Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #7

(Repetitive Starts)

Brought to you by your Motor & Drive Specialists……

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Excessive Numbers of Starts Kills Motors

A common cause of motor failure is repetitive starts. Too often operators don't realize how few a number of consecutive starts a motor is capable of. NEMA MG1 indicates that a motor manufacturer must design their motor to be capable of accelerating without injurious heating, the load inertia (wk^2) referred to the motor shaft equal to or less than the values listed in Table 12-5 (see attached) under the following conditions:

a) Applied voltage ±10% of rated, with rated frequency -or- applied frequency is ±5% of rated, with rated voltage -or- a combined variation in voltage and frequency of 10% (sum of absolute values).
b) During accelerating period, the connected load torque is equal to or less than a torque which varies as the *square of the speed* and is equal to 100 percent of rated-load torque at rated speed. (Which means for variable torque applications ONLY)
c) **Two starts in succession** (coasting to rest between starts) with the motor initially at the ambient temperature or **one start** with the motor initially at a temperature not exceeding its rated load operating temperature. **(Also referred to as '2cold/1hot start')**

More recently, in the advent of premium efficiency motors and the importance of energy management, NEMA collaborated to create another short specification, NEMA MG10. In the section called 'applications involving load cycling', it describes in more detail the starting duty limitations of a given hp motor on a variable torque load. Table 2-3 on attached shows that the ***"Starts per Hour" are to be the lesser*** of **column 'A'** (maximum allowable starts per hour) or the value stated in **column 'B'**÷inertia(wk^2) of the load. **Column 'C'** shows the minimum rest time between starts. Note that the larger the HP of the motor, the smaller the allowable number of starts/hour, and the longer the minimum rest time between starts. The larger HP motors are not generally rated for "Starts per Hour" but rather allowable number of consecutive starts.

During acceleration to full speed, the motor generates heating of the rotor and stator at a rate substantially higher than during full load running conditions (typically >100 times the full load operating condition heating). If the motor is started too frequently, this rate of heating can cause damage to either the stator insulation or the rotor bars and end rings. The specific motor design determines whether such starting condition is rotor limited or stator limited, but the large majority of motors are rotor limited. Furthermore, during starting *(especially with high inertia loads, and higher HP motors)* and during a stalled or locked rotor condition, the rotor typically heats up much more quickly than the stator does. However, during an overload, the stator overheats more quickly than the rotor. Heating is caused by current acting on the resistance as it flows through the rotor and stator. Heat is power (P) which is volts x amps (V x I). Applying ohm's law (V = I x R), it can be deduced that P = (I x R) x I or I^2xR. The total heating effect is power x time (P x t) also expressed as I^2R x t. Since every motor has different internal resistance characteristics the industry abbreviates this heating effect as I^2t. The I^2t term is used on motor thermal capability curves which describe the amount of current that a motor can sustain for how long.

Ideally, safety measures should be in place to guard against excessive number of starts. Please note that standard thermal overload relays will not protect against an excessive number of starts. Also note that many electronic overload relays will not properly protect against excessive number of starts. Repetitive start protection may require some additional circuitry to be added to a system, possibly as part of a PLC program, which locks out the motor starter until the appropriate rest time has occurred before allowing a start. If the NEMA guidelines are not followed, the end user risks premature motor failure, typically in the form of a damaged rotor.

NEMA MG1

Table 12-5: Squirrel-Cage Induction Motors Load WK^2 (Exclusive of Motor WK^2)

HP	3600	1800	1200
	Load wk^2 [lb-ft^2]	Load wk^2 [lb-ft^2]	Load wk^2 [lb-ft^2]
1	1.2	5.8	15
1.5	1.8	8.6	23
2	2.4	11	30
3	3.5	17	44
5	5.7	27	71
7.5	8.3	39	104
10	11	51	137
15	16	75	200
20	21	99	262
25	26	122	324
30	31	144	384
40	40	189	503
50	49	232	620
60	58	275	735
75	71	338	904
100	92	441	1181
125	113	542	1452
150	133	640	1719
200	172	831	2238
250	210	1017	2744

NEMA MG10

Table 2-3: Allowable Number of Starts & Minimum Time Between Starts

HP	3600			1800			1200		
	Start/hr. A	B÷wk^2 B	Rest time C	Starts/hr. A	B÷wk^2 B	Rest time C	Starts/hr. A	B÷wk^2 B	Rest time C
1	15	1.2	75	30	5.8	38	34	15	33
1.5	12.9	1.8	76	25.7	8.6	38	29.1	23	34
2	11.5	2.4	77	23	11	39	26.1	30	35
3	9.9	3.5	80	19.8	17	40	22.4	44	36
5	8.1	5.7	83	16.3	27	42	18.4	71	37
7.5	7	8.3	88	13.9	39	44	15.8	104	39
10	6.2	11	92	12.5	51	46	14.2	137	41
15	5.4	16	100	10.7	75	50	12.1	200	44
20	4.8	21	110	9.6	99	55	10.9	262	48
25	4.4	26	115	8.8	122	58	10	324	51
30	4.1	31	120	8.2	144	60	9.3	384	53
40	3.7	40	130	7.4	189	65	8.4	503	57
50	3.4	49	145	6.8	232	72	7.7	620	64
60	3.2	58	170	6.3	275	85	7.2	735	75
75	2.9	71	180	5.8	338	90	6.6	904	79
100	2.6	92	220	5.2	441	110	5.9	1181	97
125	2.4	113	275	4.8	542	140	5.4	1452	120
150	2.2	133	320	4.5	640	160	5.1	1719	140
200	2	172	600	4	831	300	4.5	2238	265
250	1.8	210	1000	3.7	1017	500	4.2	2744	440

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