

## A Practical Analysis of Benefits of AC Drives Over DC Drives in Cold Rolling Mills

Navneet Singh<sup>1</sup>, Samir Bansal<sup>1</sup>, Manish Kumar<sup>1</sup>, Ravinder Kumar<sup>2</sup>

<sup>1</sup>DIGI DRIVES PVT LTD  
148 Sector 58  
Faridabad, Haryana, India  
121004  
Phone: +91 9810005675  
Email: navneet@digidrives.in

<sup>2</sup>AVON ISPAT & POWER LTD  
GT Road, Dhandari Kalan  
Ludhiana, India  
141010  
Phone: +91 9914833046  
Email: aipl\_crs@avonispac.com

Keywords: Drives, AC Drives, DC Drives, AC Motors, DC Motors, Efficiency, Retrofit, Uptime, Modernization, Harmonics, Energy, Power Quality, Cold Rolling

### INTRODUCTION

This paper presents a practical study to document the direct and indirect benefits of AC Drives over DC Drives in cold rolling mills, including energy, efficiency, power quality, uptime, productivity and manpower. The study is based on practical data collected, compared and analysed both before and after retrofit of AC motors and drives on a 4HI Reversing Cold Rolling Mill at Avon Ispat & Power Ltd, Ludhiana, India.

### BACKGROUND

AVON decided to replace the old DC motor and drive system with the modern AC motor and drive system purely for the known energy benefits of AC Drives and lower maintenance of AC motors compared to DC motors. The dimensioning of a drive system is a task where all factors have to be considered carefully. Dimensioning requires knowledge of the whole system including electric supply, driven equipment, environmental conditions, motors and drives etc. The time spent at the dimensioning phase can mean considerable cost savings. The old DC motors were replaced with similar AC Induction motors as per Table 1. The AC system efficiency and performance depends upon suitable selection of the frequency converter to obtain desired response for the demanding applications such as a cold rolling mill.

The stages in dimensioning of a constant torque application are:

- Check the speed range
- Check the constant torque required
- Check the accelerations
- Check the moment of inertia
- Check possible starting torque required
- Check motor thermal loadability
- Check suitable frequency converter to the dimensioning current

Table 1. Details of Motors Before and After Retrofit

<b>Before Retrofit</b>					
	<b>Type</b>	<b>kW</b>	<b>RPM</b>	<b>Efficiency (%)</b>	<b>Duty</b>
MILL	DC	550	0-635-1465	90.7	S1
ETR/DTR	DC	250	0-470-1650	89.4	S1
<b>After Retrofit</b>					
	<b>Type</b>	<b>kW</b>	<b>RPM</b>	<b>Efficiency (%)</b>	<b>Duty</b>
MILL	AC	550	0-635-1465	95.5	S1
ETR/DTR	AC	250	0-470-1650	94.7	S1

The DC motors require compulsory periodic brush and commutator maintenance leading to scheduled downtime and loss of production. Also with so many years of operation, reliability of the DC motors may have deteriorated resulting in unscheduled shut downs and production loss. The parts also may be nearing end of lifecycle leading to increased spare parts cost and long lead times. These are some of the other factors in addition to energy consumption for pushing the need of conversion from DC to AC motors and drives.

It is well known that the efficiency of AC motors is 5 to 10% better than DC motors depending on the size of the motors. The power factor of AC system with IGBT supply units is always unity without need of any additional reactive power compensation. The harmonics for AC drives are also considerably lower than the DC drives. I<sup>2</sup>R losses are high in DC motors due to harmonics and poor power factor (total losses include losses in motor winding, cables and isolation transformers). The average return on investment (ROI) of converting DC to AC is considered 3 to 5 years based on the above known facts. But the data from this mill confirms that the ROI for the retrofit is close to 1 year based on the direct energy saving only.

#### UPGRADE OVERVIEW

AVON is one of the reputed suppliers of CRCA coils in North India catering to the automotive market. The 4HI mill 500 mm wide with input thickness 1.6 to 6.0 mm and minimum output thickness up to 0.30 mm was installed in 1996 with the traditional DC motors and drives. The mill used DC motors and drives for the POR, MILL and ETR/DTR. Power factor compensation with detuned harmonic filter was also installed. The existing DC motors were replaced with AC Induction motors and ABB ACS880 drives based on the patented DTC (Direct Torque Control) concept, which provide dynamic performance in terms of torque and speed accuracy.

Table 2. Consumption of Energy vs Production Before and After Retrofit

<b>Before Retrofit</b>		
	<b>Production (Tons/Month)</b>	<b>Overall Units (kWH/Ton)</b>
Jan-21	3783.040	112.398
Feb-21	3527.647	107.540
Mar-21	3807.486	135.249
<b>After Retrofit</b>		
	<b>Production (Tons/Month)</b>	<b>Overall Units (kWH)/Ton</b>
Apr-21	2631.369	45.32
May-21	4240.674	38.40
Jun-21	3005.084	36.99
Jul-21	3272.230	53.30

The 4HI cold mill was taken for retrofit on 1<sup>st</sup> April 2021. A total of 12 days were taken to bring the mill in to production which included the dismantling of old DC motors and drives and installation of the new AC motors and drives including new isolation transformer and the cabling of the new equipment. The records of the production against energy consumed before and after retrofit are tabulated in Table 2.

Overall Units/Ton							Overall Units/Ton						
DATE	UNITS	PROD	T. UNITS	T. PROD	UNITS/TON	Overall Units/Ton	DATE	UNITS	PROD	T. UNITS	T. PROD	UNITS/TON	Overall Units/Ton
01/feb/21	14707	118339	221211	253349	9914	166.64	01/mar/2021	17963	110921	17963	118921	16694	16.99
02/feb/21	19608	157311	200019	220080	2465	107.67	02/mar	15297	147045	53860	257966	108107	12.25
03/feb/21	11663	14285	302463	284896	8193	106.39	03/mar	16226	73748	50136	43124	9389	116240
04/feb/21	13865	16188	316320	300404	8602	105.29	04/mar	14163	161520	84299	572034	8760	108460
05/feb/21	16200	146393	333110	315042	7240	105.33	05/mar	14264	136182	79063	127016	10847	108457
06/feb/21	11332	149332	344442	329904	7506	104.33	06/mar	14076	136502	93139	86552	10311	107610
07/feb/21	16181	113028	360623	341292	14304	105.68	07/mar	11211	113720	103550	177223	9258	106560
08/feb/21	18768	114720	389771	352760	16351	107.54	08/mar	18441	114542	122091	109379	15625	112260
							09/mar	16197	122024	158988	1215864	19268	114312
							10/mar	9856	129253	148844	134517	7625	11665
							11/mar	15328	142060	162192	146798	9329	10898
							12/mar	18734	123207	180906	161124	15796	11227
							13/mar	23326	129022	204282	174072	18100	11258
							14/mar	22915	89545	234197	102962	33602	12294
							15/mar	16299	117230	250996	194685	14529	12892
							16/mar	20320	148423	271366	204524	13724	129513
							17/mar	19492	153552	290803	224085	12658	129513
							18/mar	23220	112434	314073	2361262	20696	133010
							19/mar	21106	122669	335779	248392	12066	134093
							20/mar	19546	105025	357225	2588997	16202	137012

Figure 1. Energy consumption record for February-March 2021 (before retrofit).

The per day production and units (kWh) are recorded and totalised to overall units per ton of material rolled. The copy of the record for the month of February-March 2021, before retrofit is shown in Figure 1. The copy of the record after retrofit for the month of May 2021 is shown in Figure 2.

The records clearly show a reduction of 54 units per ton which amount to almost 50% reduction in the energy consumed in the cold rolling of mild steel.

The average cost of electricity is Rs.6.75 per kWh or approximately US\$ 0.10

The total cost of the upgrade including motors, drives, transformer and cables is approximately US\$ 270,000

The total salvage value of old equipment motors, transformer and cables etc. is approximately US\$ 47,000

The average monthly production for this mill is 3500 tons per month or 42,000 tons per year.

So, the cost of energy saved

$$54 \text{ (kWh)} \times 42000 \text{ (tons/year)} \times 0.1 \text{ (US$/kWh)} = \text{US\$ } 226,800$$

The payback for the investment is close to 1 year for the direct savings only. The other combined benefits discussed further in the paper will bring the pay back to less than a year.

MAY-2021							KLOK						
DATE	UNITS READING	PROD	TOTAL UNITS	TOTAL PROD	UNITS/HR	OVERALL UNITS/HR	UNITS READING	PROD	TOTAL UNITS	TOTAL PROD	UNITS/HR	OVERALL UNITS/HR	
01/may/21	5156	130334	5156	130334	39.55	39.55	01/may/21	3266	808723	111542	284706	15.64	39.73
02/may/21	5246	131402	10962	222256	43.00	41.49	02/may/21	3202	128448	114744	302554	17.93	39.73
03/may/21	6221	181916	12123	444672	34.19	38.50	03/may/21	5018	102435	119762	318793	30.89	39.73
04/may/21	7244	41000	24867	585609	54.91	42.45	04/may/21	4264	132246	124526	332018	36.03	39.73
05/may/21	6288	131599	31155	312288	42.78	43.43	05/may/21	6115	168044	130641	345243	30.38	39.73
06/may/21	6290	164234	37425	881572	38.17	42.45	06/may/21	6079	195002	136720	358243	45.02	39.73
07/may/21	5283	265593	42708	1087105	25.69	39.29	07/may/21	6386	83990	183106	369123	76.03	39.73
08/may/21	4556	18766	42264	1225211	33.20	38.59	08/may/21	5142	123227	148203	379464	41.73	39.73
09/may/21	2274	23402	54538	1368203	58.90	40.48	09/may/21	5090	150357	153898	394497	37.44	39.73
10/may/21	5820	31965	60958	1480168	44.70	40.77	10/may/21	4553	162735	158431	410732	27.97	39.73
11/may/21	5064	119448	65422	1599616	42.39	40.89	11/may/21	4451	132942	162802	421069	33.48	39.73
12/may/21	5255	95599	70672	169525	54.96	41.67							
13/may/21	5390	145521	26067	1840216	37.82	40.65							
14/may/21	6607	111620	82674	1952316	58.19	42.33							
15/may/21	4604	122013	82298	2074310	37.89	42.08							
16/may/21	1007	sum	n/c	min OFF	25.25	3							
17/may/21	3706	143804	91004	2218169	28.77	41.025							
18/may/21	5661	172336	96665	2390585	32.84	40.43							
19/may/21	5303	139655	104968	253016	37.97	39.0211							
20/may/21	6308	153423	108276	268858	39.87	40.22							

Figure 2. Energy consumption record for May 2021 (after retrofit).

The average scheduled downtime for DC motor maintenance on this mill was 32 man hours every month which included brush change, commutator cleaning and lapping. The average scheduled maintenance was reduced to 8 man hours in three months for the AC motors. The mill required 20 carbon brushes every month, the cost of each being around US\$ 9 and cost of the manpower around US\$ 16 per hour. The DC motors also have air filters in the cooling circuit which needs to be cleaned every fortnight and 12 filters replaced every 6 months.

Total annual cost saved:

$$20 \text{ (brushes)} \times 12 \text{ (months)} \times 9 \text{ (cost/brush)} = \text{US\$ } 2,160$$

$$24 \text{ (filters)} \times 178 \text{ (cost/filter)} = \text{US\$ } 4,272$$

$$(32 \text{ (man hours)} \times 12 \text{ (months)}) - (8 \text{ (man hours)} \times 4 \text{ (quarters)}) \times 16 \text{ (man hour cost)} = \text{US\$ } 5,632$$

The additional hours available every year only on account of scheduled motor maintenance is 64. The additional hours available every year on account of DC motor overhaul every 3 years is 16. This would amount to additional production of 500 tons every year. The old discarded motors, drives, cables etc. also add to cost benefits even if sold at scrap value. With all the indirect cost benefits added to the direct savings and considering the unscheduled shut downs, the payback is 11 months and 16 days and the Internal Rate of Return (IRR) over a planning horizon of 5 years is 101%.

Table 3. Annual Cash Flow, Payback Period and IRR of the Project

Year	Investment	Salvage Value	Annual Electricity Savings	Annual Maintenance Savings	Annual Cash Flow
0	-\$2,70,000.00	\$46,666.67			-\$2,23,333.33
1			\$2,26,800.00	\$5,632.00	\$2,32,432.00
2			\$2,26,800.00	\$5,632.00	\$2,32,432.00
3			\$2,26,800.00	\$5,632.00	\$2,32,432.00
4			\$2,26,800.00	\$5,632.00	\$2,32,432.00
5			\$2,26,800.00	\$5,632.00	\$2,32,432.00
				Payback Period	11 Months 16 Days
				IRR	101%

### OPERATIONAL BENEFITS

It is also observed that tripping on account of voltage dips has also decreased in comparison to the DC system. The IGBT active end supply unit AC drives offer the possibility to run the mill where the nominal network voltage is below the motor nominal voltage. Power loss ride through operation is possible and has the capacity to compensate the voltage loss between the motor and drive. This can help increase the motor's maximum torque capacity in the field weakening area. The DC boost capability of the AC drive system can be utilised to overcome the voltage drop. The IGBT regeneration allows high dynamics during fast power flow on the load side. The power factor can be controlled to desired value. The DC bus voltage has approximately same value during motoring or braking. No extra voltage stress on insulation of motor winding during braking.

The superior performance of the drives has a direct impact on the process performance (better gauge control), since drives are one of the main actuators for strip tension and rolling speed when it comes to high strip quality. The mill uses the DIGI IMPACT automatic thickness control based on mass flow and speed/tension feed forward control. The fast reaction to torque variation on account of screw down movement allows a better accuracy in the strip tension control for inertia compensation on the tension reel. The coil reports before and after the retrofit when observed closely, depict reduced process disturbances and improved thickness distribution. The improvement can be observed on almost each coil report but needs a significant data analysis to be documented. The coil report includes the process capability analysis with Cp and Cpk values. A significant improvement is seen in the Cpk values post retrofit. Cpk represents the lowest value of the capability against the upper or lower specification, showing where, within the specification limits, the process is producing. Increase in the pass rolling speeds for similar reduction and gauges is also observed on account of reduced losses and more torque availability.

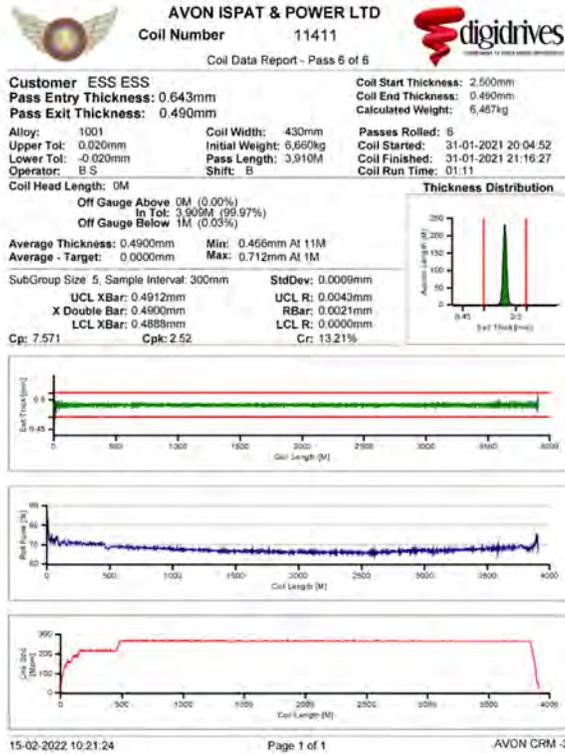


Figure 3. Coil report before retrofit.

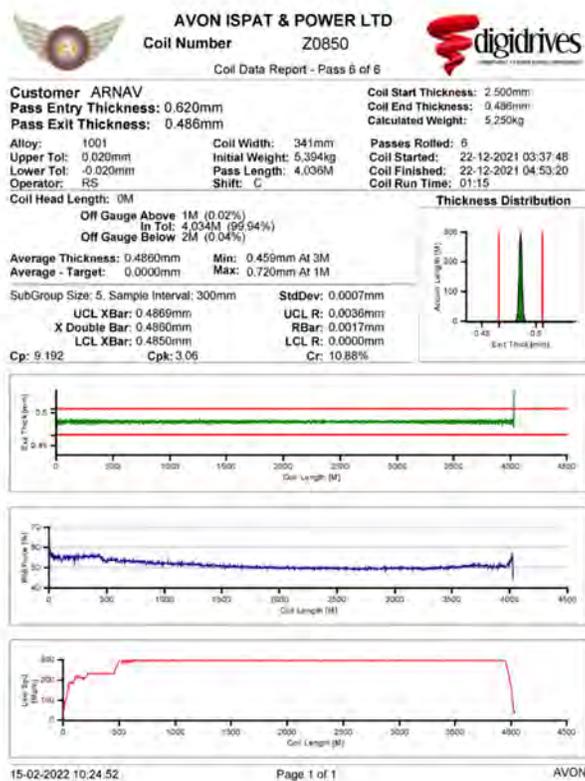


Figure 4. Coil report after retrofit.

## CAPITAL COST COMPARISON

The retrofit also provided insights that the capital cost for a new mill with AC motors and drives will also be significantly lower if compared in the total investment including civil, space, cables, transformers and reactive power compensation. The 650 kVAR reactive power compensation became redundant. The mill DC motor used twelve single core 400 mm<sup>2</sup> cables instead of four three core 95 mm<sup>2</sup> cables used for the new mill AC motor. Similarly, each of tension reel DC motors used eight single core 400 mm<sup>2</sup> cables instead of two three core 95 mm<sup>2</sup> cables used for the new reel AC motors. The 2000 kVA converter duty drive transformer was replaced with a standard 1000 kVA transformer. The half of the ECR (Electrical Control Room) lies empty after the retrofit. The picture of the vacant ECR is shown in Figure 5. So there is cost advantage in the civil cost of the ECR as well. A detailed capital cost analysis can be done on case to case basis but definitely the total investment for a new AC system for metal applications shall not exceed the cost of a DC system.



Figure 5. Free Space in the ECR after retrofit.

## CONCLUSION

To summarise, the AC motor and drive system has several benefits over the DC and investment cost of conversion can be considered seriously. Bespoke future worth analysis based on minimum acceptable rate of return can be done to calculate the estimated savings over a long term horizon.

1. Increased energy savings with low payback period for retrofit and similar acquisition cost for new system
2. Less maintenance and more uptime
3. Low harmonic content, less unwelcome disturbances and a stable power network
4. Better quality product
5. Increased productivity

## **ACKNOWLEDGMENTS**

Our sincere thanks to AVON ISPAT & POWER LTD., for providing insights to the internal company records. We enjoyed working together for the DC to AC conversion and look forward to upcoming retrofit of the second 4HI Mill.

## **REFERENCES**

1. ABB, “DC to AC Conversion” ppt, April 4, 2019.
2. ABB, “AC Drives Technical Guide Book”, 3AFE 64514482 R0125 REV C EN 21.11.2003.
3. Poojit Lingam, Anil Kanagala, Roland Resch, “Modernization of MG Set and DC Drives to AC Drives-Based Solutions – A Power Distribution and Quality Perspective”, AISTech 2019.