

Hybrid UPS Controller

User's Guide

September 2006



SIGNION SYSTEMS PVT. LTD.

Important Notes

Signion Systems (Signion®) supplies the **Hybrid UPS Controller** (Hupsco) under the following conditions:

1. This unit, intended for *engineering development*, should not be considered a finished product. It is intended for use with THIRD-PARTY products such as UPS systems, batteries, SPV modules and wind turbo-generators. While these products may satisfy the product safety requirements of various authorities, **Hupsco** may not. Specifically, it does not fall within the scope of, nor meets the technical requirements of, the European Union directive on electromagnetic compatibility.
2. Should **Hupsco** not meet the specifications indicated in this User's Guide, it may be returned within 30 days from the date of delivery, in its original packing, for a full refund. *This is the exclusive warranty made by the seller to the buyer and is in lieu of all other warranties, expressed, implied, or statutory.*
3. The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies Signion® from all claims arising from the handling or use of the goods. Please be aware that **Hupsco** may not be regulatory compliant or agency certified (FCC, UL, CE, etc). Precautions with regard to electrostatic discharge, EMI/EMC compliance and electrical safety are the user's responsibility.
4. Except to the extent of the indemnity set forth above, neither party shall be liable to the other for any indirect, special, incidental, or consequential damages.
5. Because Signion® deals with a variety of customers, our arrangement with each user is not exclusive. Signion® assumes no liability for applications assistance, customer product design, or infringement of patents.
6. Prior to handling **Hupsco**, please read this User's Guide in full, giving special attention to the *Warnings and Restrictions*. This section contains important safety information about temperatures and voltages. For further safety concerns please contact our application engineer at [support@signion.com].
7. All persons handling **Hupsco** must have electrical training. Observe best practices in assembly, wiring, inspection and installation.
8. No license is granted under any patent right or other intellectual property right of Signion® covering or relating to any machine, process, or combination in which Signion® products or service might be used.



Warnings and Restrictions

- Operate this controller within the specified input and output ranges described in the User's Guide.
- Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the controller. If you have any questions regarding the input range, please contact support@signion.com prior to connecting power.
- During normal operation, some circuit components may reach case temperatures greater than 60°C. Because the controller is designed to operate properly above 80°C, this should not be a problem, as long as the input and output ranges are maintained. These components include but are not limited to voltage regulators, micro-controllers, diodes and relays. These devices can be identified using the diagrams shown in this User's Guide.
- Do not work on the system or connect or disconnect cables during periods of lightning activity. This equipment must be grounded. Ensure that the host is connected to earth for ground during normal use.
- Before working on equipment that is connected to power lines, remove jewellery (including rings, necklaces, and watches). Metal objects will heat up when connected to power and ground and can cause serious burns or weld the metal object to the terminals. Always wear insulated footwear.



WARNING: A UPS UNIT HAS HIGH VOLTAGE AND SHOULD NOT BE OPENED FOR SERVICE UNLESS A QUALIFIED ELECTRICIAN, TRAINED IN THE USE OF THE PRODUCT, IS AVAILABLE. THE BATTERIES SHOULD BE DISCONNECTED AND THE UNIT'S DC-BUS CAPACITOR SHOULD BE DE-ENERGIZED BEFORE TOUCHING ITS INTERNALS.

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About this document

Webster defines *hybrid* as “the offspring of two animals or plants of different races, varieties, species, etc.” The hybrid discussed in this User’s Guide is an offspring of different technologies rather than life forms, but, like hybrids in the biological world, the Hybrid UPS Controller (**Hupsco**) brings together the best of its components to create something better.

This manual describes Signion’s **Hupsco**, which can be described as a battery management relay controller. **Hupsco** is a unique device that enables near-optimum utilisation of two alternative sources of non-polluting power: a solar photovoltaic (SPV) device and a wind generator, both of which are connected to a commercially available uninterrupted power supply (UPS). In this manual, you will find descriptions of:

- ◆ Interfacing **Hupsco** to your SPV array, wind generator and UPS
- ◆ Range of UPS/SPV array/wind generator powers over which **Hupsco** will operate
- ◆ Troubleshooting and maintaining your **Hupsco** system

A product brochure is available at www.signion.com/hybridups.htm , and a technical description is at www.signion.com/hybridups.pdf .



1. INTRODUCTION

By combining SPV and wind power and connecting both to an off-the-shelf UPS system, all the while maintaining a standard connection to the local power grid, **Hupsco** allows unprecedented performance. A key advantage is that the system streams the power generated by the SPV-wind combination directly to the load, thus eliminating losses incurred when charging and discharging batteries (what is referred to as *coulometric inefficiency* in the trade). While power is provided at prices comparable to grid power, the real advantage of using **Hupsco** is that it controls wear and tear on batteries. Specifically, **Hupsco**:

- Automatically switches in the appropriate power source, whether it be solar, wind or grid
- Minimises the probability of power outage
- Maximises expected solar/wind power utilisation
- Minimises expected grid power utilization
- Minimises expected life cycle costs (including capital amortisation, battery replacement and system maintenance).



2. MODIFICATIONS TO ONLINE UPS

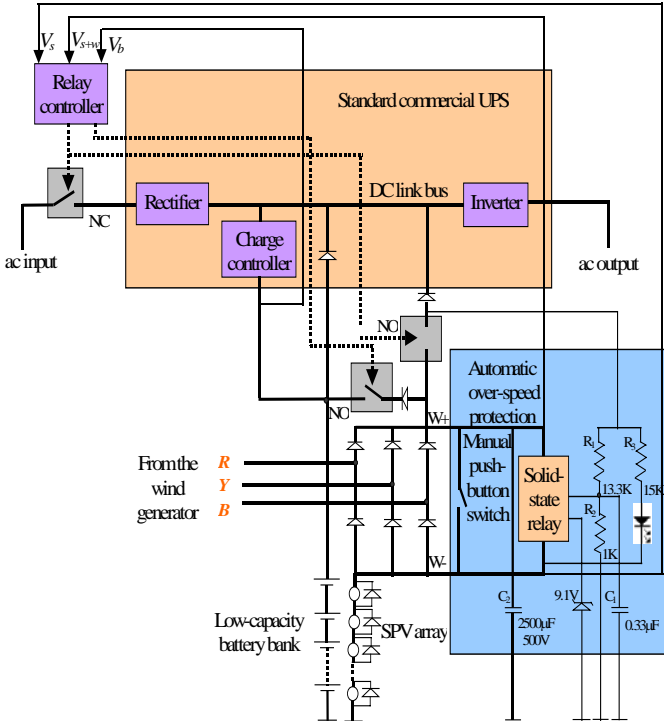


Figure 1. Line diagram of hybrid SPV/wind UPS

Connecting your SPV array-wind generator series combination to a UPS

1. To configure your SPV array (as explained in Appendix A), you need to know the number of serial cells, N , the number of parallel strings, M , and the series resistance of each cell (typically 25m Ω) of your array.



2. Connect your wind generator to a rectifier of current rating $I_d = I_s + I_w$, where:

- $I_s = P_s / V_{dc}$ and
- $I_w = P_w / V_{dc}$ (V_{dc} =UPS dc bus voltage, P_s =SPV array's rated power output and P_w =wind power at rated wind speed)

Ensure that your rectifier's heat sink has sufficient size that it can dissipate $I_d \cdot 2 \cdot V_f$ watts while limiting the temperature rise to 60°C above ambient with normal convective cooling.

For a $P_s=3\text{kWp}$ and $P_w=1.243\text{ kWp}$ design at $V_{dc}=112\text{V}$, the surface area is about 568 cm^2 .

3. Connect your SPV negative (SPV-) to UPS-.
4. Connect your SPV array+ to wind-.
5. Use a diode (of current rating I_d) to couple your SPV array-wind generator to the dc bus of your UPS (diode D1 in Figure 1). Ensure that your diode's heat sink has the capacity to dissipate $I_d \cdot V_f$ watts while limiting the temperature rise to 60° C above ambient with normal convective cooling. The surface area is about 284 cm^2 .
6. Use a diode (D2 in Figure 1) of current rating

$$I_d = I_s + I_w \text{ where}$$

$$I_s = [V_{mp}^{\text{STC}} - V_b^{\text{min}} - V_f] / (N_b \cdot 50\text{m}\Omega + N \cdot R_s / M)$$

to couple your wind generator-SPV array to the battery (Appendix A).

Example: If the settings are...

- $V_{mp}^{\text{STC}} = 112\text{V}$
- $V_b^{\text{min}} = 100\text{V}$
- $V_f = 0.6\text{V}$
- $N_b = 9$
- $N = 252$
- $R_s = 25\text{m}\Omega$
- $M = 6$



... the maximum battery charging current from the SPV array will be $I_s=7.6A$.

The total current through the diode I_d is limited by maximum cycling charging current of the battery (10A for 12V, 15AH lead acid batteries). In this case, this diode's heat sink surface area may only be 66 cm^2 since it dissipates only $I_p \cdot V_f$ watts (allowing at most 60°C temperature rise above ambient with normal convective cooling).

7. Connect the solid-state relay (SSR) of current rating I_d across the wind terminals W+ and W-. Ensure that your relay heat sink has sufficient capacity to dissipate $I_d \cdot V_{od}$ watts (V_{od} being the SSR's on-state voltage drop), allowing at most 60°C temperature rise above ambient with normal convective cooling. The surface area is about 568 cm^2 .
8. Connection details for Relay 1:
 - a. Connect Relay 1 [normally closed (NC)] point in the control path of ac mains to the UPS input.
 - b. Connect Relay 1 [normally open (NO)] point in the control path of SPV array-wind generator to UPS dc bus.
9. Connect Relay 3 (NO) in the control path of SPV array-wind generator to battery.
10. Select wire gauge to limit line loss:

Unlike your home wiring systems, where wiring gauge is determined based on the wire insulation's temperature rise, your hybrid UPS's battery and renewable source wiring gauge is determined essentially by the wire's voltage drop at the maximum current (remember that load sharing between two paralleled sources, e.g., battery and hybrid generators, nominally at the same voltage, is determined by their respective source impedances). For example, when a 3kWp



SPV array is connected to a 100V (min) UPS's DC bus, the maximum current flow being $3000/100=30A$. If your SPV array is situated 20m from your UPS, the worst-case line voltage drop, with an 0.0011 Ohm/m AWG6 (16 mm²) wire, is $2 \times 20 \times 0.0011 \times 30 = 1.2V$, an acceptable drop (<2% of the dc bus voltage) for such a system.

11. Selecting your battery capacity (AH):

A hybrid UPS reduces your investment in batteries and the cost of their replacement. In addition, your Hupsco has been designed to maximize the life of its relays by cycling them at a rate between 25-200s. Thus, when the ac mains is disconnected, a partially discharged battery (e.g., at 40% capacity) may be required to support the maximum load for 200s. In the example above, this implies that each new battery must be rated by a minimum of $30 \times (200/3600) / 0.4 = 4.17AH$. Allowing a de-rating factor of 2 (because a battery's capacity reduces with age), 9AH batteries are recommended.



3. HYBRID CONTROLLER I/O DESCRIPTION

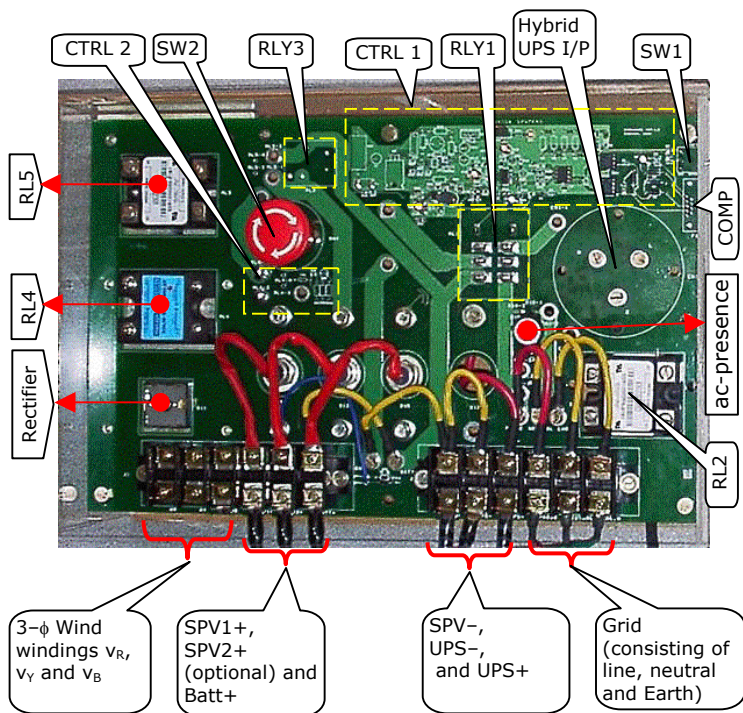


Figure 2: Typical Hupsco set-up



PART SPECIFICATIONS

Hupsco (CTRL1)

Power supply

I/P voltage range	:	65–400V dc
Output voltage	:	12V(default)/ 18V (jumper selectable)
Output current	:	150mA@12V/ (100mA@18V)

PC Interface

Type	:	RS232
Data rate	:	9600 bps
Character size	:	8 bits
Parity	:	None
Number of stop bits	:	1
Flow control	:	None

Over voltage protection circuit (CTRL2)

Over voltage set point ($V_{cut-off}$)	:	200V dc
Potential divider ratio	:	27:1

Solid State Relay (Relay 4):

Input voltage	:	3-32V dc
Input current	:	10mA at 5V dc
Output voltage	:	12-280V ac
Rated current	:	40A
Max on state voltage drop	:	1.5V ac at rated current (V_{od})



3- ϕ Bridge Rectifier:

Part No. (International Rectifier): 36MT40

Max DC output current : 35A

Max repetitive peak reverse

voltage : 400V (V_{RRM})

Control relays**Relay 1:**

Part No. (Leone) : P40 FC

Configuration : 1A/1C/2A/2C

Contact rating : 2C-30A/40A at 240V ac

Nominal coil voltage : 12V dc

Coil power consumption : 1.8 W

Life (electrical operations) : 5×10^4

Relay 3:

Part No. (O/E/N) : 63-12-1A

Configuration : 1A/1C

Contact rating : 1A-30A
240V ac / 24V dc

Nominal coil voltage : 12V dc

Coil power consumption : 525mW

Relay Life Time:

No. cycles/day : 600 (assuming 24 hrs/day)

Relay 1 lifetime : 2 years

Relay 3 lifetime : 4½ years

Push-button switch (SW2):

Contact type : Push to ON

Current rating : 10A (min)



4. USER INTERFACE

A toggle switch allows you to bypass the **Hupsco** operation. In this mode, grid power is always active and the SPV array-wind generator delivers no power to the load.

Toggle switch (SW1)

Switch position	Function
0	Control mode
1	Bypass mode

PC interface

Hupsco allows a PC to monitor and calibrate it through an optically isolated comport.

Data transmitted by **Hupsco**:

Column no.	Data transmitted
1	Hexadecimal (Hex) equivalent of battery voltage
2	Hex equivalent of SPV voltage
3	Hex equivalent of SPV+W voltage
4	System Status Word*

* Appendix C



System calibration

The system is calibrated by connecting **Hupsco's** comport (DCE) to a PC and exercising a DOS-based menu-driven software called 'smmon.exe'. The system calibration parameters will vary according to the rating of your UPS, your wind generator and the configuration of your SPV array.

Note: Data may also be received from a PC's comport using HYPERTERMINAL with the following settings:

Data rate	9600 bps
Character size	8 bits
Parity	None
Number of stop bits	1
Flow control	None

Example: Suppose that these data are received in hex format from your PC's comport using HYPERTERMINAL (with the above internal settings and with the three bytes separated by SPACE and followed by CR and LF):

70 82 A0 01

- The first byte represents a battery voltage of 112V dc.
- The second, an SPV+ voltage of 130V dc.
- The third, an SPV+W voltage of 160V dc.
- The fourth shows that **Hupsco** is in bypass mode.



Automatic over-voltage protection

When the sum of SPV and rectified wind voltages, under load (V_{S+W}^L), exceeds the UPS's maximum dc bus voltage, an over-voltage protection circuit shorts the wind generator's windings through a solid-state relay.

Manual reset

Case1: Heavy wind, sunny conditions and/or AC mains present.

When the wind speed abates*, press SW2 (by pushing and rotating it clockwise) to unlatch the solid-state relay (RLY4).

Case 2: Overcast conditions, no AC mains

Hupsco's high wind speed protection circuit activates when the wind voltage exceeds a threshold. This abrupt removal of wind power may cause your UPS to trip under cloudy conditions. Resetting your UPS using the following sequence helps avoid trip recurrence:

1. Put **Hupsco's** toggle switch to 'bypass mode'.
2. Reset your UPS.
3. Switch on required load.
4. Put **Hupsco's** toggle switch to 'normal mode'.
5. Reset SW2.

* $V_{S+W}^L < V_{\text{cut-off}}$



5. HUPSCO I/O DESCRIPTION

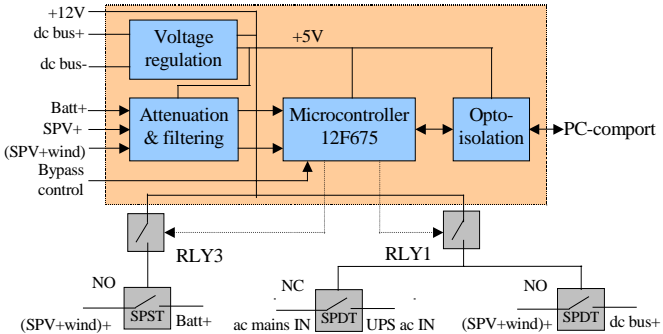
Hupsco connections

With respect to Figure 3 below:

1. Connect the dc bus- point to SPV-.
2. Connect dc bus+ to the your UPS dc bus+.
3. Connect SPV+ to your SPV array+.
4. Connect SPV+W to your series-connected SPV array and wind generator.
5. Connect Batt+ to your Battery+.
6. Connect the power supply (+12V) to the coil terminals of both the relays.

Connect terminals RLY1 and RLY2 to negative terminals of the respective relay coils.

Figure 3. Relay controller schematic



APPENDIX A

6. CONFIGURATION OF SPV MODULES

The configuration of SPV array for a particular rating of UPS should satisfy the following criteria:

1. $V_{mp}^{0.25-STC} \approx N_b \cdot V_b^{0.4-SOC}$
2. $V_{dc}^{ac\ on} > (V_{oc} \times N_s) > V_{dc}^{Min}$

where

- $V_{mp}^{0.25-STC}$ = maximum power voltage of solar array at 0.25 ASTM standard conditions
- N_b = the number of serial batteries
- $V_b^{0.4-SOC}$ = nominal battery voltage when state of charge equal to 0.4
- $V_{dc}^{ac\ on}$ = UPS DC bus voltage when AC input is present
- V_{oc} = open circuit voltage of each solar cell
- N_s = No. SPV serial cells

Example:

UPS rating	: 5-KVA
No. batteries in series (N_b)	: 12
Each battery nominal voltage ($V_b^{0.4-SOC}$)	: 12.2 V
Total battery voltage ($N_b \cdot V_b^{0.4-SOC}$)	: 146.4 V
Each SPV module nominal voltage	: 16.6V
Total No. modules in series	: 9
SPV array nominal voltage ($V_{mp}^{0.25-STC}$)	: 149.4 V
No. SPV strings in parallel	: 3
Total No. modules	: 27
Wattage of each SPV module	: 110 W
Rating of SPV array	: 2.97 KW



APPENDIX B

7. PERFORMANCE OF SPV AND WIND GENERATOR

A new 3kWp SPV array's typical diurnal power limits, without helio-tracking, are provided below. However, your SPV module supplier can tell you how to de-rate your modules as they age.

Climate	Time of day	SPV power (kW)
Sunny	Morning (0730-1100)	0.7-2.0
	Mid-day (1100-1500)	2.0-2.5
	Afternoon (1500-1730)	1.5-0.7
Cloudy	Morning (0730-1100)	0.3-0.7
	Mid-day (1100-1500)	0.7-1.2
	Afternoon (1500-1730)	0.7-0.3
Overcast	Morning (0730-1100)	0.0-0.3
	Mid-day (1100-1500)	0.3-0.5
	Afternoon (1500-1730)	0.3-0.0



APPENDIX C

8. TROUBLE-SHOOTING AND MAINTENANCE

As mentioned in Page 14 (PC Interface), **Hupsco** also provides a system status word (SSTW), the fourth column of transmitted data, to aid troubleshooting.

Bit index	Bit value	System status	Possible causes
0	1	Controller in bypass mode	
1	1	RLY 1 on	
2	1	RLY 3 on	
3	1	V_b less than UPS's charging voltage	AC absent; AC input fuse open; Faulty UPS rectifier section; Faulty UPS charger; Defunct battery bank; Relay controller's input signal conditioning faulty; Ac mains relay open;
4	1	Battery voltage less than desired battery SOC voltage	Defunct battery bank; SPV-to-battery diode open; Battery relay open; SPV to battery fuse open; SPV array cabling faulty;
5	1	Unstable battery voltage	Defunct battery bank; SPV-to-UPS dc bus diode open; SPV-to-UPS dc bus relay open; Controller input signal conditioning section faulty; SPV array cabling faulty;
6	1	Internal UPS fault	UPS charger faulty; Battery-to-UPS dc bus diode shorted; Controller inputs signal conditioning faulty;
7	1	Wind generator windings shorted	High wind speed; Insufficient UPS load; <i>CTRL2</i> faulty;



Hupsco device failure probabilities (α)[†]

Device type	Failure Model	α
Control relays RLY1 RLY3	Fails to trip	0.55
	Spurious trip	0.26
	Short	0.19
Coupling diodes D1 D2	Short	0.49
	Open	0.36
	Parameter change	0.15
Push-button switch toggle SW1, SW2	Open	0.65
	Sticking	0.19
	Short	0.16
UPS/ relay connection	Open, poor (intermittent) contact	0.61
		0.23
		0.16
Hybrid dc BUS capacitor C1	Short	0.69
	Open	
	Changed value	
Lead Acid batteries	Degraded output	0.70
	Short	0.20
	Intermittent output	0.10
UPS and Hupsco rectifiers/ diodes	Short	0.51
	Open	0.29
	Parameter change	0.2

[†] Derived from Reliability Analysis Center's
([http://rac.alionscience.com/pdf/PartFailureMode Distributions.pdf](http://rac.alionscience.com/pdf/PartFailureMode%20Distributions.pdf))



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