



Technology Training that Works

Practical Variable Speed Drives for Instrumentation and Control Systems

Contents

1	Introduction	1
1.1	The need for variable speed drives	1
1.2	Fundamental principles	2
1.3	Torque-speed curves for variable speed drives	6
1.4	Types of variable speed drives	10
1.5	Mechanical variable speed drive methods	11
1.6	Hydraulic variable speed drive methods	12
1.7	Electromagnetic or 'Eddy Current' coupling	14
1.8	Electrical variable speed drive methods	17
2	3-Phase AC Induction Motors	31
2.1	Introduction	31
2.2	Basic construction	31
2.3	Principles of operation	33
2.4	The equivalent circuit	36
2.5	Electrical and mechanical performance	38
2.6	Motor acceleration	41
2.7	AC induction generator performance	43
2.8	Efficiency of electric motors	44
2.9	Rating of AC induction motors	44
2.10	Electric motor duty cycles	47
2.11	Cooling and ventilation of electric motors (IC)	51
2.12	Degree of protection of motor enclosures (IP)	53
2.13	Construction and mounting of AC induction motors	55
2.14	Anti-condensation heaters	56
2.15	Methods of starting AC induction motors	57
2.16	Motor selection	57
3	Power Electronic Converters	59
3.1	Introduction	59
3.2	Definitions	59
3.3	Power diodes	61
3.4	Power thyristors	63
3.5	Commutation	66
3.6	Power electronic rectifiers (AC/DC converters)	66



Technology Training that Works

3.7	Gate commutated inverters (DC/AC converters)	82
3.8	Gate controlled power electronic devices	90
3.9	Other power converter circuit components	101
4	Electromagnetic Compatibility (EMC)	103
4.1	Introduction	103
4.2	The sources of electromagnetic interference	105
4.3	Harmonics generated on the supply side of AC converters	106
4.4	Power factor and displacement factor	116
4.5	Voltages and current on the motor side of PWM inverters	117
5	Protection of AC Converters and Motors	127
5.1	Introduction	127
5.2	AC frequency converter protection circuits	127
5.3	Operator information and fault diagnostics	134
5.4	Electric motor protection	136
5.5	Thermal overload protection – current sensors	137
5.6	Thermal overload protection – direct temperature sensing	138
6	Control Systems for AC Variable Speed Drives	141
6.1	The overall control system	141
6.2	Power supply to the control system	142
6.3	The DC bus charging control system	144
6.4	The PWM rectifier for AC converters	146
6.5	Variable speed drive control loops	147
6.6	Comparison of voltage source and current source inverters	151
6.7	Vector control for AC drives	153
6.8	Current feedback in AC variable speed drives	159
6.9	Speed feedback from the motor	161
7	Selection of AC Converters	163
7.1	Introduction	163
7.2	The basic selection procedure	164
7.3	The loadability of converter fed squirrel cage motors	164
7.4	Operation in the constant power region	167
7.5	The nature of the machine load	168
7.6	The requirements for starting	177
7.7	The requirements for stopping	178
7.8	Control of speed, torque and accuracy	184
7.9	Selecting the correct size of motor and converter	185
7.10	Summary of the selection procedures	186



Technology Training that Works

8	Installation and Commissioning	193
8.1	General installation and environmental requirements	193
8.2	Power supply connections and earthing requirements	195
8.3	Start/stop control of AC drives	198
8.4	Installing AC converters into metal enclosures	200
8.5	Control wiring for variable speed drives	204
8.6	Commissioning variable speed drives	209
9	Special Topics and New Developments	211
9.1	Soft-switching	211
9.2	The matrix converter	213
Appendix A Motor Protection – Direct Temperature Sensing		215
Appendix B Current Measurement Transducers		225
Appendix C Speed Measurement Transducers		229
Appendix D International and National Standards		241
Appendix E Glossary		245
Appendix F Soft Starters		253
Appendix G Practical Exercise		281