

GE Consumer & Industrial
Power Protection

UPS technical note no. 3

Digital Energy™ Uninterruptible Power Supply

Three phase UPS battery sizing

SitePro Series 6

400 Vac CE – Series 6

SG Series

400 Vac CE – Series 0

LP 33 Series

400 Vac CE – Series 3&4

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1 Abstract

Battery in a UPS system cover the strategic role to supply the required energy to the load during mains utility fails or when the input mains voltage and frequency are out of acceptable values. Moreover battery cover an important part in the total cost of a UPS system.

Therefore a correct battery size is very important in the UPS design.

In particular this document consider battery type VRLA (Valve Regulated Lead Acid) and UPS of the following families:

- SitePro Series 6
- SG Series 400 Vac CE series 0
- LanPro 33 Series 3 & 4

2 Battery sizing methodology

Battery manufactures provide different types of information for sizing the batteries and can assist you in the calculations.

Beside general information, battery manufactures supplied tables for Watt/cell or Amp to end of cell voltage discharge (Vpc).

The batteries characteristics change among the different manufacturer, therefore use the specific data for the selected battery manufacturer.

Battery calculation must be done taking into consideration the following items:

- the capacity shall be dimensioned considering the specific required load (kW) and not for the UPS size (kVA)
- UPS inverter losses (or efficiency) shall be take into consideration
- the UPS shall be able to recharge the battery, therefore the maximal UPS battery charging current has to be considered
- battery design lifetime, usually 5 years (C20) or 10 years (C10)
- the required battery recharging current, that typically is:
 - $0.10 \dots 0.2 \cdot C_{20}$ for 5 years batteries
 - $0.05 \dots 0.2 \cdot C_{10}$ for 10 years batteriesAttention: at a lower recharge current than $0.10 \cdot C_{20}$ (5 years batteries) or $0.05 \cdot C_{10}$ (10 years batteries) the battery can not be recharged 100%, therefore it's strongly recommended to not underneath these values.
- the average battery room temperature, that usually is 20...25 °C

Two are the methods used to calculate the type of battery cell:

**Constant power discharge
(Watts/Cell)
at different end voltages/rates.**

**Method used for back-up time
up to 90 min.**

**Constant current discharge
(Amps)
at different end voltages/rates**

**Method used for back-up time
more than 90 min.**

2.1 Battery sizing for discharge by constant power

1. Load active power calculation, in Watts:
 $W_{Load} = \text{Load apparent power [kVA]} \times \cos\phi$
2. Battery power, in Watt:
 $W_{Battery} = W_{load} / \text{Inverter efficiency}$
3. Battery cells number:
 $N^{\circ}\text{Cells} = \text{Battery Floating Voltage} / \text{Cell Floating Voltage}$
4. Watts per cell:
 $(W_{pc}) = W_{bat} / N^{\circ}\text{Cells}$
5. End discharge volt per cell:
 $(V_{pc}) = \text{Battery minimum discharge voltage} / N^{\circ}\text{Cells}$
6. From the Battery documentation select the table with value of V_{pc}
7. Find out the column for the requested autonomy in minutes
8. W_{pc} value define the battery type and battery blocks number.

Note: for SitePro and LP 33 battery calculation, the typical Inverter efficiency can be used, that is 93÷94% for load between 50 to 100%.

2.1.1 Example 1 – UPS type SitePro or SG-Series 400 Vac CE (discharge by constant power)

Project data:

- Load 60 kVA,
- Power factor p.f. 0.80
- Autonomy 30min.
- UPS SitePro 60 kVA
- UPS inverter efficiency 94%
- UPS floating voltage 409 V
(405 ÷ 436 data from Technical Data Sheet)
- Minimum discharge voltage 317 V
- Battery floating voltage: 2.27 Vpc

BATTERY					
Battery type	Valve regulated lead-acid (VRLA)-standard vented lead-acid, NiCd				
Number of 12 V blocks, 6 cells/block	30 to 32, placed in external cabinets				
Float voltage at 20°C	405 ÷ 436V (dependent on the number of blocks)				
Min. discharge voltage (programmable)	1.9V/cell				
Recharge time	<5 hours up to 90% of battery capacity				
"Battery to earth" fault detection	Standard				
Automatic and manual battery test	Standard				
Automatic battery connector	Standard				
BATTERY POWER DATA	kVA	60	80	100	120
DC power at full load and PF=0.8 lag.	kW	51	67	84	101
DC power at full load and PF=0.9 lag.	kW	57	76	95	114
DC power at full typical computer load (PF=0.66 lag.)	kW	41.8	55.7	69.7	83.6
Matching battery cabinets	See optional features on page 3				

Battery sizing:

1. Load Power in kW $60 \times 0.80 = 48 \text{ kW}$
2. Battery Power in kW $48 / 0.94 = 51 \text{ kW}$
3. N° of cells $409 / 2.27 = 180$
4. Watt per cell $51'000 / 180 = 283 \text{ Wpc}$
5. End discharge volt per cell $317 / 180 = 1.76 \text{ Vpc}$
6. Select on battery catalogue the table 'Watts per cell' to 1.75Vpc
7. From column 30 min select the nearest value to 283 Wpc, that is 299 Wpc
8. With the Wpc define the battery type: 60 blocks 6V-135Ah.

Constant power data to 1.75 Vpc at 20°C (Watt/cell)																
Type	Cells	Minutes run time														
		5	10	15	20	30	60	90	120	180	240	300	480	600	720	1200
12V-50Ah	6	279	207	166	139	106	64.5	47.2	37.5	27	21.3	17.7	11.7	9.7	8.2	5.2
12V-100Ah	6	514	381	305	256	196	119	86.8	69	49.7	39.3	32.5	21.5	17.8	15	9.5
12V-150Ah	6	838	622	498	418	319	194	142	113	81	64	53	35	29	24.5	15.5
12V-26Ah	6	153	111	88.1	73.3	55.4	33	24	19.1	13.8	10.9	9.1	6.1	5.1	4.4	2.8
12V-39Ah	6	229	167	132	110	83.2	49.5	36	28.7	20.7	16.3	13.7	9.2	7.7	6.5	4.2
12V-52Ah	6	305	222	176	147	111	66	48.2	38.3	27.7	21.8	18.2	12.3	10.2	8.7	5.7
12V-65Ah	6	381	278	220	183	139	82.5	60.2	47.8	34.5	27.2	22.7	15.3	12.7	10.8	7
6V-60Ah	3	348	256	204	170	129	78	57	45.3	32.7	25.7	21.3	14.3	11.7	10	6.3
6V-80Ah	3	465	341	272	227	173	104	76	60.3	43.3	34	28	18.7	15.3	13	8.3
6V-100Ah	3	581	427	339	284	216	130	95	75.7	54.3	42.7	35.3	23.7	19.3	16.3	10.3
6V-115Ah	3	692	510	405	338	256	153	111	88	62.7	49	40.7	27	22	18.7	11.7
6V-135Ah	3	809	595	473	394	299	179	130	103	73	57	47	31	25.3	21.3	13.3
6V-155Ah	3	923	679	540	450	342	204	148	117	83.3	65.3	53.7	35.3	29	24.7	15.3
4V-185Ah	2	1046	768	611	510	389	234	171	136	98	77	64	42.5	35	29.5	19
4V-205Ah	2	1163	856	680	567	431	260	191	152	110	86	71.5	47	38.5	32.5	20
4V-225Ah	2	1257	947	758	634	480	286	207	164	118	93	77.5	52	43	37	24
2V-180Ah	1	866	677	550	464	359	225	170	138	102	80	66	42	34	28	17
2V-240Ah	1	1152	901	737	625	485	299	222	178	129	102	85	57	47	40	25
2V-300Ah	1	1443	1128	916	774	598	375	283	230	169	134	110	71	57	47	28

2.1.2 Example 2 – UPS type SitePro or SG-Series 400 Vac CE (discharge by constant power)

Project data:

- Load 60 kVA,
- Power factor p.f. 0.80
- Autonomy 90 min.
- UPS SitePro 60 kVA
- UPS floating voltage 409 V
(405 ÷ 436 data from Technical Data Sheet)
- Minimum discharge voltage 317 V
- Battery floating voltage: 2.27 Vpc

BATTERY	
Battery type	VRLA - regulated lead-acid (VRLA)-standard vented lead-acid, NiCd
Number of 12 V blocks, 6 cells/block	30 to 32, placed in external cabinets
Float voltage at 20°C	405 ÷ 436V (dependent on the number of blocks)
Min. discharge voltage (programmable)	1.90V/cell
Recharge time	<5 hours up to 90% of battery capacity
"Battery to earth" fault detection	Standard
Automatic and manual battery test	Standard
Automatic battery contactor	Standard
BATTERY POWER DATA	
	kVA 60 80 100 120
DC power at full load and PF=0.8 lag.	kW 51 67 84 101
DC power at full load and PF=0.9 lag.	kW 57 76 95 114
DC power at full typical computer load (PF=0.66 lag.)	kW 41.8 55.7 69.7 83.6
Matching battery cabinets	See optional features on page 3

Battery sizing:

1. Load power in kW $60 \times 0.80 = 48 \text{ kW}$
2. Battery power in kW 51 kW (from Technical Data Sheet)
3. No. of cells $409 / 2.27 = 180$
4. Watt per cell $51'000 / 180 = 283 \text{ Wpc}$
5. End discharge Volt per cell $317 / 180 = 1.76 \text{ Vpc}$
6. Select on battery catalogue the table 'Watts per cell' to 1.75 Vpc
7. From column 90 min select the nearest value to 283 Wpc, that is 284 Wpc
8. With the Wpc, define the battery type: 180 blocks 2V-300 Ah.

Alternative configuration

As alternative solution it is possible to install 2 battery strings in parallel.

The required battery Watt per cell will be $283 / 2 = 141.5 \text{ Wpc}$, that means 2x 60 blocks type 6V-155 Ah.

Constant power data to 1.75 Vpc at 20°C (Watt/cell)																
Type	Cells	Minutes run time														
		#	5	10	15	20	30	60	90	120	180	240	300	480	600	720
12V-50Ah	6	279	207	166	139	106	64.5	47.2	37.5	27	21.3	17.7	11.7	9.7	8.2	5.2
12V-100Ah	6	514	381	305	256	196	119	86.8	69	49.7	39.3	32.5	21.5	17.8	15	9.5
12V-150Ah	6	838	622	498	418	319	194	142	113	81	64	53	35	29	24.5	15.5
12V-26Ah	6	153	111	88.1	73.3	55.4	33	24	19.1	13.8	10.9	9.1	6.1	5.1	4.4	2.8
12V-39Ah	6	229	167	132	110	83.2	49.5	36	28.7	20.7	16.3	13.7	9.2	7.7	6.5	4.2
12V-52Ah	6	305	222	176	147	111	66	48.2	38.3	27.7	21.8	18.2	12.3	10.2	8.7	5.7
12V-65Ah	6	381	278	220	183	139	82.5	60.2	47.8	34.5	27.2	22.7	15.3	12.7	10.8	7
6V-60Ah	3	348	256	204	170	129	78	57	45.3	32.7	25.7	21.3	14.3	11.7	10	6.3
6V-80Ah	3	465	341	272	227	173	104	76	60.3	43.3	34	28	18.7	15.3	13	8.3
6V-100Ah	3	581	427	339	284	216	130	95	75.7	54.3	42.7	35.3	23.7	19.3	16.3	10.3
6V-115Ah	3	692	510	405	338	256	153	111	88	62.7	49	40.7	27	22	18.7	11.7
6V-135Ah	3	809	595	473	394	299	179	130	103	73	57	47	31	25.3	21.3	13.3
6V-155Ah	3	923	679	540	450	342	204	148	117	83.3	65.3	53.7	35.3	29	24.7	15.3
4V-185Ah	2	1046	768	611	510	389	234	171	136	98	77	64	42.5	35	29.5	19
4V-205Ah	2	1163	856	680	567	431	260	191	152	110	86	71.5	47	38.5	32.5	20
4V-225Ah	2	1257	947	758	634	480	286	207	164	118	93	77.5	52	43	37	24
2V-180Ah	1	866	677	550	464	359	225	170	138	102	80	66	42	34	28	17
2V-240Ah	1	1152	901	737	625	485	299	222	178	129	102	85	57	47	40	25
2V-300Ah	1	1443	1128	916	774	598	375	284	230	169	134	110	71	57	47	28

2.1.3 Example 3 – UPS type LP 33 (discharge by constant power)

Project data

- Load 30 kVA
- Power factor p.f. 0.80
- Autonomy 20 min.
- UPS LP 33 - 30 kVA
- Inverter efficiency 94%
- UPS floating voltage 2x273 V (from Technical Data Sheet)
- End discharge voltage 2x198 V (from Technical Data Sheet)
- Battery floating voltage: 2.27 Vpc

BATTERY				
Battery type	Standard: valve regulated lead-acid (VRLA)			
Number of 12V 7Ah batteries (standard cabinet)	1 x 40 (10 kVA)	2 x 40 (20 kVA)	3 x 40 (30 kVA)	
Float voltage at 20°C	2 x 273V			
Min. discharge voltage	198V			
Recharge time	6.5-8 hours			
Automatic and manual battery test	Standard			
BATTERY POWER DATA				
	kVA	10	20	30
DC power at full load and PF=0.8 lag	kW	8.42	16.84	25.26
DC power at full typical computer load (PF=0.66 lag.)	kW	6.95	13.9	20.85
Standard autonomy time at 100% load and PF=0.8 lag	min.	7	7	7
Standard autonomy time at 50% load and PF=0.8 lag	min.	18	18	18
Standard autonomy time at 100% typical computer load	min.	10	10	10
Matching battery cabinets	See table on page 4			

Battery sizing:

1. Load power in kW $30 \times 0.80 = 24 \text{ kW}$
2. Battery power in kW $24 / 0.94 = 25.5 \text{ kW}$
3. No. of cells $2 \times 273 / 2.27 = 2 \times 120$ (standard and fixed value not modified)
4. Watt per cell $25'500 / (2 \times 120) = 106 \text{ Wpc}$
5. End discharge volt per cell $198 / 120 = 1.65 \text{ Vpc}$
6. Select on battery catalogue the table 'Watts per cell' to 1.65 Vpc
7. From column 20 min select the nearest value to 106 Wpc, that is 119 Wpc
8. With the Wpc, define the battery type: 20+20 blocks 12V-39 Ah.

Constant power data to 1.65 Vpc at 20°C (Watt/cell)															
Type	Cells	Minutes run time													
		#	5	10	15	20	30	60	90	120	180	240	300	480	600
12V-50Ah	6	339	239	185	153	114	67.2	48.7	38.5	27.5	21.5	17.8	11.8	9.7	8.2
12V-100Ah	6	624	439	341	281	210	124	89.5	70.8	50.6	39.6	32.8	21.8	17.8	15
12V-150Ah	6	1017	716	556	458	342	202	146	116	82.5	64.5	53.5	35.5	29	24.5
12V-26Ah	6	180	125	96.8	79.2	58.7	34.2	24.6	19.5	14	11	9.2	6.2	5.1	4.4
12V-39Ah	6	271	188	145	119	88.2	51.3	37	29.2	21	16.5	13.7	9.3	7.7	6.5
12V-52Ah	6	361	251	194	159	118	68.3	49.3	39	28	22	18.3	12.3	10.3	8.8
12V-65Ah	6	451	313	242	198	147	85.3	61.7	48.7	35	27.5	22.8	15.5	12.8	11
6V-60Ah	3	407	286	222	183	137	80.7	58.3	46.3	33	26	21.3	14.3	11.7	10
6V-80Ah	3	542	382	296	244	182	107	77.7	61.3	44	34.3	28.3	18.7	15.3	13
6V-100Ah	3	678	477	370	305	228	134	97.3	77	55	43	35.7	23.7	19.3	16.3
6V-115Ah	3	810	571	442	363	271	158	114	89.7	63.7	49.7	41	27	22	18.7
6V-135Ah	3	944	665	516	424	316	184	133	104	74	57.7	47.3	31.3	25.3	21.7
6V-155Ah	3	1079	761	590	485	361	211	151	119	84.3	66	54.3	35.7	29.3	24.7
4V-185Ah	2	1221	859	667	549	410	242	175	139	99	78	64.5	43	35	30
4V-205Ah	2	1345	951	738	607	453	268	195	155	111	87	72	47.5	39	33
4V-225Ah	2	1368	1029	811	670	501	293	211	167	119	94	78	52.5	43.5	37
2V-180Ah	1	1066	793	624	516	389	237	176	143	104	82	67	43	34	28
2V-240Ah	1	1417	1055	837	696	526	315	230	183	132	104	86	57	47	40
2V-300Ah	1	1776	1321	1040	860	649	394	294	237	173	136	112	71	57	47

2.2 Battery sizing for discharge by constant current

1. Calculate the power in Watts of the load:
 $W_{load} = kVA \times \cos\phi$
2. Calculate the power in Watts of the battery:
 $W_{bat} = W_{load} / \text{Inverter efficiency}$
3. Define the N° of cells:
 $N^{\circ}\text{Cells} = \text{Battery Floating Voltage} / \text{Cell Floating Voltage}$
4. Calculate the Max. battery current
 $\text{Max. discharge Current} = W_{bat} / \text{Battery Minimum Voltage}$
5. To calculate end discharge volt per cell:
 $(V_{pc}) = \text{Battery minimum discharge voltage} / N^{\circ}\text{Cells}$
6. From the Battery documentation select the table with the calculated value of V_{pc}
7. Find out the column for the requested autonomy in minutes
8. The current value define the battery type and battery blocks number.

Note: for SitePro and LP 33 battery calculation the typical Inverter efficiency can be used, that is 93÷94% for load between 50 to 100%.

2.2.1 Example 4 – UPS type SitePro (discharge by constant current)

Project data

- Load 60 kVA
- Power factor p.f. 0.80
- Autonomy 120 min.
- UPS SitePro 60 kVA
- UPS inverter efficiency 94%
- UPS floating voltage 409 V
(405 ÷ 436 data from Technical Data Sheet)
- Minimum discharge voltage 317V
- Battery floating voltage: 2.27 Vpc

BATTERY					
Battery type	Valve-regulated lead-acid (VRLA)-standard vented lead-acid, NiCd				
Number of 12 V blocks, 6 cells/block	30 to 32, placed in external cabinets				
Float voltage at 20°C	405 ÷ 436V (dependent on the number of blocks)				
Min. discharge voltage (programmable)	1.75V/cell				
Recharge time	<5 hours up to 90% or battery capacity				
"Battery to earth" fault detection	Standard				
Automatic and manual battery test	Standard				
Automatic battery contactor	Standard				
BATTERY POWER DATA	kVA	60	80	100	120
DC power at full load and PF=0.8 lag.	kW	51	67	84	101
DC power at full load and PF=0.9 lag.	kW	57	76	95	114
DC power at full typical computer load (PF=0.66 lag.)	kW	41.8	55.7	69.7	83.6
Matching battery cabinets	See optional features on page 3				

Battery sizing:

1. Load Power in Kw $60 \times 0.80 = 48 \text{ kW}$
2. Battery power in kW $48 / 0.94 = 51 \text{ kW}$
3. No. of cells $409 / 2.27 = 180$
4. Max discharge current $51'000 / 317 = 161 \text{ A}$
5. End discharge Volt per cell $317 / 180 = 1.76 \text{ V}$
6. Select on battery catalogue the table 'Amps to 1.75Vpc'
7. From column 120 min select the nearest value to 161 A, that is 160 A
8. Define the battery type: 180 blocks 2V-405Ah.

RECTIFIER						
Rectifier bridge	Three phase, 6 thyristors, overtemperature protection					
Standard input voltage	Nominal: 3x380/400/415V + N Rectifier accepted ph-ph voltage range: 320-460V (320V only for 405VDC battery floating)					
Other input voltages	On request					
Input frequency	50/60Hz +/-10% (45-66Hz)					
Power factor	0.8 lag.					
Inrush current	Limited by soft-start circuit					
Power walk-in	>30 seconds					
Output voltage tolerance	+/- 1%					
DC voltage ripple	<1%					
DC current ripple	Max. 5% the battery capacity [Ah], expressed in A					
Battery charging characteristic	IU (DIN 41773), T° compensated floating voltage					
Battery charging current limit	Programmable					
INPUT POWER DATA	kVA	60	80	100	120	
Input power at inverter nominal load	at PF=0.8 lag.	kW	51.9	69.2	86	103.2
and charged battery	at PF=0.9 lag.	kW	58.4	77.8	96.8	116.1
Max. input power at inverter nominal load and max. battery recharge current (programmable)	at PF=0.8 lag.	kW	70	93.4	116.1	139.4
Max. battery charging current (programmable) at the beginning of battery recharge at nominal load	at PF=0.8 lag.	A	33	43	54	64
	at PF=0.9 lag.	A	37	47	57	67

Constant current data in Amps to 1.75 Vpc at 20 °C																
Type	Minutes run time															
	5	10	15	20	30	60	90	120	180	240	300	480	600	720	1200	
6V-60Ah	194	141	111	92.7	70.1	41.5	30	23.7	16.9	13.2	10.9	7.3	6	5.1	3.3	
6V-80Ah	258	188	149	124	93.4	55.4	40	31.6	22.5	17.6	14.6	9.7	8	6.9	4.4	
6V-100Ah	323	235	186	155	117	69.2	50	39.5	28.1	22	18.2	12.2	10	8.6	5.5	
6V-115Ah	385	280	222	184	138	81.4	58.5	46	32.6	25.5	21	14	11.5	9.9	6.4	
6V-135Ah	449	327	259	215	162	94.9	67.9	53.3	37.7	29.5	24.4	16.4	13.6	11.6	7.5	
6V-155Ah	512	374	296	246	185	108	77.5	60.8	43.1	33.7	27.9	18.8	15.6	13.4	8.6	
4V-185Ah	580	422	334	278	210	124	89.6	70.7	50.4	39.6	32.9	22.3	18.6	16	10.4	
4V-205Ah	641	471	373	310	233	138	99.6	78.9	56.6	44.6	37	25	20.7	17.7	11.5	
4V-225Ah	696	523	416	346	259	152	110	87	62.3	49.1	40.8	27.4	22.6	19.3	12.3	
2V-180Ah	487	377	303	255	195	120	89.7	72.6	53.2	42	34.7	22.5	18.2	15.2	9.4	
2V-240Ah	650	502	404	339	260	160	120	96.8	70.9	56	46.3	30.1	24.3	20.3	12.5	
2V-300Ah	819	637	511	427	325	200	151	123	90.5	71.7	59.1	37.9	30.3	25.2	15.3	
2V-345Ah	799	694	598	518	400	236	171	137	100	79.7	66.3	43.4	34.9	29	16.9	
2V-405Ah	932	810	698	604	467	275	200	160	117	93.2	77.5	50.8	40.9	34.1	19.9	
2V-465Ah	1065	925	798	690	533	315	228	183	134	107	88.9	58.4	47	39.1	22.9	
2V-450Ah	889	756	650	569	456	290	216	174	127	101	83.7	55.8	45.6	38.4	22.9	

Note: taking into consideration that for a SitePro 60 kVA the max battery charging current at p.f.=0.80 is 33A (data available from Data Sheet). Therefore it is necessary to check if the battery can be recharged with this current level (below 10% of rating capacity Ah). In case this current is not enough, a larger UPS size must be selected (e.g. SitePro 80 kVA).