TECHNICAL BULLETIN

T-009

SELECTING ELECTRIC GENERATING SETS FOR ELECTRIC MOTOR LOADS

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Onan®

ONAN

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Introduction

The concern for public safety and the increased cost of "down time" during power outages is increasing interest in standby and prime power electric generating sets. Because of initial cost of the generating set, of the installation and other equipment involved, it's extremely important to select the correct unit. Given the information in this bulletin, Onan hopes to simplify the generating set selection. When determining the size of the unit, consider the fact that electricity usage has doubled approximately every ten years.

Part I of the bulletin covers the detailed listing of motor loads and starting, tables, a sample selection problem and a form for compiling data for the actual generating set selection.

Part II covers theory and common problems associated with load applications when considering generating set selection. Voltage dip, reduced voltage motor starting, elevator and X-ray applications are just some of the subjects discussed.

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PART I

SELECTION OF ELECTRIC GENERATING SET

DESCRIPTION OF MOTOR STARTING FORM

MOTOR STARTING FORM

MOTOR INFORMATION FROM MOTOR NAMEPLATE				REDUCED VOLTAGE MOTOR STARTING		MOTOR STARTING LOAD			MOTOR RUNNING LOAD		ACCUMULATED LOAD PLUS LOAD OF INCOMING STARTING MOTOR		ACCUMULATED LOAD		NOTES: NAME OF LOAD, VOLTAGE DIP, ETC.
1	2	3	4	5		6	PF	7	8	9	10	11	12	13	
											Max. KVA	Max. KW	Cont. KVA	Cont. KW	
HP	Code	ϕ	Volts	Tap	Mult.	KVAs		KWs	KVA	KW	Add 6 to 12	Add 7 to 13	Add 8 to 12	Add 9 to 13	
1															
2															

The following numbered paragraphs explain each of the first nine columns on the motor starting form above.

1. **MOTOR HORSEPOWER (HP)**
   The National Electrical Manufacturers Association (NEMA) lists standard horsepower ratings of 1/2 through 200 horsepower for induction motors. Except for certain motors, a standard horsepower rating is found on the motor's nameplate.

2. **MOTOR CODE LETTER (CODE)**
   A code letter can be found on the nameplate of most alternating current motors. The letter is a code for starting KVA per horsepower. Starting KVA per horsepower has been compiled for 1 through 200 horsepower in Table 2.

   NOTE: *Don't confuse the code letter with the design letter.*

TABLE 1. REDUCED VOLTAGE MOTOR STARTING

STARTING METHOD	TAP	MULTIPLIER
Full Voltage	100	1.0
Autotransformer	80 65 50	.64 .42 .25
Series Reactor or Resistor	80 65 50	.80 .65 .50
Star Delta	*	*
Part Winding	*	*
Wound Rotor	*	*

* No standard values of KVA and torque available. Contact supplier for information.

3. **PHASE (ϕ)**
   Both single phase and three phase motors are available in ratings up to 7 1/2 horsepower. Motors more than 7 1/2 horsepower are usually three phase.

4. **VOLTAGE**
   When listing the voltage, list the motor nameplate voltage and not the alternator voltage.

5. **REDUCED VOLTAGE MOTOR STARTING**
   List the amount of voltage reduction in percent (%) tap. Use a 1.0 when across the line starting is used. An explanation of reduced voltage motor starting and examples are given in Part II of this bulletin (see table of contents).

6. **KVA STARTING (KVAs)**
   Starting KVA required by a motor is found in Table 2 under the appropriate code letter column. For any motor of given horsepower and code letter, the starting KVA draw is the same regardless of the phase, speed and voltage rating on the motor nameplate (provided the proper table is used). The table used must be based on the relationship between the motor voltage and the alternator voltage.

7. **KW STARTING (KWs)**
   Starting KW is determined by multiplying the starting KVA (KVAs) by the motor starting power factor (PF). If the power factor for motors of ten horsepower or larger is unknown, use a .4 PF; for less than ten horsepower, use a .5 PF.

8. **MOTOR RUNNING (KVA)**
   KVA for a running motor is the reactive power required by the motor at rated speed and load.

9. **MOTOR RUNNING (KW)**
   KW for a running motor is the real power required by the motor at rated speed and load.

TABLE 2. RUNNING KVA, KW AND STARTING KVA OF MOTORS

ALTERNATOR VOLTAGE	MOTOR VOLTAGE	HP	RUNNING		STARTING KVA – 1ϕ OR 3ϕ, 50 OR 60 HERTZ														
					CODE LETTER														
			KVA	KW	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
USE WHEN MOTOR VOLTAGE IS THE SAME AS ALTERNATOR VOLTAGE		1	1.33	.99	3	3.3	3.7	4.25	4.75	5.3	5.95	6.7	7.55	8.5	9.5	10.6	11.85	13.25	15
		1.5	1.9	1.45	4.5	5	5.6	6.4	7.1	8	8.9	10	11.3	13	14	16	18	20	22
		2	2.47	2	6	6.7	7.5	8.5	9.5	10.6	11.9	13	15.1	17	19	21	24	26	30
		3	3.42	2.8	9	10	11.2	12.7	14.2	15.9	17.8	20	22.6	26	28	32	35	40	45
		5	5.7	4.8	15	16.7	18.7	21.2	23.7	26.1	30	34	38	43	47	53	59	66	75
		7.5	8.35	7.1	22.5	25	28	32	36	40	45	50	56	64	71	80	89	99	112
		10	10.3	8.7	30	33.5	38	43	48	53	59	67	75	85	95	106	118	132	150
		15	15.2	13.2	45	50	56	64	71	79	89	100	113	128	143	159	178	199	225
		20	19.8	17.1	60	67	75	85	95	106	119	134	151	170	190	212	237	265	300
		25	24.4	21	75	83	94	106	119	132	148	167	188	212	237	265	296	331	375
		30	29.6	26	90	100	112	127	142	159	178	201	226	255	285	318	355	397	450
		40	39.6	35	120	134	150	170	190	212	238	268	302	340	380	424	474	530	600
		50	47.5	41.5	150	167	187	212	237	265	297	335	377	425	475	530	592	662	750
		60	57	51	180	201	225	255	285	318	357	402	453	510	570	636	711	795	900
		75	70	62	225	250	281	318	356	397	445	502	565	637	712	795	888	993	1125
		100	93.5	82.5	300	335	375	425	475	530	595	670	755	850	950	1060	1185	1325	1500
		125	118	105	375	417	468	531	593	662	742	837	942	1062	1187	1325	1480	1655	1875
		150	137	123	450	502	562	637	712	795	892	1000	1130	1280	1430	1590	1780	1990	2250
		200	182.5	164	600	670	750	850	950	1060	1190	1340	1510	1700	1900	2120	2370	2650	3000

ALTERNATOR VOLTAGE	MOTOR VOLTAGE	HP	RUNNING		STARTING KVA – 1ϕ OR 3ϕ, 50 OR 60 HERTZ														
					CODE LETTER														
			KVA	KW	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
208	220	1	1.33	.99	2.68	2.3	3.4	3.8	4.2	4.7	5.3	5.9	6.7	7.6	8.5	9.5	10.6	11.8	13
		1.5	1.9	1.45	4	4.5	5	5.6	6	7	8	9	10	11	12	14	16	18	20
416	440	2	2.47	2	5	5.98	6.7	7.5	8.5	9.5	10.6	12	13	15	17	19	21	24	27
		3	3.42	2.8	8	9	10	11	12.7	14	15.9	18	20	23	25	28	32	36	40
		5	5.7	4.8	13.4	14.9	16.7	19	21	23	26	30	34	38	42	47	53	59	67
		7.5	8.35	7.1	20	22	25	28	31.8	35	40	45	51	57	65	71	79	89	100
		10	10.3	8.7	26.8	29.9	33.5	38	42	47	53	60	67	76	85	94	106	118	134
		15	15.2	13.2	40	44	50	56	63	70	79	89	101	113	127	142	158	177	201
		20	19.8	17.1	53.6	59.8	67	75	84	94	106	119	134	151	169	189	211	236	268
		25	24.4	21	67	74	83	94	106	118	132	149	168	189	212	236	264	296	335
		30	29.6	26	80	89	100	113	127	141	159	179	202	227	254	284	317	355	402
		40	39.6	35	107	119	134	152	168	189	212	239	269	304	340	380	424	474	536
		50	47.5	41.5	134	149	167	189	212	236	265	299	337	379	424	473	529	592	670
		60	57	51	160	179	201	227	254	283	319	359	404	455	509	568	635	710	804
		75	70	62	201	224	251	285	318	354	399	449	506	570	637	711	794	888	1005
		100	93.5	82.5	268	299	335	379	424	473	531	598	674	759	849	947	1059	1184	1341
		125	118	105	335	373	418	475	530	590	665	749	843	950	1062	1184	1324	1480	1675
		150	137	123	402	448	502	569	636	710	797	898	1012	1139	1273	1421	1588	1776	2011
		200	182.5	164	536	598	670	759	848	946	1063	1197	1349	1519	1698	1895	2118	2369	2682

Table 2 continued on next page.

TABLE 2. RUNNING KVA, KW AND STARTING KVA OF MOTORS

ALTERNATOR VOLTAGE	MOTOR VOLTAGE	HP	RUNNING		STARTING KVA – 1ϕ OR 3ϕ, 50 OR 60 HERTZ														
					CODE LETTER														
			KVA	KW	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
208	200	1	1.33	.99	3.3	3.6	4	4.6	5.2	5.8	6.5	7.3	8	9	10.4	11.5	13	14	16
416	400	1.5	1.9	1.45	4.9	5.5	6	6.9	7.7	8.6	9.7	10.9	12	14	15	17.3	19	22	24
600	575	2	2.47	2	6.5	7.3	8.2	9.3	10.3	11.5	13	14.6	16.4	18.5	21	23	26	29	33
		3	3.42	2.8	9.8	10.9	12	13.9	15.5	17	19.4	21.9	24.6	27.7	31	34.6	38	43	49
240	230	5	5.7	4.8	16.4	18	20.4	23	25.8	28.8	32.4	36.5	41	46	52	57.7	64	72	82
480	460	7.5	8.35	7.1	24.5	27.5	30.5	34.5	39	43.5	48.5	55	61.5	69.5	77	86	97	108	122
		10	10.3	8.7	33	36	41	46	52	58	65	73	82	93	103	116	129	144	164
		15	15.2	13.2	49	55	61	69	78	87	97	110	123	139	155	173	194	217	245
		20	19.8	17.1	65	73	82	93	104	116	130	146	165	185	207	231	258	289	327
		25	24.4	21	82	92	102	116	130	145	162	183	205	232	258	289	323	361	409
		30	29.6	26	98	110	123	139	155	173	194	219	247	278	310	346	387	433	491
		40	39.6	35	130	146	164	186	208	232	260	292	330	370	414	462	516	578	653
		50	47.5	41.5	164	183	204	232	259	289	324	365	411	463	517	577	646	722	817
		60	57	51	196	220	246	278	310	346	388	438	494	556	620	692	774	866	982
		75	70	62	245	275	305	345	390	435	485	550	615	695	775	865	970	1085	1225
		100	93.5	82.5	327	365	409	463	518	578	648	730	823	926	1035	1155	1291	1444	1635
		125	118	105	410	460	510	580	650	725	810	915	1025	1160	1290	1445	1615	1805	2045
		150	137	123	491	548	613	695	776	866	972	1095	1234	1389	1550	1730	1936	2166	2450
		200	182.5	164	654	730	817	926	1035	1155	1296	1460	1645	1853	2070	2310	2582	2888	3270

ALTERNATOR VOLTAGE	MOTOR VOLTAGE	HP	RUNNING		STARTING KVA – 1ϕ OR 3ϕ, 50 OR 60 HERTZ														
					CODE LETTER														
			KVA	KW	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
240	220	1	1.33	.99	3.57	3.98	4.46	5	5.65	6.3	7	7.97	8.98	10	11.3	12.6	14	15.8	17.8
480	440	1.5	1.9	1.45	5.35	5.97	6.7	7.6	8	9	10.5	11.9	13.5	15	16.9	18.9	21	24	27
		2	2.47	2	7	7.96	8.9	10	11.3	12.6	14.1	15.9	18	20	23	25	28	32	36
		3	3.42	2.8	10.7	11.9	13.4	15	16.9	18.9	21	23.9	26.9	30	33.9	37.8	42	47	54
		5	5.7	4.8	17.8	19.9	22.3	25	28	31.5	35	39.8	44.9	50	56	63	70	79	89
		7.5	8.35	7.1	26.7	29.8	33	37.9	42.3	47	52.7	59.7	67	75.8	84.8	94	106	118	134
		10	10.3	8.7	35.7	39.8	44.6	50.5	56.5	63	70.8	79.7	89.8	101	113	126	141	158.7	178.5
		15	15.2	13.2	53.5	59.7	67	75.7	84.5	94.5	105	119	135	151	170	189	211	236	268
		20	19.8	17.1	71.4	79.6	89.2	101	113	126	141.6	159.4	179.6	202	226	252	282	315.4	357
		25	24.4	21	89	100	112	127	141	158	177	199	225	253	283	315	353	394	446
		30	29.6	26	107	119	134	152	169	189	211	239	269	303	339	378	423	472	536
		40	39.6	35	142.8	159	178	202	226	252	283	318	359	404	452	504	564	630	714
		50	47.5	41.5	178	199	223	252	282	315	352	398	449	505	565	630	705	788	892
		60	57	51	214	238	268	304	338	378	422	478	538	606	678	756	846	944	1072
		75	70	62	267	298	335	379	423	473	528	597	674	758	848	945	1058	1180	1338
		100	93.5	82.5	357	398	446	505	565	630	708	797	898	1010	1130	1260	1410	1577	1785
		125	118	105	445	500	560	635	705	790	885	995	1125	1265	1415	1575	1765	1970	2230
		150	137	123	535	597	669	758	845	945	1055	1194	1347	1515	1695	1890	2115	2360	2675
		200	182.5	164	714	796	892	1010	1130	1260	1416	1594	1796	2020	2260	2520	2820	3154	3570

Standard voltages for alternators differ from the corresponding standard voltages for motors. The two NEMA standards MG1-10.30 and MG1-22.13 list motor and alternator voltages as shown in Table 3.

TABLE 3. STANDARD ALTERNATOR AND MOTOR VOLTAGES

60 HERTZ MOTORS	60 HERTZ ALTERNATORS
Universal Motor Voltages: 115 and 230	Single Phase Voltages: 120, 120/240, 240
Single Phase Motor Voltages: 115 and 230	
Alternating Current Polyphase Motor Voltages:	Three Phase Voltages:
200	208/120
*230	240
460	480
575	600

* Previous standard voltage was 220 volts. Should be operated on 240 volts whenever possible.

TABLE 4. TYPICAL STARTING CHARACTERISTICS OF FRACTIONAL, SINGLE PHASE MOTORS (1725 RPM, 60 HERTZ)

HP	TYPE	CODE	1 KVAs	4 FLKVA	5 FLKW
1/6	CS	M	1.84	.345	.200
1/6	SP	P	2.13	.322	.203
1/4	CS	M	2.53	.46	.29
1/4	SP	M	2.55	.46	.29
1/3	CS	K	2.99	.552	.358
1/3	SP	L	3.22	.552	.358
1/2	CS	K	4.36	.805	.522
1/2	RSIR	G	3.1	.874	.522
3/4	CS	K	6.67	1.196	.775
3/4	RSIR	G	4.60	1.196	.765

CS - Capacitor start
SP - Split phase
RSIR - Repulsion start induction run

RATINGS OF ONAN ELECTRIC GENERATING SETS

Column numbers in tables correspond to column numbers in motor starting form.

TABLE 5. RATINGS OF 3 PHASE, 60 HERTZ SETS

	UNIT	MAXIMUM KVA			MAX. KW	SET KVA	SET KW
		Col. 10			Col. 11	Col. 12	Col. 13
REVOLVING ARMATURE	3.0DJA	6			3	3	3
	4.0CCK	9.96			5	4	4
	5.0CCK	12.5			5	5	5
	6.5NH	16			6.5	6.5	6.5
	10.0CCKB	15			10	10	10
REVOLVING FIELD BRUSH TYPE	6.0DJB	12.4			8	7.5	6
	7.5JB	16			7.5	9.4	7.5
	12.0DJC	25			15	15.6	12.5
	12.5JC	25			15	15.6	12.5
	12.5RJC	25			15	15.6	12.5
	15.0RDJC	30			15	18.7	15
	15.0JC	37.5			15	18.7	15
	15.0RJC	37.5			15	18.7	15
	17.5RDJF	37.5			17.5	21.8	17.5
	200.0DFP	437			200	250	200
	230.0DFM	500			230	287	230
	250.0FT	500			250	312	250
	250.0DYB	500			250	312	250
		120/208, 240/416	120/240 (1 ϕ), 120/240D, 127/220, 254/440	139/240, 277/480, 347/600			
REVOLVING FIELD BRUSHLESS TYPE	30.0EK	86	97	111	30	37.5	30
	30.0DEH	86	97	111	30	37.5	30
	45.0EM	130	146	166	45	56	45
	45.0DEF	130	146	166	45	56	45
	50.0DEG	130	146	166	50	62.5	50
	55.0KB	152	170	189	55	68.7	55
	60.0DYA	176	194	218	60	75	60
	65.0KB	176	194	218	65	81.2	65
	70.0KR	204	225	250	70	87	70
	75.0DYC	204	225	250	75	94	75
	85.0KR	231	253	280	85	106	85
	90.0DYC	231	253	280	90	112.5	90
	100.0DYD	270	292	320	100	125	100
	115.0WA	306	332	360	115	144	115
	125.0DYD	350	376	405	125	156	125
	140.0WE	350	376	405	140	175	140
	150.0WE	400	423	453	150	187	150
	150.0DYG	400	423	453	150	218	150
	170.0WB	450	473	500	170	212	170
	175.0DYG	450	473	500	175	218	175
	300.0DFT	900		970	300	375	300
	350.0WF	900		970	350	437	350
	350.0DFU	900		970	350	437	350
	400.0WK	980		1040	400	500	400
	400.0DFV	980		1040	400	500	400
	450.0DFW	1060		1120	450	562	450

TABLE 6. RATINGS OF 1 PHASE, 60 HERTZ SETS

	UNIT	MAX. KVA	MAX. KW	SET KVA	SET KW
		Col. 10	Col. 11	Col. 12	Col. 13
REVOLVING ARMATURE	1.0AJ	2.3	1	1	1
	1.5AK	2.56	1.5	1.5	1.5
	1.7PC	2.56	1.7	1.7	1.7
	2.0TE	2.56	2	2	2
	2.5AJ	4.4	2.5	2.5	2.5
	2.5LK	5.8	2.5	2.5	2.5
	2.5AJ *	6	2.5	2.5	2.5
	2.8TF	4.4	2.85	2.85	2.85
	3.0NB	6	3	3	3
	3.0DJA	6	3	3	3
	4.0TD	6	4	4	4
	4.0CCK	7.5	5	3.5	3.5
	5.0CCK	12.5	5	5	5
	6.5NH	16	6.5	6.5	6.5
	10.0CCKB	15.9	10	10	10
REVOLVING FIELD BRUSH TYPE	6.0DJB	12.4	8	6	6
	7.5JB	16	7.5	7.5	7.5
	12.5JC	25	15	12	12
	12.0DJC	25	15	12	12
	12.5RJC	25	15	12	12
	15.0JC	37.5	15	15	15
	15.0RDJC	30	15	15	15
	15.0RJC	37.5	15	15	15
	17.6RDJF	37.5	17.5	17.5	17.5
REVOLVING FIELD BRUSHLESS	30.0EK	110	30	37.5	30
	30.0DEH	110	30	37.5	30
	45.0EM	140	45	56	45
	45.0DEH	140	45	56	45

* Electric start

CAUTION *On revolving armature generating sets, maximum KVA in column 10 is not a true value but an equivalent we use to permit standardization on unit selection procedures. It is what the generating set would appear to produce if it could maintain rated voltage under motor starting conditions. Actually, the voltage will dip to about 70 percent of rate value resulting in about 50 percent reduction of KVA during motor starting. Similar to reduced voltage starters, this permits starting relatively larger motors. Remember, the starting torque of the motor is proportional to the KVA input and reducing it by 50 percent will cut the stalled torque in half. This may cause some problems if the motor must start while it is heavily loaded (compressors, piston pumps, conveyors, etc.). If such is the case, it may be necessary to select a larger generating set.*

Column numbers in tables correspond to column numbers in motor starting form.

TABLE 7. RATINGS OF 3 PHASE, 50 HERTZ SETS

	UNIT	MAXIMUM KVA		MAX. KW	SET KVA	SET KW
		Col. 10		Col. 11	Col. 12	Col. 13
REVOLVING FIELD BRUSH TYPE	4.5DJB	11.2		4.5	5.6	4.5
	6.0JB	15		6	7.5	6
	9.0DJC	22.5		9	11.25	9
	12.5JC	31.2		12.5	15.6	12.5
	12.5RJC	31.2		12.5	15.6	12.5
	12.5RDJC	25		12.5	15.6	12.5
	165.0DFP	362		165	206	165
	190.0DFM	417		190	203	190
	200.0DYB	437		200	250	200
	210.0FT	437		210	262	210
		110/190, 220/380	115/200, 234/400			
REVOLVING FIELD BRUSHLESS TYPE	25.0EK	56	59	25	31.2	25
	25.0DEH	56	59	25	31.2	25
	37.5EM	86	90	37.5	46.8	37.5
	37.5DEF	86	90	37.5	46.8	37.5
	40.0DEG	86	90	40	50	40
	45.0KB	100	105	45	56.2	45
	50.0DYA	115	120	50	62.5	50
	55.0KB	115	120	55	68.7	55
	62.5DYC	133	140	62.5	78.2	62.5
	70.0KR	154	160	70	87.5	70
	75.0DYC	154	160	75	93.7	75
	80.0DYD	177	185	80	100.	80
	95.0WA	202	212	95	119	95
	100.0DYD	232	246	100	125	100
	115.0WE	232	246	115	144	115
	125.0DYG	262	274	125	156	125
	140.0WB	300	312	140	175	140
	145.0DYG	300	312	145	181	145
	250.0DFT	810		250	312	250
	290.0WF	810		290	362	290
	290.0DFU	810		290	362	290
	330.0WK	870		330	412	330
	330.0DFV	870		330	412	330
	400.0DFW	930		400	500	400

TABLE 8. RATINGS OF 1 PHASE, 50 HERTZ SETS

	UNIT	MAX. KVA	MAX. KW	SET KVA	SET KW
		Col. 10	Col. 11	Col. 12	Col. 13
REVOLVING ARMATURE	1.2AK	2.1	1.25	1.25	1.25
	1.4PC	2.1	1.4	1.4	1.4
	1.6TE	2.1	1.6	1.6	1.6
	1.7LK	4	1.75	1.75	1.75
	2.0AJ	3.7	2	2	2
	2.3NB	5	2.3	2.3	2.3
	2.3TF	5	2.3	2.3	2.3
	3.2TD	5	3.2	3.2	3.2
	3.5CCK	6.2	3.5	3.5	3.5
	5.5NH	11	5.5	5.5	5.5
REVOLVING FIELD BRUSH TYPE	4.5DJB	10	5	4.5	4.5
	6.0JB	13	6	6	6
	9.0DJC	22.5	9	9	9
	12.5JC	31.2	12.5	12.5	12.5
	12.5RJC	31.2	12.5	12.5	12.5
	12.5RDJC	25	12.5	12.5	12.5
	14.5RDJF	31	14.5	14.5	14.5

SAMPLE SELECTION OF ELECTRIC GENERATING SET

MOTOR STARTING FORM

MOTOR INFORMATION FROM MOTOR NAMEPLATE				REDUCED VOLTAGE MOTOR STARTING		MOTOR STARTING LOAD			MOTOR RUNNING LOAD		ACCUMULATED LOAD PLUS LOAD OF INCOMING STARTING MOTOR		ACCUMULATED LOAD		NOTES: NAME OF LOAD, VOLTAGE DIP, ETC.
1	2	3	4	5		6	PF	7	8	9	10	11	12	13	
HP	Code	ϕ	Volts	Tap	Mult.	KVAs		KWs	KVA	KW	Max. KVA Add 6 to 12	Max. KW Add 7 to 13	Cont. KVA Add 8 to 12	Cont. KW Add 9 to 13	
1				120		1.0							50	50	ENTIRE BUILDING, LIGHTS, RECEPTACLES
2	30	F	3	200	65	.42	173 X .42 = 73	0.4	29	29.6	26	73 + 50 = 123	29 + 50 = 79	29.6 + 50 = 79.6	26 + 50 = 76	ELEVATOR (ONE AT A TIME) PUMPBACK OK.
3	10	G	3	200		1.0	65	0.5	32.5	10.3	8.7	144.6	108.5	89.9	84.7	BLOWER MOTOR
4	7.5	G	3	200		1.0	48.5	0.5	24.3	8.4	7.1	138.4	109.0	98.3	91.8	AIR CONDITIONING

STEP-BY-STEP PROCEDURE

The following step-by-step procedure shows how to fill out the form above.

1. List all the loads in the order they will be applied to the generating set. For the smallest generating set, the larger motors should be started first, if possible.
2. On the first line under "ACCUMULATED LOAD" (columns 12 and 13), list all the lighting and heater loads that will be on the circuit before the motors are started.

   If no lighting or heater loads are on the circuit, list on line one the first motor to be started (as shown in step 3).
3. In columns 1, 2, 3 and 4, enter the horsepower, code letter, phase and voltage of each motor. List the motors in the sequence they will be started and use a separate line for each motor.
4. Decide on the electric generating set voltage to be used (208 volt generating set used in sample). The different voltage combinations are listed on the left side of Table 2. The standard motor and generating set voltages are listed in Table 3.

   Obtain the starting KVA under the proper code letter for each motor. Enter this value in column 6, if across-the-line starting.
5. For reduced voltage starting, enter the tap and multiplier in column 5. Enter the product of starting KVA times the multiplier in column 6.

   NOTE: *For information on reduced voltage motor starting, see Part II of this technical bulletin.*
6. Multiply the starting KVA (column 6) times the starting power factor (PF) and enter this value in column 7.
7. Obtain the running KVA and running KW for each motor from Table 2 and enter these values in columns 8 and 9.

DETERMINING MAXIMUM AND CONTINUOUS LOAD

The electric generating set selected must be capable of supplying the maximum load during the starting for each motor and the continuous load when the motors are running. Progressive totals of the accumulated load and the incoming motor's starting load will show the maximum KVA and KW demand during the time each motor is starting. Progressive totals of the accumulated load and the incoming motor's running load will show the continuous KVA and KW demand after each motor is running.

8. Start with the first motor; add the KVA from column 6 to the KVA from column 12 of the line above. Enter this total in column 10.
9. Start with the first motor; add the KW from column 7 to the KW from column 13 of the line above. Enter this total in column 11.
10. Add the KVA from column 8 to the KVA from column 12 of the line above. Enter this total in column 12.
11. Add the KW from column 9 to the KW from column 13 of the line above. Enter this total in column 13.
12. Repeat steps 8 through 11 for each motor in turn. This completes the calculations.
13. Circle the largest numbers in columns 10, 11, 12 and 13.
14. Refer to tables 5, 6, 7 and 8. Select the table describing units of the phase and frequency used in the calculation. In the table, the columns which give the generating set ratings are numbered to correspond with the column numbering in the compilation form. Select the smallest electric generating set which has maximum KVA and KW capabilities, and continuous KVA ratings equal to or greater than the circled numbers on the compilation form.

NOTE: *Consider additional capacity for future requirements when making the selection.*

ELECTRIC GENERATING SET SELECTION FORM

ONAN 1400 73RD AVENUE N.E. • MINNEAPOLIS, MINNESOTA 55432
A DIVISION OF ONAN CORPORATION

CUSTOMER _____
ADDRESS _____
CITY _____ STATE _____ ZIP _____

DEALER/DISTRIBUTOR _____
SALESMAN _____
ONAN REPRESENTATIVE _____

RECOMMENDED UNIT _____
VOLTAGE _____ PHASE _____
KW _____ KVA _____ PF _____
DERATINGS: Altitude _____
Fuel _____ Temperature _____
RATING FOR APPLICATION - KW _____ KVA _____
MAXIMUM VOLTAGE DIP _____

	MOTOR INFORMATION FROM MOTOR NAMEPLATE				REDUCED VOLTAGE MOTOR STARTING		MOTOR STARTING LOAD			MOTOR RUNNING LOAD		ACCUMULATED LOAD PLUS LOAD OF INCOMING STARTING MOTOR		ACCUMULATED LOAD		NOTES: NAME OF LOAD, VOLTAGE DIP, ETC.
	1	2	3	4	5		6	PF	7	8	9	10	11	12	13	
	HP	Code	ϕ	Volts	Tap	Mult.	KVAs		KWs	KVA	KW	Max. KVA Add 6 to 12	Max. KW Add 7 to 13	Cont. KVA Add 8 to 12	Cont. KW Add 9 to 13	
1																
2																
3																
4																
5																
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PART II

THEORY AND PROBLEMS ASSOCIATED WITH COMMON LOAD APPLICATIONS

GENERAL CONSIDERATIONS

Because an electric generating set is a smaller or limited source of power when compared to the electric utility power source, special considerations must be made for the size and types of load.

Motors, incandescent lamps and many other types of loads have the undesirable characteristic of requiring several times full load current (inrush current) under starting conditions. A typical motor starting curve is shown in Figure 1.

If a motor is started across an infinite power source with no resistance in the power lines, there is no voltage dip. However, the lines have resistance and the generating set is limited in the amount of power it can deliver. Therefore, voltage dip should be considered when selecting a generating set. In addition to inrush current and voltage dip when starting loads, power factor must be considered with all motors and other types of inductive loads (does not include heating or lighting loads). Power factor (PF), during the starting of a motor, can range from 0.15 to 0.9 PF depending upon type and design.

FIGURE 1. TYPICAL MOTOR STARTING CURVE

VOLTAGE DIP

Excessive voltage dip can cause lights to dim or contactors to drop out and disrupt the operation of critical equipment. If the motor load is large compared to the size of the generating set, the voltage may dip to the point where the motor will not develop sufficient torque to gain full speed.

The voltage dip on typical Onan electric generating sets is shown in Figures 2, 3 and 4. With a regulated type generating set (UR alternator series for example), shown in Figure 2, the voltage dips until the regulator senses the change in voltage and makes an adjustment. A saturated field type generating set (UN alternator series for example) has a voltage dip proportional to the load. See Figure 3. There is no regulator to

FIGURE 2. VOLTAGE DIP AND RECOVERY ON ALTERNATOR WITH REGULATOR

FIGURE 3. VOLTAGE DIP ON A SATURATED FIELD ALTERNATOR

readjust the voltage to 100%. Figure 4 illustrates the result of too large a load for the alternator. Voltage drops to less than the required voltage.

The amount of voltage dip is determined by the size of the electric generating set, line losses and the

FIGURE 4. VOLTAGE DIP ON AN OVERLOADED ALTERNATOR

FIGURE 5. TYPICAL MOTOR STARTING APPLICATION

motor type and size. When the starting contactor for the motor is closed, voltage divides instantaneously between the alternator's reactance, line losses and motor reactance in proportion to their ohmic values (as shown in Figure 5).

For most applications, only the voltage dip caused by the alternator's reactance (X) and the motor starting reactance (Z load) will be considered. Line losses are normally small and have to be considered only when the application is marginal or the line leads are very long. See the section VOLTAGE DROP OF CONDUCTORS.

Calculating Voltage Drop (Proportion Method)

Voltage dip figures are usually given in percent of rated voltage. On Onan sample specification sheets, the voltage dip is given for the application of full rated 0.8 PF load in one step. For an approximation of the voltage dip, use proportions as shown in the following example.

Example: An alternator has a continuous rating of 225 KVA and a rated voltage dip of 13% when a rated KVA 0.8 PF load is applied in one step. If a 440 volt, 50 horsepower, code F motor requiring 315 starting KVA is applied to a 480 volt generating set, the voltage dip would be approximately:

$$\text{Voltage Dip} = \frac{315\ \text{KVA (load)}}{225\ \text{KVA (alternator rating)}} \times 13\% = 18\%$$

The proportion method is most accurate within 50 to 150% of the rating of the generating set.

CODE LETTER

All standard motors which meet NEMA (National Electrical Manufacturers Association) specifications have the starting KVA printed on the nameplate in the form of a code letter. A code letter is used because the starting KVA varies with the power source voltage. The higher the power source voltage compared to the motor's rated voltage, the higher the starting KVA. A 440 volt, 50 horsepower code F motor started by a 480 volt generating set will draw 315 KVA (see Table 2 in Part I). When the motor is started by a 416 volt generating set, the starting KVA is 236.

In certain cases, a smaller electric generating set can be used with better code letter type motors. The money saved on the generating set can offset the increased cost of the motor with the lower starting KVA. Following is an example of the choice of generating sets when considering motors of different code letters.

Example: Motors A and B are 440 volt, 50 horsepower, have a 0.4 PF during starting and are started by a 480 volt generating set. Data for example is taken from Table 2 in Part I.

	Motor A	Motor B
Code Letter	B	R
Starting KVA	159	892
Starting KW @ 0.4 PF	64	358
Recommended Electric Generating Set	65.0KB	400.0WK

Though the example may be exaggerated since it is difficult to find a code B or code R in a particular motor size, it demonstrates that it pays to compare the potential cost savings on the motor to that of the generating set.

CAUTION *Do not confuse the code letter with the design letter. A design letter is the NEMA designation denoting the torque versus speed characteristics (Figure 6). The design letter is not associated with the starting KVA and is not used in selecting the generating set.*

Standard NEMA minimum torque values for squirrel-cage induction motors. These values are for Designs A, B, C, D and F which are rated 30 to 50 hp.

FIGURE 6. MOTOR TORQUE VERSUS SPEED CHARACTERISTICS

REDUCED VOLTAGE MOTOR STARTING

Although voltage dip often causes various problems, a controlled reduction in voltage can be beneficial when used to reduce the starting KVA of a motor. Whenever the starting KVA is reduced, the size of the electric generating set required is reduced, voltage dip is reduced and the motor load has a softer start. Reduced voltage starters can be used whenever the reduction of the motor's torque will not hinder the application.

CAUTION *Before adding reduced voltage motor starters to equipment, consult the manufacturer of the equipment. The torque of the motor may be reduced to the point the motor can't start or accelerate the load. Motor damage could result.*

Table 9 compares different types of reduced voltage motor starting methods with their associated reduction in KVA and torque. Variations of these types of reduced voltage motor starters may be available from local suppliers.

Application Note: If the reduced voltage motor starter has a time or rate adjustment, adjust the settings to about two seconds between taps. This allows shaft speed to approach synchronous speed and reduce the peak KVA at the time of switching. A reduced voltage starter set in minimum position is not much of an improvement over full voltage starting as shown in Figure 7.

In some applications, the inrush current is so low, the motor shaft will not turn on the first and often the second tap. For this type of application, there is little reduction of starting KVA from the standpoint of the generating set.

TABLE 9. REDUCED VOLTAGE STARTING METHODS WITH CHARACTERISTICS

STARTING METHOD *	% VOLTS APPLIED (TAP)	% F.V. KVA	% F.V. TORQUE	MULTIPLYING FACTOR
Full Voltage	100	100	100	1.0
Reduced Voltage Autotransformer	80 65 50	64 42 25	64 42 25	.64 .42 .25
Series Reactor or Resistor	80 65 50	80 65 50	64 42 25	.80 .65 .50
Star Delta	*	*	*	*
Part Winding (Typical)	*	*	*	*
Wound Rotor Motor	*	*	*	*

* No standard values of KVA and torque are available. Contact supplier for information.

FIGURE 7. REDUCED VOLTAGE MOTOR STARTING EFFECTS

FULL VOLTAGE MOTOR STARTING

STARTING	APPLICATION NOTES	
Full voltage starting should always be used unless limited capacity of the generating set makes reduced KVA starting necessary or reduced voltage dip is required during motor starting. There is no limit to the HP, size, voltage rating or type of motor.	Across-the-line, full voltage starting most commonly used due to simplicity and initial low cost. Note on KVA and torque curves that starting KVA remains fairly constant until motor almost reaches full speed.	STARTING DIAGRAM PRIMARY CONNECTIONS START: CLOSE 1-2-3 RUN: NO CHANGE TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

OPEN TRANSITION, AUTOTRANSFORMER MOTOR STARTING

STARTING	APPLICATION NOTES	
Switched in line during starting, the autotransformer reduces voltage to the motor. Opening of circuit during transition to full voltage sometimes gives objectionable line surges.	Open transition types of reduced voltage starters should be avoided for generating set applications. The KVA drawn immediately after switched to the line is almost equal to the starting KVA. Lowers power factor during starting.	STARTING DIAGRAM PRIMARY CONNECTIONS START:CLOSE 2-3-5-6-7 RUN: OPEN 2-3-5-6-7 CLOSE 1-4-8 TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

CLOSED TRANSITION, AUTOTRANSFORMER MOTOR STARTING

STARTING	APPLICATION NOTES	
Circuit is not interrupted during starting. On transfer, part of autotransformer reactance remains in series with the stator winding.	Preferred to open type because it minimizes the electrical disturbance; but more expensive. Can have automatic or remote operation. Most commonly used of reduced voltage starting types. Principle advantage is more torque per current than other types of reduced voltage starters. Lowers power factor during starting.	STARTING DIAGRAM PRIMARY CONNECTIONS START: CLOSE 6-7-2-3-4 TRANSFER: OPEN 6-7 RUN: CLOSE 1-5 TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

CLOSED TRANSITION, REACTOR MOTOR STARTING

STARTING	APPLICATION NOTES	
Reactor starting, used for large motors, has advantage of simplicity and closed transition, but gives lower starting torque per KVA drawn from the line than with autotransformer starting.	Generally not used except in high voltage or high current installations. Exceptional low power factor. More cost because each must be designed for the application.	STARTING DIAGRAM PRIMARY CONNECTIONS START: CLOSE 1-2-3 RUN: CLOSE 4-5-6 TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

CLOSED TRANSITION, RESISTOR MOTOR STARTING

STARTING	APPLICATION NOTES	
Resistor starting is occasionally used for smaller motors where several steps of starting are required and no opening of motor circuit between steps is allowed.	Also available as a stepless transition starter which provides a smoother start. Resistor starting is usually the least expensive with small motors. Has a higher starting power factor. When actual power factor isn't known, use 0.8. Accelerates loads faster because the voltage increases with a decrease in current.	STARTING DIAGRAM PRIMARY CONNECTIONS START: CLOSE 1-2-3 SECOND STEP: CLOSE: 4-5-6 THIRD STEP: CLOSE 7-8-9 TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

OPEN TRANSITION, STAR-DELTA MOTOR STARTING

STARTING	APPLICATION NOTES	
Star-delta starting requires no autotransformer, reactor or resistor. The motor starts as a star-connected motor and runs delta connected.	This starting method is becoming more popular where low starting torques are accepted. Has the following disadvantages: 1. Open transition; closed transition available at extra cost. 2. Low torque. 3. Often no advantage when motor is run by generating set.	STARTING DIAGRAM PRIMARY CONNECTIONS START: CLOSE 1-2-3-4-5-6 RUN: OPEN 4-5-6 CLOSE 7-8-9 TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

CLOSED TRANSITION, PART WINDING MOTOR STARTING

STARTING	APPLICATION NOTES	STARTING DIAGRAM PRIMARY CONNECTIONS
Part winding starting is less expensive because it requires no autotransformer, reactor or resistor and uses simple switching. Available in two or more starting steps depending on size, speed and voltage of motor.	Automatically provides closed transition. First, one winding is connected to the line; after a time interval, the second winding is paralleled with the first. Starting torque is low and is fixed by the motor manufacturer. The purpose of part winding is not to reduce starting current but to provide starting current in smaller increments.	START: CLOSE 1-2-3 RUN: CLOSE 4-5-6

TYPICAL KVA AND TORQUE CURVES FOR SQUIRREL-CAGE INDUCTION MOTORS

CLOSED TRANSITION, WOUND ROTOR MOTOR STARTING

STARTING	APPLICATION NOTES	STARTING DIAGRAM PRIMARY CONNECTIONS
A wound rotor motor can have the same starting torque as a squirrel cage motor but with less current. Differs from squirrel cage motors only in the rotor. Squirrel cage motor has short circuit bars, wound rotor motor has windings, usually three phase.	Starting current, torque and speed characteristics can be changed by connecting the proper amount of external resistance into the rotor.	START: CLOSE 1-2-3 FIRST STEP: CLOSE 4-5 SECOND STEP: CLOSE 6-7 RUN: CLOSE 8-9

TYPICAL KVA AND TORQUE CURVES FOR WOUND ROTOR MOTORS

Following is a sample motor starting problem using reduced voltage starting. The motor is 50 horsepower, 460 volt, code F, has a starting KVA of 289 and a 0.4 starting PF. The generating set output is 480 volts. See Table 10.

TABLE 10. SAMPLE MOTOR STARTING PROBLEM

	TYPE OF STARTER		
	AUTOTRANSFORMER	RESISTOR	FULL VOLTAGE
% of applied volts (tap)	65	50	100
% of full voltage (multiplier)	.42	.50	1.0
Starting KVA with reduced voltage motor starter	289 x .42 = 118	289 x .50 = 145	289 x 1.0 = 289
Starting KW with starter	118 x 0.4 = 47	145 x 0.8 PF * = 116	289 x 0.4 PF = 116
Run KVA	47.5	47.5	47.5
Run KW	41.5	41.5	41.5
† Generating set (gasoline)	55.0KB	115.0WA	115.0WA
† Generating set (diesel)	50.0DEG	125.0DYD	125.0DYD

* See description of closed transition, resistor motor starting.
† From Tables 5 and 6 of Part I.

Conclusion: Autotransformer starting and wound rotor motor starting require the least motor starting capacity from the electric generating set, and allow the smallest capacity generating set to be purchased. Resistor starting and part winding motors have little effect on reducing the capacity requirement of the generating set.

ELEVATOR MOTORS AND PUMP BACK

The design of elevator motors depends on the operating speed, capacity, number of floors and duty cycle. Basic types of elevators are: hydraulic, direct drive and motor generator (MG). Because each elevator is chosen for its particular application and many variations are available, contact the local representative of the manufacturer for the elevator involved.

CAUTION *In many applications, the manufacturer may use an undersized motor (10 horsepower motor for a 15 horsepower load). Calculate using the actual load and not the nameplate rating.*

PUMP BACK

"Pump back" of power is a concern for MG type elevator applications. In some elevator applications, the motor is used as a brake when the elevator is descending and generates electricity. Electricity is then pumped back into the power source. If the source is commercial utility power, it can easily be absorbed. If the power source is an electric generating set, the pumped back power can cause the generating set and the elevator to overspeed.

To prevent overspeed of the elevator, the maximum amount of power that can be pumped back into the generating set must be known. Permissible amount of absorption is 20% of the generating set's rated KW. If the pump back is greater than 20%, other loads must be connected to the generating set, as emergency light or "dummy" load resistance. Emergency lighting should be permanently connected to the generating set for maximum safety. A dummy load could be automatically switched on the line whenever the elevator is operating from the generating set.

The following information is required for elevator applications:

1. Number of elevators in full service when operating on emergency power.
2. Horsepower, code letter, maximum KW and KVA of motor(s).
3. The accelerating KVA and power factor (full load up) for each elevator motor.
4. Determine if motor is started on demand each time elevator is used.
5. Maximum amount of "pumped back" power.

Sample Elevator Application: Starting a hydraulic elevator.

1. One elevator.
2. A 25 horsepower, 200 volt, 3 phase motor to operate from a 208 volt generating set.

	STARTING KVA WYE START	80% SPEED DELTA	F.V. RUNNING DELTA
Volts	200	200	200
Amps	150	316	70
KVA	52	110	25
KW	30	65	21.5
PF	58%	60%	85.5%

3. Acceleration is 30% greater than run load.
4. Starts on demand.
3. No "pumped back" power. Lighting load 11 KW, 1.0 PF.

From the starting requirement of 30 KW plus 11 KW lighting, it appears a 45 KW electric generating set is satisfactory. However, as the elevator starts to rise, the motor's requirement in order to accelerate the elevator, may exceed the running requirement by 30% or more. Due to the critical application, Onan is requested to supply a generating set that starts the elevator motor even if switched from wye to delta at less than full speed. At 80% of rated speed in the delta connection, the motor requires 65 KW. With this motor requirement plus 11 KW of lighting, a 75 KW electric generating set is recommended.

X-RAY APPLICATIONS

X-ray applications are somewhat difficult due to the limited information available from the X-ray equipment manufacturers. The essential information needed to properly size a generating set is the peak KVA load (KVP x ma) and the allowable voltage dip. If this information is available, then the solutions given in the section on VOLTAGE DIP can be used.

For all X-ray applications, two important factors must be understood:

1. The operator must realize when the X-ray equipment is powered by the generating set, the picture may be different than when powered by the commercial utility line.

   Figure 8 shows the stability of the power line during the X-ray, but the generating set has a greater voltage dip and also attempts to regulate during the X-ray.

FIGURE 8. VOLTAGE DIP OF GENERATING SET AND UTILITY POWER

would

2. Between the time the operator makes the adjustment for the X-ray and takes the X-ray, no large load changes should take place from elevators or air conditioning switching on or off. This is of particular concern in mobile applications where there are usually two large loads, the X-ray equipment and the air conditioner. For these applications, it is recommended the air conditioning be left on continuously and the temperature be controlled by changing the ratio of outside air to cooled air with a small motorized control.

The X-ray machine is designed to operate from the power line. Most have a line voltage compensator, some of which are installer adjustable and others are adjustable by the operator. In applications where the generating set is the only power source, the line voltage compensator can be adjusted for the generating set's voltage dip. For X-ray equipment having been adjusted for power line operation, the generating set must duplicate the voltage dip of the utility power line as close as possible. X-ray engine and alternator requirements are shown in Table 11.

TABLE 11. X-RAY MINIMUM ENGINE AND ALTERNATOR REQUIREMENTS

X-RAY RATING		PEAK LOAD (Max. KVP x 1.0 PF) MIN. ENGINE KW	MIN. KVA RATING* MIN. ALTERNATOR KVA
ma	KVP		
15	100	1.5	3.8
20	85	1.7	4.3
40	125	5.0	12.5
50	125	6.3	15.8
100	125	12.5	31.3
200**	125**	25.0	62.5
300	125	37.5	93.8
300	150	45.0	112.0
500	125	62.5	156.0
500	150	75.0	187.0
700	110	77.0	192.0
1200	90	108.0	270.0

* Minimum Alternator KVA = $\frac{\text{PEAK LOAD}}{0.4}$

** Onan special X-ray model available for this popular size.

Past experience shows whenever the X-ray unit's peak load is approximately 40% of the generating set's continuous rating, the X-ray pictures will be satisfactory. This results in approximately 6% voltage dip on most Onan units. Higher current and voltage settings on the X-ray machine may not be usable if the voltage dip approaches 10%.

Sample X-ray problem: The X-ray loads can be calculated by multiplying the KVP by the ma. With 200 ma X-ray, 125 KVP, .95 PF, we find:

$$0.2 \text{ amps} \times 125{,}000 \text{ volts} = 25 \text{ KVA}$$

$$\text{KW} = \text{KVA} \times .95 \text{ PF} = 23.8 \text{ KW}$$

To find the minimum size continuous KVA alternator for this application, divide

$$\frac{25 \text{ KVA}}{40\% \text{ or } 0.4} = 62.5 \text{ KVA}$$

Generating set selection results in two model choices.

Choice 1: 30.0EK-3R/17 X-ray model.
This choice will allow a miscellaneous load of 6.2 KW (30 KW − 23.8 KW = 6.2 KW).

Choice 2: 55.0KB, full output single phase.
Allows for a 21.2 KW miscellaneous load (55 KW − 23.8 KW = 21.2 KW).

STARTING GENERATING SET WITH APPLIED LOAD

Simultaneous starting of an electric generating set and load must not be considered in attempts to start a load larger than can be started in "across-the-line" type starting. Experience indicates almost every load capable of starting simultaneously with the generating set could also have been started across the line.

Because of all the variables and uncertainties involved in simultaneous starting, Onan personnel will not recommend, nor use, simultaneous starting when calculating load applications.

POWER FACTOR

Power factor must be considered in all motor starting applications. The starting power factor determines the starting KW (Figure 9). If actual power factor is unobtainable, see Table 12. Starting amperes or KVA (code letter) is available from the nameplate on the motor or from the motor manufacturer.

FIGURE 9. TYPICAL POWER FACTOR CURVE

These two examples demonstrate the effect of PF on the starting KW.

Example 1:

50 KVA starting x 0.2 PF starting = 10 KW starting

Example 2:

50 KVA starting x 0.5 PF starting = 25 KW starting

TABLE 12. STARTING AND RUNNING POWER FACTORS

	POWER FACTOR	
	START	RUN
3 Phase motors less than 10 hp	0.5	0.8 -0.9
3 Phase motors 10 hp and larger	0.4	0.8 -0.9
1 Phase motors larger than 1 hp (permanent split, capacitor start)	0.75	0.75 -0.85
1 Phase motors less than 1 hp and capacitor start	0.5	0.5 -0.75
Welder – motor type	0.3	0.5 -0.6
Welder – transformer type		0.5 -0.7
Incandescent lamps		1.0
Fluorescent lamps		0.95
Resistor heating		1.0

VOLTAGE DROP

For most applications, the line voltage loss can be ignored if the wire size meets the requirements of the National Electric Code. Determining voltage drop of a conductor is relatively simple, assuming the DC resistance equals the AC impedance. It's important to note the conductor distance is twice the distance from the generating set to the load. Table 13 gives the standard resistances at 20 C (68 F). Calculations are the same for single and three phase.

Volts drop of a conductor is equal to:

$$\frac{\text{Conductor dist. (ft) x ohms per 1000 ft. x amps}}{1000}$$

Example: An electric generating set 50 feet from the load using copper wire has a voltage drop of:

$$\frac{100\text{ ft. x } 0.098\text{ (1/0 wire) x } 100\text{ amps}}{1000} = 0.98\text{ volts}$$

This voltage drop of the conductor is in addition to the voltage drop of the generating set.

TABLE 13. CONDUCTOR RESISTANCES

WIRE SIZE Awg	COPPER Ohms/1000 ft. at 20 C (68 F), 100% Conductivity	ALUMINUM Ohms/1000 ft. at 20 C (68 F), 100% Conductivity
4/0	.04901	.07930
3/0	.06182	.1000
2/0	.07793	.1261
1/0	.09825	.1590
1	.1239	.2005
2	.1563	.2529
3	.1971	.3189
4	.2485	.4021
5	.3134	.5072
6	.3952	.6395
7	.4981	.8060
8	.6281	1.016
9	.7925	1.282
10	.9988	1.616
11	1.26	2.04
12	1.59	2.57
13	2.00	3.24
14	2.52	4.08
15	3.18	5.15

VARIABLE VOLTAGE AND FREQUENCY EFFECTS ON INDUCTION MOTORS

All generating sets vary in voltage and frequency with load. An ideal generating set is represented by the dot in the center of Figure 10. The voltage and frequency variation would be zero at full load. Because an ideal power source as this is impossible to build, motors are designed to withstand variations. Any variation of voltage or frequency within the dashed lines is acceptable to most motors (MG1-20.45). Larger generating sets have better governors and voltage regulators, and are closer to the ideal power source. Two examples of generating set variations have been added to Figure 10 for comparison.

FIGURE 10. EFFECTS OF FREQUENCY AND VOLTAGE VARIATIONS

Though motors will operate successfully over the above voltage and frequency range, their performance will change. Figures 11 and 12 show the approximate effects of variations in voltage and frequency. These effects will vary with design and size of the motor.

Table 14 is from the AMERICAN NATIONAL STANDARD FOR VOLTAGE RATINGS FOR ELECTRIC POWER SYSTEMS AND EQUIPMENT (ANSI C84.1-1970). The table shows the maximum and minimum voltages supplied by public utilities. Equipment

FIGURE 11. EFFECTS OF FREQUENCY VARIATIONS

FIGURE 12. EFFECTS OF VOLTAGE VARIATIONS

manufacturers must design their equipment to operate over these voltage ranges. Occasionally, customers request closer voltage regulation than normally supplied by the power company. The equipment necessary for closer regulation is expensive and usually unnecessary.

TABLE 14. STANDARD SYSTEM VOLTAGES

NOMINAL SYSTEM VOLTAGE			VOLTAGE RANGE		
			Minimum		Maximum
Two Wire	Three Wire	Four Wire	Utilization Voltage	Service Voltage	Utilization and Service Voltage
SINGLE PHASE SYSTEMS					
120			110	114	126
	120/240		110/220	114/228	126/252
THREE PHASE SYSTEMS					
		208Y/120	191Y/110	197Y/114	218Y/126
		240/120	220/110	228/114	252/126
	240		220	228	252
		480Y/277	440Y/254	456Y/263	504Y/291
	480		440	456	504
	600		(Limits Not Established)		

ALLOWABLE SINGLE AND THREE PHASE UNBALANCE

Loads often consist of both three phase and single phase equipment. In general, any combination of single phase and three phase loads is permissible as long as the nameplate line current rating is not exceeded. A good approach is to divide the single phase load into three equal loads and distribute across each phase. This makes the single phase loads look like a three phase load to the alternator. For allowable combinations of unbalanced loads, see Figure 13.

Example: Determine the single phase load possible for an electric generating set with a 125 KVA, 100 KW rating and has a 62 KVA, 3 phase load. Then calculate:

$$\frac{\text{KVA Load}}{\text{KVA Alternator Rating}} = \%;$$

$$\frac{62\text{ KVA Load}}{125\text{ KVA Alternator Rating}} = 50\%.$$

The maximum single phase load allowed according to Figures 13 and 14 is approximately 34% of the

FIGURE 14. DETERMINING MAXIMUM SINGLE PHASE LOAD WITH A THREE PHASE LOAD

FIGURE 13. ALLOWABLE COMBINATIONS OF UNBALANCED LOADS

three phase rating (125 KVA x 34% = 42.5 KVA).

NOTE: *The total KVA, 62 KVA + 42.5 KVA = 104.5 KVA, is less than the 125 KVA rating of the generating set. If the single phase load could be split into three equal loads, the full rating of the generating set could be used.*

CAUTION *When unbalanced loads are connected to a three phase alternator, the phase voltages are no longer balanced. The amount of unbalanced voltage can be greater than 10% between phases, depending upon the amount of unbalanced load connected to the alternator. Therefore, place any critical load on the same phase as the voltage reference circuit.*