	102.65	24.60

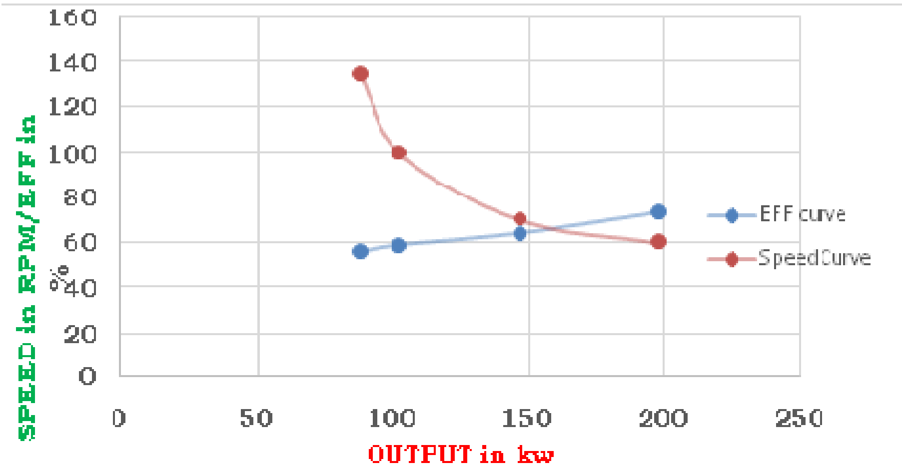

Fig 3. Speed/ Efficiency V/s Output for 7.5kg LOAD

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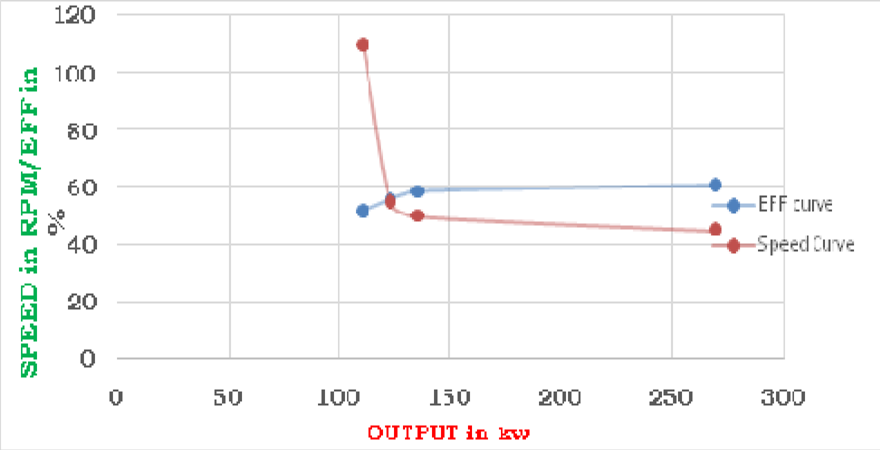

Fig 4 Speed/ Efficiency V/s Output for 12.5kg Load

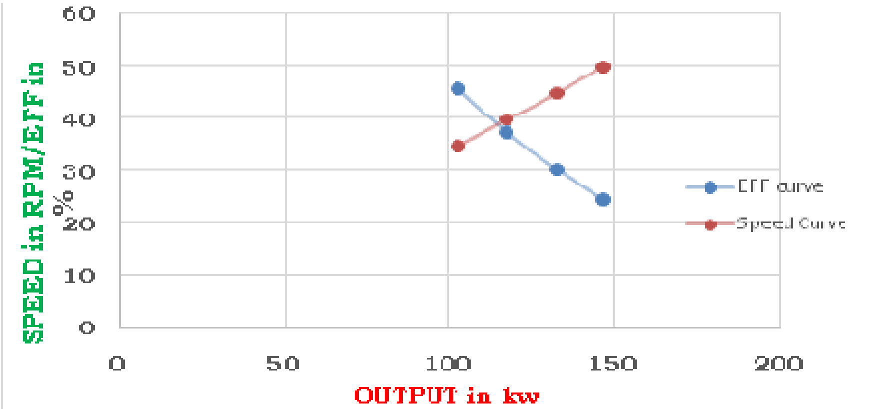

Fig 5. Speed/ Efficiency V/s Output for 15kg Load

Case 2: Static method of speed control (Chopper control method):The Experimental results for case 2 are given in table 4 and 5 for various loading condition and tub weight is also taken for calculation . The graphs are plotted for speed, and efficiency verses output powers for various loads are as shown in figure.6 and 7.

Table IV. Experimental result for 7.5kg load

SI.No	V1 (Volts)	I1 (Amps)	W1 (watts)	V2 (Volts)	I2 (Amps)	N1 RPM)	N2 (RPM)	TIME sec	Ton	Toff	O/P	η%
1	220	1.7	100	70	0.8	45	450	24	15	5	66.02	66.02
2	320	2.6	320	85	1	130	1300	12	16	4	190.74	59.60
3	360	3.0	480	90	1.1	140	1400	10	17	3	205.41	42.79
4	400	3.8	640	95	1.2	145	1450	8	18	2	212.75	33.24

Table V.Experimental result for 12.5kg load

SI.No	V1 (Volts)	I1 (Amps)	W1 (watts)	V2 (Volts)	I2 (Amps)	N1 RPM)	N2 (RPM)	TIME sec	Ton	Toff	O/P	η%
1	220	2.0	140	90	0.6	35	350	30	16	4	85.59	61.14
2	310	3.1	400	60	0.7	75	750	22.8	17	3	183.4	45.85
3	360	3.4	720	75	0.9	130	1300	17	18	2	317.9	44.15
4	400	4.6	800	95	0.8	140	1400	12	19	1	342.3	42.79

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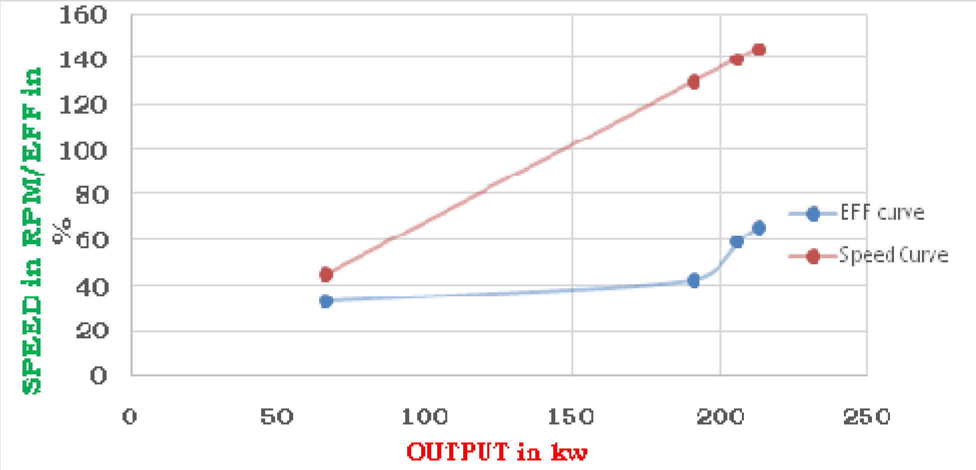

Fig 6. Speed/efficiency V/s output for 7.5kg load

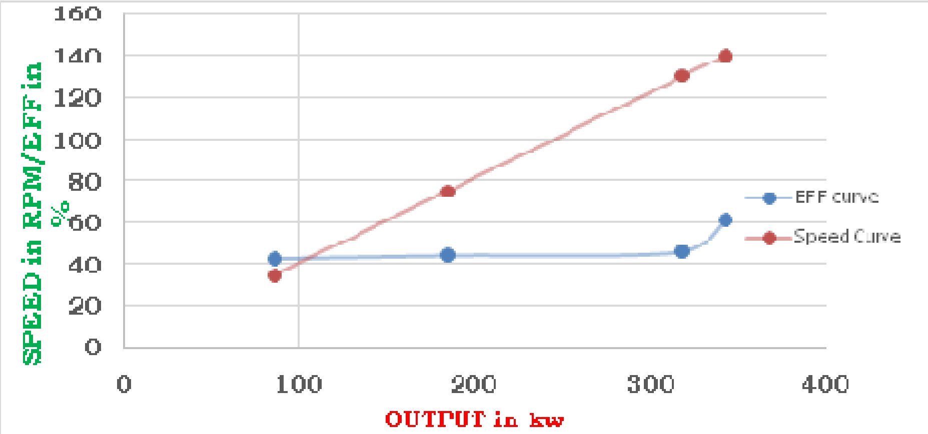

Fig 7. Speed/efficiency V/s output for 12.5kg load

IV. COST ANALYSIS

The energy consumption cost analysis for the conventional method of slip ring induction motor with different load conditions are calculated are as shown in table VI and VII. The consumption cost analysis chart for conventional and static method is also shown in figure .8 and figure.9. This analysis clearly shows the comparison between the two different speed control methods in different loading condition.

7.5kgs		12.5kgs		15kgs	
Energy cons./kwh	Energy cost Rs	Energy cons./ kwh	Energy cost Rs	Energy cons/ kwh	Energy cost Rs
0.0614	1.42	0.0764	1.83	0.2222	5.33
0.0713	1.71	0.0849	2.03	0.2447	5.87
0.1019	2.61	0.0934	2.24	0.2670	6.41
0.1375	3.30	0.1868	4.48	0.2898	6.95

Table.VI. Cost analysis table for conventional method

Load 7.5kgs		Load 12.5kgs		Load 15kgs	
Energy cons. /kwh	Energy cost	Energy cons./ kwh	Energy cost	Energy cons. /kwh	Energy cost
0.0458	1.10	0.0594	1.43	0.0611	1.47
0.1324	3.18	0.1273	3.06	0.0815	1.96
0.1426	3.42	0.2208	5.30	0.1019	2.45
0.1477	3.55	0.2377	5.71	0.1222	2.93

Table.VII. Cost Analysis Table for Static Method

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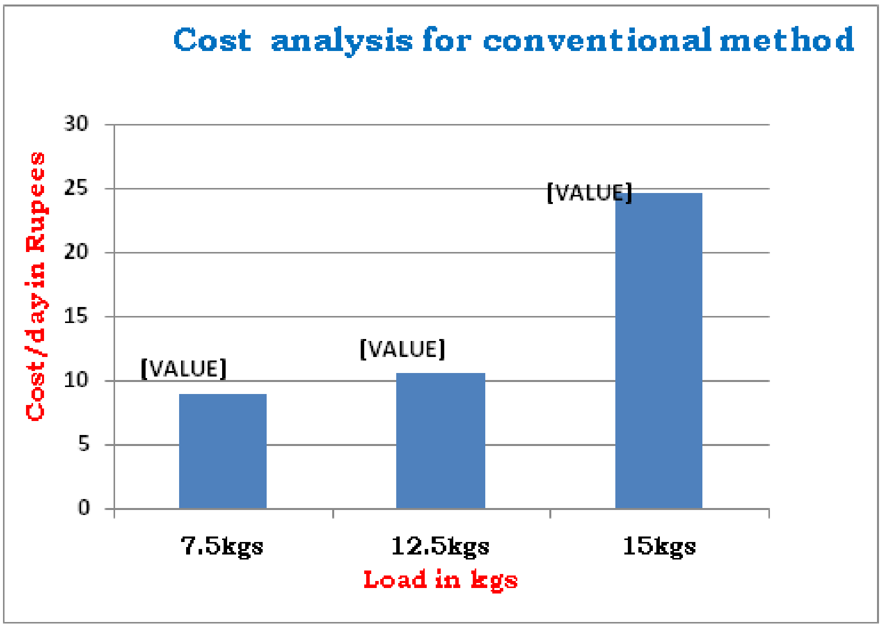

Fig 8.Cost analysis for conventional method

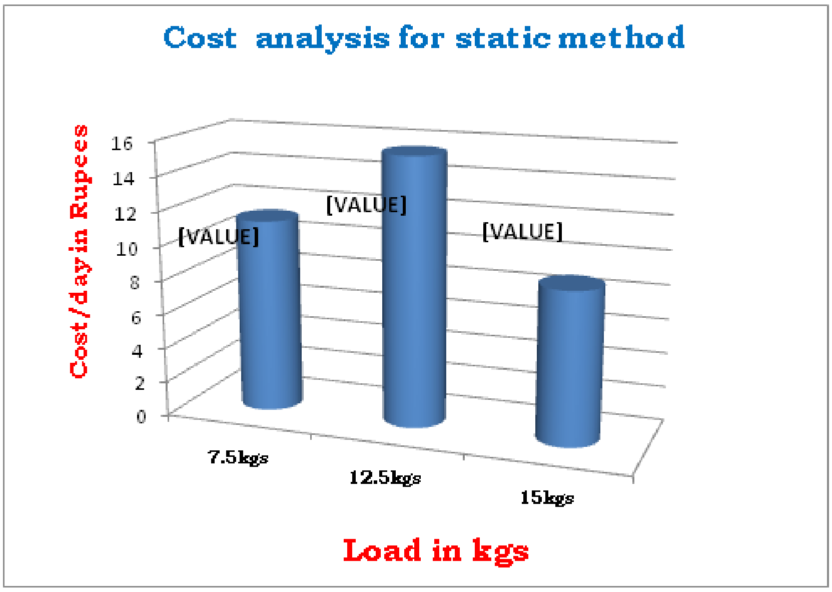

Fig 9. Cost analysis for static method

The cost analysis will shows that the energy consumption of the static method is less than the conventional method. Hence we prefer static method is suitable for underground mining drive system applications.

V. CONCLUSION

In this paper, the conventional speed and static speed control of three- phase wound- rotor induction motors with rectifier chopper control is presented. By properly controlling the duty cycle of the chopper to adjust the equivalent rotor resistance, higher output torque with lower starting current can be obtained [6]. The cost analysis is made both the method of control. The comparative study which clearly indicates the static method is the best method of speed control. The discussion about the energy conservation in speed control methods, particularly in slip ring induction motor. Then, it gives a brief but comprehensive review of the recent advances in power electronics and speed control method of slip ring induction motor [7]. The cost analysis chart shows static speed control method will reduce the energy consumption and this drive system can be implemented in

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underground coal mine application. To reduce the Energy consumption static control method over conventional method, thereby saving valuable amount of energy.

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