MAXI POWER PLUS

COMPANY LIMITED

SIZING CALCULATION UPS

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SIZING CALCULATION

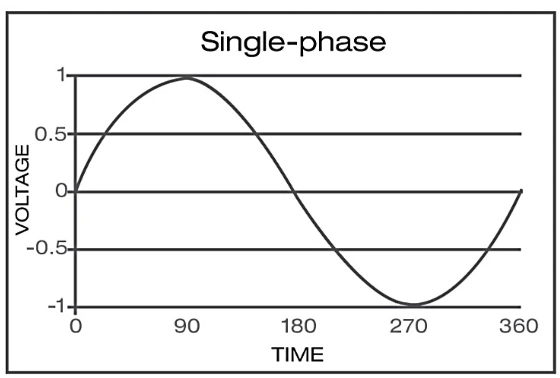
Prior to selecting the UPS, it is necessary to determine the need. UPS may be needed for a variety of purposes such as lighting, startup power, transportation, mechanical utility systems, heating, refrigeration, production, fire protection, space conditioning, data processing, communication, life support, or signal circuits.

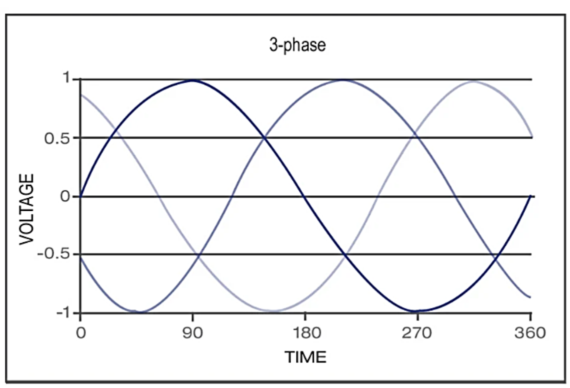
Some facilities need an UPS for more than one purpose. It is important to determine the acceptable delay between loss of primary power and availability of UPS power, the length of time that emergency or backup power is required, and the criticality of the load that the UPS must bear. All of these factors play into the sizing of the UPS and the selection of the type of the UPS

SELECTION OF PHASE UPS

Single Phase power is used in most homes and small businesses and adequate for running lights, fans, 1 or 2 ACs, some computers and motors up to about 5 horsepower; a single phase motor draws significantly more current than the equivalent 3-Phase motor, making 3-Phase power a more efficient choice for industrial applications

Most consumers of electricity in India have a three phase mains connection if the total load is more than 5-7 KW. Only if expected load is below 5-7KW, then the consumer gets a single Phase connection. Even when the consumer has a three phase connection, the choice of three phase or single phase UPS depends on several factors like the loads to be connected to UPS and also electrical distribution within the facility from the building incomer, electrical switchgear and distribution units to the room the loads to be protected are within. This not only builds up a complete picture of the electrical circuits on-site. It also helps to determine whether to offer a three phase or single phase UPS system.





INPUT AND OUTPUT PHASE

In UPS there are three potential phase configurations available. This is because a 3 phase mains or generator supply actually consists of three single phase supplies (and a neutral) with a 120 degree phase orientation between them. A 3 phase supply can deliver more electrical power than a single phase supply.

The laws of physics and Ohms Law also come into play, meaning that cable sizes also increase in diameter as amperages rise. A 10KVA output is generally the largest single Phase UPS system available. This is due to the output amperage and cable requirements. 10KVA=10,000VA / 230Vac = 43.5Amps.

In the world of UPS, it is common to refer to a single phase UPS only by its KVA/KW rating i.e. 5KVA. However for a three phase UPS it is common to refer to the KVA/KW rating along with the number of phases i.e. 20KVA 3/1 or 100KVA 3/3.

3 PHASE UPS SYSTEM (3/3 AND 3/1)

Most datacentres, commercial and industrial buildings will have a 3 phase electrical incomer that connects them via a local distribution transformer to the Mains. Three phase circuits may be required throughout the building to carry the large amounts of electrical power required for large KVA three phase This is a generalisation as many environments can include both single and three phase loads of course.

From a UPS systems perspective, if we are to connect the UPS to a three phase supply we require a UPS with a 3/x configuration. If the loads are three phase as well, then we require a 3/3 configuration. If the loads are single phase we may need a 3/1 configuration.

Using a three phase UPS system can simplify a power continuity plan and allows a site to adopt a centralised power protection plan, where one large UPS is used to protect a complete building or critical circuits and operations within it. This is in contrast to a decentralised power continuity plan using a number of smaller UPS dispersed to protect clusters of loads like computers and lower power equipment (<10KVA) within a facility.

SINGLE PHASE UPS SYSTEM (1/1)

The wall sockets that we typically plug into are single phase supplies rated at 230Vac 50Hz in India. Typical examples would include ATMs, small lab equipments, desktop computers, file servers, switches, routers, hubs and telecoms systems.

Single Phase UPS systems up to 2KVA can be supplied with a plug or with covered terminals for hardwired installation. At 3KVA, the power required means that the UPS will be supplied as either a hardwired system or with a 16A plug. Above 5KVA to the largest single phase UPS system available (typically 10KVA) the UPS will require a hardwired installation and should also include an UPS maintenance bypass switch.

SYSTEM LOAD SIZING

When sizing UPS it is important to know the phase configuration required by both the mains supply and the loads, in addition to the overall load size. Electrical consultants and electrical contractors will often state both load size and phase configuration. An example would include '120KVA three phase'. This refers to a 120KVA load run from a three phase 415Vac, 50Hz supply. In terms of load sizing, this means that each phase (of the 3 phase electrical supply) will deliver up to 40KVA (or 174Amps at 230Vac). If the statement was 120KVA per phase then we would be looking at 3×120KVA per phase = 360KVA UPS load. The need for a 120KVA three phase UPS could be met with three single phase output 40KVA UPS provided the connected loads are single phase loads. These would be 3/1 configured and installed one per phase. However, the overall capital, installation and energy efficiency costs just rose by a factor of 3 compared to a single 120KVA UPS system installation. 3/1 UPS up to 60KVA are also used in office environment where the loads are single phase and this removes the need to balance the load connections in each of the three phases. Larger 3/1 UPS even up to 200KVA are typically required for DCS and SCADA loads in heavy industries like Power Plant, Steel Plant etc.

Input	Output	Nomenclature	Mains Voltage	Typical UPS Sizes
1 Phase	1 Phase	1/1	230/230Vac, 50Hz	400VA-10KVA
3 Phase	1 Phase	3/1	415/230Vac, 50Hz	5 - 200KVA
3 Phase	3 Phase	3/3	415/415Vac, 50Hz	10KVA – 4.8MVA

UPS SIZING STEADY STATE LOAD CONDITIONS

1. NEED OF LOAD

Tabulate the need of load as shown in the below table and arrive at the load demand of the loads expected to be connected to the UPS.

(**Note:** The load power factor has to be measured at the site or can be assumed based on the past experience)

Load	KVA Demand	Load Power Factor	KW Demand
Load 1	KVA1	PF 1	KVA x PF1
Load 2	KVA2	PF2	KVA x PF2
Load 3	KVA3	PF3	KVA x PF3
Load n	KVAn	PFn	KVA x PFn
Total Load	**KVA**	**KW/KVA**	**KW**

2. CONFIGURATION OF UPS

The criticality, of the loads will determine the necessary availability of the UPS. Based on the criticality the UPS capacity or configuration can be selected.

Where N is the no of UPS, required to support the Load. For critical load with 66% redundancy N>2, where a minimum of 2 UPS is required to support the load and 1 UPS for redundancy

Type of Load	Redundancy Level	Configuration of UPS
Non-Critical Load	0%	N
Critical Loads	66%	N+1
Critical Loads	100%	N+N
Critical Loads Fault Tolerant System	100%	2 N

3. CHECK ON THE KVA & KW DEMAND SUPPLIED BY THE UPS

Based on the total demand and the configuration of UPS, the capacity of UPS is selected. The total load in KVA and KW derived in step 1 will have to divided by N as selected in step 2 to arrive the UPS capacity.

$$\text{UPS Capacity in KW} = \frac{\text{Total Load in KW (From Step 1)}}{\text{N (from Step 2)}} \Rightarrow \text{Total UPS in KW}$$

$$\text{UPS Capacity in KVA} = \frac{\text{Total Load in KVA (From Step 1)}}{\text{N (from Step 2)}} \Rightarrow \text{Total UPS in KVA}$$

UPS SIZING DYNAMIC LOADING CONITIONS

The sizing of UPS for loads which are dynamic in nature is a complicated subject, but with the recorded information as shown below, the optimised UPS capacity can be derived based on

- Inrush Current-Nature & Duration
- Peak Process Current–Nature & Duration
- Number of Loads, sequence of their operation
- Load Power Factor
- KVA and KW Demand of the UPS

BATTERY SIZING CALCULATION

The purpose of the battery is to provide DC power to the inverter of the UPS when the mains fail and becomes an important component in the UPS system. There are different technologies of battery available in the market like Lead acid battery which is further classified as Tubular battery, Sealed Maintenance free(SMF,VRLA)Battery, Nickel Cadmium and Lithium Ion battery.

Sealed Maintenance Free, Valve Regulated Lead Acid (SMF VRLA Battery) is mostly used with the UPS systems today.

A VRLA battery utilizes a one-way, pressure-relief valve system to achieve a "recombinant" technology. This means that the oxygen normally produced on the positive plate is absorbed by the negative plate. This suppresses the production of hydrogen at the negative plate. Water (H_2O) is produced instead, retaining the moisture within the battery. It never needs watering, and should never be opened as this would expose the battery to excess oxygen from the air.

- The nominal cell voltage of a battery cell is 2V, 6 cells are connected in series inside the battery container to have a final voltage of 12V.
- The capacity of the battery is defined as "Ampere Hour (AH)".
- The batteries are connected in series to increase the voltage of the battery bank and are connected in parallel to increase the capacity of the battery bank.

By design, the battery has to be operated in a controlled electrical and environmental conditions and the critical elements affecting battery life are:

1. Under charge Charging of battery with a lower voltage and current
2. Cycling Cyclic usage of battery
3. Overcharge Charging of battery with a higher voltage or current which is above the recommended conditions of the manufacturer
4. Temperature The ambient temperature

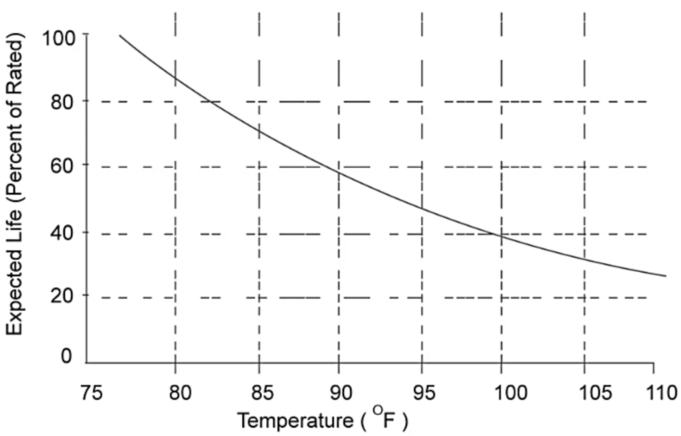
REFERENCE

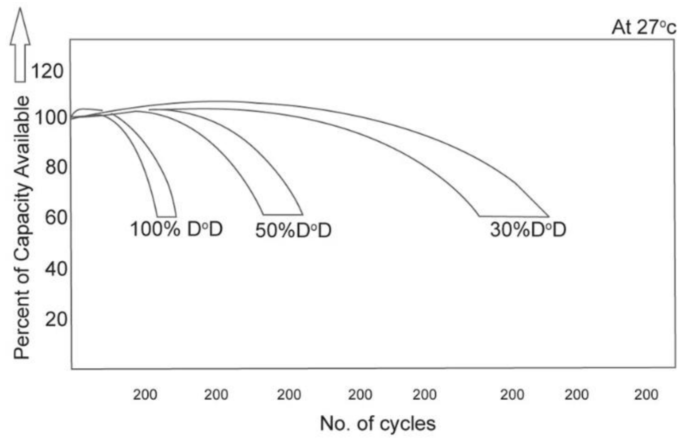
- IEEE 1184:2006 IEEE Guide for Batteries for Uninterruptible Power Supply Systems
- IEEE 485:1997 IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
- Datasheet's of major battery manufacturer's

DESIGN LIFE OF BATTERY

Design life is determined by the manufacturer and takes into account cell design and battery ageing under controlled conditions in the manufacturer's lab. However, the design life of battery can be only used for reference as the real service life of battery depends on the various factor like

- Operating Temperature
- Number of charge, discharge cycle Paragraph Text
- Charging conditions
- Depth of discharge





UPS EFFICIENCY AND POWER FACTOR

UPS power ratings are quoted in volt-amperes (VA) and/or watts. The rating in watts is equal to the rating in volts-amperes multiplied by the power factor.

UPS output power rating in watts = UPS output in volts-amperes × power factor

The battery load for sizing purpose is the UPS output rating in watts divided by the efficiency of the inverter. The efficiency should be based on rated UPS output

$$\text{Nominal battery load in W} = \frac{\text{UPS output power in kilo watts X1000}}{\text{Inverter efficiency}}$$

$$\text{Nominal battery load in W/Battery} = \frac{\text{Nominal battery load in W}}{\text{No of Battery}}$$

BATTERY SIZING CALCULATION

- Calculate the load in Watts-hours as accurate as possible.
- Include system losses due to efficiencies of power conditioning (inverter, battery charger – DC/DC converters).
- Include the appropriate factors: Temperature, autonomy, design margin, and depth of discharge (DOD), ageing factor
- Consider shallow DOD (max 20% recommended) and occasional deeper DOD (max 80%)
- Select highest battery capacities per unit to reduce the number of battery strings in parallel for better charge balance. The recommended maximum number of strings in parallel is 4.

Constant power discharge rating watts per battery @ 27 OC*

ECV	DURATION									
	10 min	15 min	20 min	30 min	60 min	2 hrs	3 hrs	5 hrs	8 hrs	10 hrs	20 hrs
1.60	3594	2801	2269	1817	1125	680	495	340	225	183	93
1.65	3441	2764	2223	1786	1100	670	483	325	219	181	92
1.70	3288	2727	2177	1755	1075	659	470	318	213	180	92
1.75	3135	2690	2127	1724	1050	649	456	310	210	178	91
1.80	2982	2570	2078	1693	1024	638	442	302	207	177	90

Sample calculation :
15 mins backup on a 500KVA UPS with an output power factor of 0.9

UPS Rating (KVA)	500KVA	Specified by Customer or Consultant
Actual Load on UPS (KVA)	500KVA	Specified by Customer or Consultant
Output Power Factor	0.8	Specified by Customer or Consultant
Inverter Efficiency (n)	95%	Based on UPS Manufacturer's data
No of Batteries	50 Nos	Based on UPS Manufacturer's data
End Cell Voltage (ECV)	1.75V	Specified by Customer or Consultant
Backup time required (in mins)	10 mins	Specified by Customer or Consultant
Ageing Factor	1.25	Specified by Customer or Consultant
Design Margin	1	Specified by Customer or Consultant
Temperature Correction Factor	1	Specified by Customer or Consultant

Step 1:

Arrive UPS output power rating in watts = UPS output in volts-amperes × power factor
= 500 X 0.8 KW = 400KW

Step 2:

Arrive the nominal battery load in W

$$\text{Nominal battery load in W} = \frac{\text{UPS output power in kW X1000}}{\text{Inverter efficiency}} = \frac{\text{Answer of Step 1}}{\text{Inverter efficiency}}$$

$$= \frac{400 \text{ X } 1000}{0.95} = 421053 \text{ W}$$

Step 3:

Arrive the nominal battery load in W per Battery

$$\text{Nominal battery load in W/Battery} = \frac{\text{Answer of step 2}}{\text{No of Battery}} = \frac{4721053}{50} = 8421\ \text{W/Battery}$$

Step 4:

Arrive at the adjusted battery power required by taking into consideration design margin, ageing factor and TCF (Temperature correction factor)

Adjusted nominal battery load in W/Battery = Answer of Step 3 X Design Margin X Ageing Factor X TCF
= 8421.05 X 1 X 1.25 X 1
=10526 W/Battery

As the maximum available AH is 200AH Battery in 12V SMF VRLA battery, we need to parallel multiple strings of battery to achieve the desired backup time.

Step 5:

$$\text{No of strings required} = \frac{\text{Watts/Per battery required (Answer of step 4)}}{\text{Watts the battery can deliver (from battery manufacturer datasheet)}}$$

A 160AH battery can deliver 3552 W at end cell voltage of 1.75V/Cell for 10 mins

$$= \frac{10526\ \text{W}}{3552\text{W}} = 2.96\ \text{strings} = 3\ \text{strings}$$

Hence in this scenario, 3 strings of 160AH battery with 50 battery in each string will provide 10 mins backup at end cell voltage of 1.75V/Cell.

INPUT, OUTPUT AND UPS TO BATTERY CABLES

The cross section of cables required for the input of the UPS can be derived using the same formula like output cables, but the input power in KVA needs to be derived based on the

- Connected Load
- Efficiency of the Inverter
- Battery charging Power
- Efficiency of Rectifier
- Input power factor of rectifier
- Minimum operating Voltage of Rectifier

INPUT CABLES

Step 1: Arrive at the input power of Inverter

$$\text{Inverter Input Power} = \frac{\text{Capacity of UPS in KVA X Output Power Factor X 1000}}{\text{Inverter Efficiency}}$$

Step 2: Calculate the battery charging power in W

Battery Charging Power = 2.2VX No of Cells X Charging Current
The charging current is typically 10% of AH Capacity

Step 3: Calculate the Input power of Rectifier in W

$$\text{Rectifier Input Power} = \frac{\text{Inverter Input Power + Battery Charging Power}}{\text{Efficiency of Rectifier}}$$

Step 4: Calculate the input current drawn

The rectifier input power calculated in step 3 needs to be converted to KVA by taking into consideration the input power factor

$$\text{Input Power in VA} = \frac{\text{Rectifier Input Power in W}}{\text{Input Power Factor}}$$

OUTPUT CABLES

To arrive at the cross section of the cable, the output current needs to be calculated using the below formula

$$\text{Rated Current in A(I)} = \frac{\text{KVAX1000}}{\sqrt{3} \text{ X } V_{ph\text{-}ph}}$$

using the cable manufacturer's datasheet and the conditions linked with routing and bunching of cables, the required cable can be selected.

As thumb rule, we can consider 2A/sq mm to arrive the cross section of the required cables.

$$\text{Cross Section of cables in sq mm} = \frac{\text{Rated Current in A(I)}}{2}$$

UPS TO BATTERY CABLES

The inverter of UPS provides a constant voltage to the loads connected to it. During a battery discharge the battery supplies constant power to the inverter of the UPS. The DC input voltage to the inverter decreases during the discharge. To maintain a constant power output, the battery discharge current increases accordingly.

The selection of UPS to battery bank cables has to be based on the current at minimum discharge voltage, which can be derived based on the below formula

$$\text{Current } I_{dc} \text{ in A} = \frac{\text{UPS Capacity in KVA X Power Factor X 1000}}{\text{No of Cells X End Cell Voltage X Inverter efficiency}}$$

Uninyvin cables are generally preferred for cables between UPS & battery due to high current carrying capacity and smaller cross sectional area.

Cable datasheet

Uninyvin Cable	Size(area)	Conductor Diameter "Max"	Overall Diameter "Max"	Conductor Resistance at 20°C "Max"	Max Current Rating "Amps"
Core	"Sq. mm"	"mm"	"mm"	" Ω/ 900m"	BS-G-177
22	0.347	0.838	2	49.66	11
20	0.566	1.04	2.3	30.95	14
18	0.966	1.32	2.5	17.82	18
16	1.17	1.55	2.8	14.7	21
14	2.05	1.95	3.4	8.41	31
12	3.22	2.43	3.8	5.35	43
10	5.33	3.15	5	3.23	61
8	8.76	4.24	6.3	1.97	87
6	13.3	5.54	7.5	1.3	115
4	21.5	6.9	9.3	0.802	160
2	33.3	8.76	11	0.517	200
1	40.7	9.75	12.2	0.423	220
0	53	11	13.7	0.325	240
0	68.3	12.4	15.4	0.252	270
0	84.2	13.9	16.9	0.204	300
0	109	15.6	18.7	0.158	350

Ambient Tem. °C	40	45	50	55	60	65	70	75	80	85	90	95	100
Derating Factors	1	0.96	0.92	0.88	0.83	0.78	0.75	0.73	0.68	0.62	0.53	0.48	0.3